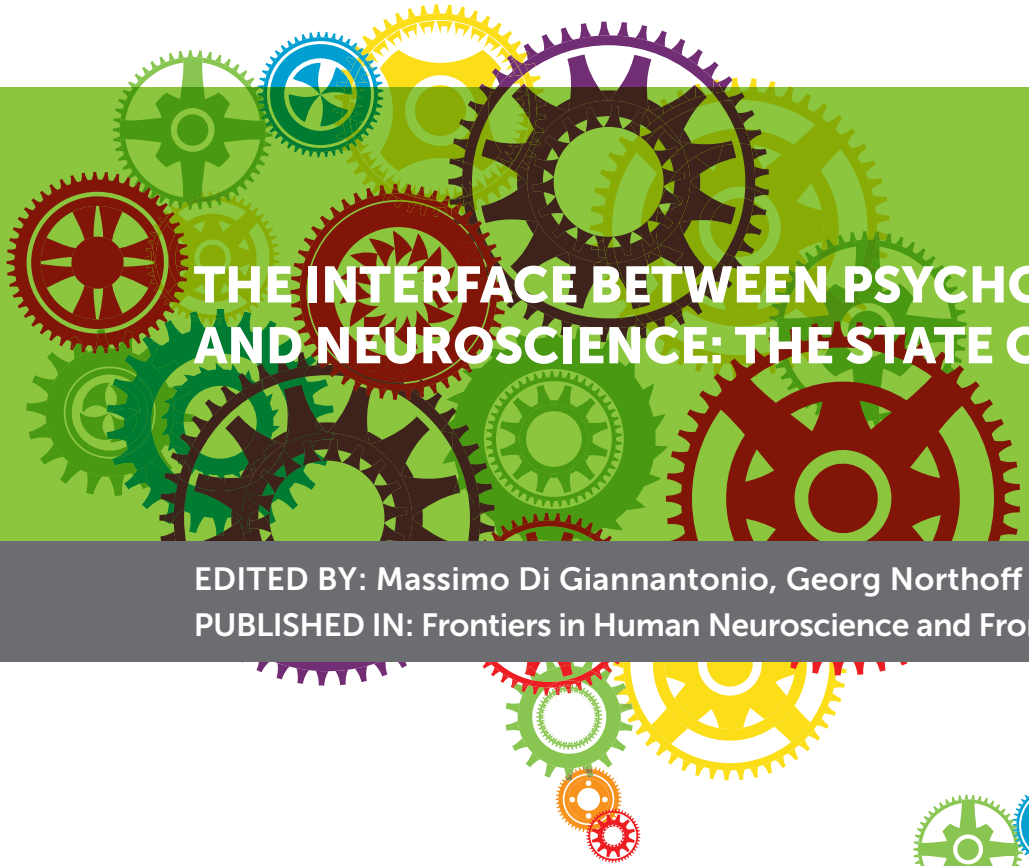
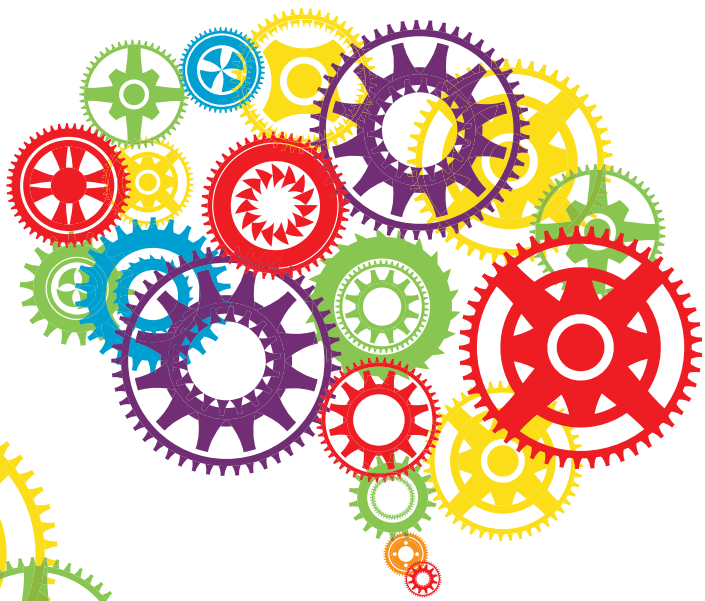


THE INTERFACE BETWEEN PSYCHOANALYSIS AND NEUROSCIENCE: THE STATE OF THE ART

EDITED BY: Massimo Di Giannantonio, Georg Northoff and Anatolia Salone

PUBLISHED IN: Frontiers in Human Neuroscience and Frontiers in Psychology



frontiers Research Topics

ISSN 1664-8714
ISBN 978-2-88963-849-9
DOI 10.3389/978-2-88963-849-9

About Frontiers

Frontiers is more than just an open-access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers Journal Series

The Frontiers Journal Series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the Frontiers Journal Series operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to Quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews.
Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the Frontiers Journals Series: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area! Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers Editorial Office: researchtopics@frontiersin.org

THE INTERFACE BETWEEN PSYCHOANALYSIS AND NEUROSCIENCE: THE STATE OF THE ART

Topic Editors:
Massimo Di Giannantonio, University of Studies G. d'Annunzio Chieti and Pescara, Italy
Georg Northoff, University of Ottawa, Canada
Anatolia Salone, University of Studies G. d'Annunzio Chieti and Pescara, Italy

Citation: Di Giannantonio, M., Northoff, G., Salone, A., eds. (2020). The Interface Between Psychoanalysis and Neuroscience: The State of the Art. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-88963-849-9

Table of Contents

frontiers in Human Neuroscience

EDITORIAL
published: 03 June 2020
doi: 10.3389/fnhum.2020.00199

Editorial: The Interface between Psychoanalysis and Neuroscience: the State of the Art

Massimo di Giannantonio[1], *Georg Northoff*[2,3] *and Anatolia Salone*[1]*

[1] Department of Neuroscience, Imaging and Clinical Sciences, G. D'Annunzio University, Chieti, Italy, [2] University of Ottawa Institute of Mental Health Research, Ottawa, ON, Canada, [3] Brain and Mind Research Institute, University of Ottawa, Ottawa, ON, Canada

Keywords: psychoanalysis, neuroscience, neuropsychoanalysis, neuroimaging, psychodynamic psychotherapy

Editorial on the Research Topic

The Interface between Psychoanalysis and Neuroscience: the State of the Art

The Research Topic "The Interface Between Psychoanalysis and Neuroscience: The State of the Art" was cross-linked in two Frontiers journals: *Frontiers in Human Neuroscience* and *Frontiers in Psychology* and the contributing authors could choose to submit their article to the journal that best suited the research content. Among the 11 contributions finally accepted, 7 have been published in *Frontiers in Human Neuroscience* and the other 4 in *Frontiers in Psychology*. This balanced distribution between the two journals is in line with the wide range of topics dealt with by the various authors, from the theoretical reviews aiming at converging psychoanalytic concepts with discoveries in neuroscience, to the neuroscientific investigation of the mechanisms involved in psychodynamic psychotherapy.

The Research Topic includes articles presented in the form of Review, Hypothesis and Theory, Perspective Article, and Original Research Article.

The implicit question posed to the contributors was to offer their point of view on the usefulness of combining a theoretical psychoanalytic approach with an empirical-experimental one derived from neuroscientific studies. The idea was to encourage an overall theoretical expansion capable of promoting a more complex vision of the mental and psychic functioning underlying scientific research. A validation of psychoanalytic theories has not been deliberately indicated as the purpose of the Research Topic, in favor of a possible and bidirectional conjugation of the same theories with empirical evidence, with the belief that a conceptual enlargement of psychic and cerebral functioning could be an indispensable necessity both for psychoanalysis and for neuroscience. As expected, the authors answered the question starting from different perspectives. In papers of a more theoretical nature, some authors have placed psychoanalytic concepts at the basis of neuroscientific reflection, whereas others applied a psychodynamic theory of mind to benefit the interpretation of empirical neuroscientific evidence. Still other authors have designed experimental studies aimed at investigating psychic mechanisms that were not explicitly conceived according to a psychoanalytic theoretical framework, but that paved the way for a re-evaluation and reconceptualization of psychoanalytic concepts themselves. Finally, for some, these mixed aspects represented the starting point for implementing therapeutic approaches in specific mental disorders.

In particular, several authors have used a framework of the discoveries that derive from Affective Neuroscience: one paper investigated the instinctive component of the imagination, combining cardinal concepts of psychoanalytic theory (dynamic mental structures such as Unconscious

Edited and reviewed by:
Lutz Jäncke,
University of Zurich, Switzerland

***Correspondence:**
Anatolia Salone
asalone@unich.it

Specialty section:
This article was submitted to Cognitive Neuroscience, a section of the journal Frontiers in Human Neuroscience

Received: *29 April 2020*
Accepted: *04 May 2020*
Published: *03 June 2020*

Citation:
di Giannantonio M, Northoff G and Salone A (2020) Editorial: The Interface between Psychoanalysis and Neuroscience: the State of the Art. Front. Hum. Neurosci. 14:199. doi: 10.3389/fnhum.2020.00199

Fantasies) with the function of the basic emotional-motivational systems, especially the SEEKING SYSTEM, in a neuro-ethological context, possibly leading to perspective changes in psychology and psychotherapy (Alcaro and Carta); another article highlighted different components of aggression, especially the Dominance motivational/emotional system, at the basis of competitive behaviors in human relationships, often compromised in different mental disorders (Giacolini and Sabatello).

Another neuroscientific model, based on the centrality of the Default Mode Network and Cortical Midline Structures in the expression of Self, was used in relation to a psychodynamic perspective, with consequent, important clinical and therapeutic implications. Some authors conceived multiple levels of the Self (relational alignment, self-constitution, self-manifestation, self-expansion), corresponding to different levels of personality organization, theorizing for the first time an integrated neurobiological and clinical personality model in which spontaneous brain activity plays a fundamental role (Scalabrini et al.). According to other authors, a similar neuropsychodynamic perspective could be useful to conceive an imbalance between the Default Mode Network and the Executive Network as a core feature in depressive disorders, hypothesizing therapeutic interventions aimed at contrasting this imbalance by acting on specific mechanisms of compensation and defense (Boeker and Kraehenmann).

Focusing on unresolved trauma in mothers, a neuroscientific perspective of the Attachment Theory (in particular, the Dynamic Maturational Model of Attachment and Adaptation—DMM) is used to investigate the reorganization of their attachment style and the neurobiological correlates underlying the behavioral response of adaptation to motherhood (Iyengar et al.).

The experience of pleasure, starting from classic psychoanalytic concepts of instinct and affect, is conceptually enriched in the light of studies on primary-process emotional feelings with a consequent reflection on libido-independent intrinsic motivations and their role in structuring self-related processes (Moccia et al.).

Among the authors who promote the importance of the link between psychoanalytic theories and neuroscientific investigations for therapeutic approaches for specific psychic disorders, the proposal of emotional regulation as a central ability favoring a balanced defensive structure in healthy psychological functioning stands out (Frederickson et al.).

Also the interrelation between a theoretical approach based on Embodied Cognition studies and classical psychoanalytic theory frames the therapeutic proposal of authors who suggest the importance of psychoanalytic psychodrama for the treatment of internet addiction disorder and eating disorders, which is proposed to stimulate a recovery of the Embodied Self with respect to the excessive Narrative Self (Scorolli et al.).

Moreover, a reflection on improving the specificity of therapeutic approaches is presented in the context of pharmacotherapy and its psychic meaning within a psychoanalytical treatment (Iannitelli et al.).

Finally, with a focus on unconscious processes, two Original Research Articles propose interesting results both on the unconscious influence of phonological ambiguity detection in response to subliminal stimuli, correlated with the defensive personality structure of the subject (Bazan et al.) and on the effects of 3-Hz binaural beat stimulation on sleep stages (Jirakittayakorn and Wongsawat).

In addition to the satisfactory number of published articles, our Research Topic has garnered considerable interest among readers. In our opinion, this represents the signal of a growing interest in the area of dialogue between psychoanalysis and neuroscience, the response to the need of both disciplines to broaden their horizons in the direction of the complexity of the human being, in which a separation between psychic and neurobiological functioning can no longer be hypothesized. Psychoanalysis represents a most complex theoretical model of the human mind and could be a useful stimulus for neuroscientific research oriented toward the subjectivity and the relational nature of human experience, and the importance of unconscious processes. On the other hand, while remaining two distinct areas, adequately designed neuroscientific research can contribute to an expansion of the metapsychological perspectives of psychoanalysis itself.

Much work certainly remains to be done and the present Research Topic is not representative of all the areas of interest currently investigated in neuropsychoanalysis; yet, in our opinion it represents a fruitful stimulus to move forward in a definitely constructive direction.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Human Neuroscience

HYPOTHESIS AND THEORY
published: 27 June 2018
doi: 10.3389/fnhum.2018.00247

Neuropsychodynamic Approach to Depression: Integrating Resting State Dysfunctions of the Brain and Disturbed Self-Related Processes

Heinz Boeker[1,2]* *and Rainer Kraehenmann*[1]

[1]Department of Psychiatry, Psychotherapy and Psychosomatics, Psychiatric Hospital, University of Zürich, Zürich, Switzerland, [2]Center for Psychiatry, Psychotherapy, and Psychoanalysis, Psychiatric University Hospital Zurich, Zürich, Switzerland

A mechanism-based approach was developed focusing on the psychodynamic, psychological and neuronal mechanisms in healthy and depressed persons. In this integrative concept of depression, the self is a core dimension in depression. It is attributed to negative emotions (e.g., failure, guilt). The *increased inward focus* in depression is connected with a *decreased environmental focus*. The development of neuropsychodynamic hypotheses of the altered self-reference is based on the investigation of the emotional-cognitive interaction in depressed patients. It may be hypothesized that the increased negative self-attributions—as typical characteristics of an increased self-focus in depression—may result from altered neuronal activity in subcortical-cortical midline structures in the brain, especially from hyperactivity in the cortical-subcortical midline regions and hypoactivity in the lateral regions. The increased resting state activity in depression is especially associated with an increased resting state activity in the default mode network (DMN) and a dysbalance between DMN and executive network (EN) activity. Possible therapeutic consequences of the neuropsychodynamic approach to depression involve the necessary emotional attunement in psychotherapy of depressed patients and the adequate timing of therapeutic interventions. The hypotheses which have been developed in the context of the neuropsychodynamic model of depression may be used for more specific psychotherapeutic interventions, aiming at specific mechanisms of compensation and defence, which are related to the increased resting state activity and the disturbed resting state-stimulus-interaction.

Keywords: depression, neuropsychodynamic psychiatry, self, resting state, default mode network (DMN), mechanism-based approach, psychotherapy

OPEN ACCESS

Edited by:
Anatolia Salone,
Università degli Studi G. d'Annunzio Chieti e Pescara, Italy

Reviewed by:
Irene Messina,
Università degli Studi di Padova, Italy
Marcella Brunetti,
Università degli Studi G. d'Annunzio Chieti e Pescara, Italy

***Correspondence:**
Heinz Boeker
heinz.boeker@bli.uzh.ch

Received: *08 April 2018*
Accepted: *30 May 2018*
Published: *27 June 2018*

Citation:
Boeker H and Kraehenmann R (2018) Neuropsychodynamic Approach to Depression: Integrating Resting State Dysfunctions of the Brain and Disturbed Self-Related Processes. Front. Hum. Neurosci. 12:247. doi: 10.3389/fnhum.2018.00247

INTRODUCTION

The development of a neuropsychodynamic theory of depression should take into account the correlation between neuroscience and psychoanalysis, the complexity of subjective experience in the first-person perspective, and the impossibility to localize this subjective experience in specific brain regions. The starting point for the neuropsychodynamic theory of depression is a psychic-orientated term of localization, which considers the biological, psychological and social dimension of depression, with the differentiation between higher and lower regions of functions being of only secondary importance. In this neuropsychodynamic concept, the different modes

of correlation between biological, psychological and social dimensions are central. Therefore, contrary to a merely biologically-oriented perspective in which the brain is generally looked upon as isolated from the psychosocial context, the psychodynamic perspective looks upon the brain as "embedded" in the psychosocial context (Northoff, 2000, 2004, 2013; Northoff and Boeker, 2006; Northoff et al., 2004). In this view, first-person neuroscience should indeed search for non-localistic ways of finding correlations between subjective experience and neuronal conditions. Therefore, neuronal integration over different brain regions, rather than neuronal localization in one or more regions, will be discussed in the following neuropsychodynamic framework of depression.

PSYCHODYNAMIC KEY FEATURES OF DEPRESSION

In view of the development of the variety of psychoanalytic theories of depression (overview in Brenner, 1991; Mentzos, 1995, 2009; Böker, 1999, 2005; Gabbard, 2005, 2014; see also Force, 2008; for an operationalized research approach to Psychodynamic Psychotherapy of depression), we will focus on the essential dimensions of depression, which are related to Freud's outstanding contribution "Mourning and Melancholia" (Freud, 1917). Contrary to mourning, in which the loss of the significant other is elevated by symbol formation (Segal, 1957), the depressive syndrome does not have a symbolizing function, but is the consequence of the inhibition or the somatopsychic-psychosomatic dead-end of depression (Gut, 1989; Böker, 2002, 2003a). At an early stage, Freud differentiated depression, paraphrased as "melancholia," from mourning (Trauerarbeit): "In mourning it is the world which has become poor and empty; in melancholia it is the ego itself." (Freud, 1917, p. 246). This citation underlines the functional perspective on depressive symptoms: a primary useful reaction to loss (withdrawal of the mourning person to stabilize one's self) develops into becoming dysfunctional in the further course (lack of emotional resonance, predominance of negative, dysfunctional cognitions and extreme withdrawal behavior). Freud stressed the ego-regression from object cathexis to narcissism and pointed to the loss of reality function connected with this:

> *"...; then, owing to a real slight or disappointment coming from this loved person, the object-relationship was shattered. The result was not the normal one of a withdrawal of the libido from this object and a displacement of it on to a new one, but something different, for whose coming-about various conditions seem to be necessary. The object-cathexis proved to have little power of resistance and was brought to an end. But the free libido was not displaced on to another object; it was withdrawn into the ego. There, however, it was not employed in any unspecified way, but served to establish an identification of the ego with the abandoned object. Thus, the shadow of the object fell upon the ego, and the latter could henceforth be judged by a special agency, as though it were an object, the forsaken object. In this way an object-loss was transformed into an ego-loss and the conflict between the ego and the loved person into a cleavage between the critical activity and the ego as altered by identification"*
>
> *— (Freud, 1917, p. 249).*

Freud's original phenomenological distinction between mourning and depression is supported by recent neurobiological studies. For example, Gündel et al. (2003) showed that mourning is mediated by a distributed brain network related to affect processing, mentalizing, emotional memory, face processing, visual imagery and autonomic regulation. Other studies (O'Connor et al., 2002, 2008; Najib et al., 2004) also found neurobiological changes in mourning that are distinct from changes in depression (e.g., activation of nucleus accumbens, activation of amygdala, variation in the monoamine oxidase A (MAO-A) promoter gene, variation in heart rate variability).

The important relation between loss of the object and loss of the self will be focussed on in a neuro-scientific perspective (see Boeker and Northoff, 2018). Along this line, we will refer to the following "psychodynamic essentials of depression":

1. Reactivation of earlier experiences of loss in childhood.
2. Introjection of the lost objects in childhood in connection with negative emotions.
3. Loss of object relations in connection with increased self-focussed attention.

Studies and theories which are influenced by object-relations psychoanalysis and infant research are of outstanding importance for the neuropsychodynamic approach of depression described in this article. In fact, previous studies consistently showed that mental representations of care-giving relationships are key components in understanding the development of a vulnerability to depression (Stolorov, 1986; Adroer, 1998; Malancharuvil, 2004; Fonagy et al., 2007). Most importantly, the *early loss of objects in childhood* is part of the bio-psycho-social vulnerability of persons likely to develop a depressive disorder in later life (Jacobson, 1971; Kernberg, 1976; Bowlby, 1980; Lichtenberg, 1983; Stern, 1983, 1985; Gut, 1989; Blatt, 1998). The fixation on the mental representation of the lost objects involves great psycho-energetic exertion, which Freud compared to an "open wound" taking psychic energy from the self and object representations. This regressive process leads to both the outer world and the self being completely depleted of representations. Besides the early loss of objects in childhood and the increased inner focus, the loss of actual object relations represents the third psychodynamic key feature of depression. The mental representation of the lost object includes a disregarding encountering of other objects in the actual environment of the adult. Others are exclusively or predominantly perceived in the perspective of the lost object. Depressed persons develop an increased inner focus and are no longer able to focus on the outer world. This *self-focussed attention* is the focus of perception of interpersonal relationships: the self-focused attention in depressed patients (Ingram, 1990) is often connected with interactional vicious circles which may cause an increasing helplessness of both partners. Previous studies on social interaction (Coyne, 1976a,b, 1985; Coyne et al., 1987; Boeker et al., 2000; Boeker, 2004),

for instance, showed that the environmental response may play an important role in the maintenance of depressed behavior; further, that partners are important for the self identity of the depressive patient in a much stronger way than for non-depressed controls; and finally, that half of the depressive patients "construed" the partner as similar to the self and similar to the ideal self. With regard to the sensory perception, it can be assumed that the attention shifts from the exteroceptive sensory system (signalizes environmental events and the relationship between the subject and her/his environment) to the interoceptive system, which processes the stimuli of the body.

A great number of studies with different measures and methodologies underline the self focused perception in depression. The results converge in an increased and possibly altered level of self focused attention in depression (Ingram, 1990). It is unclear up to now, whether this increased self focus exclusively exists on an explicit, conscious level—according to our definition—or already on an implicit, unconscious level.

The self in depression is attributed to negative emotions (failure, guilt, hypochondriacal fear of illness and death, in some cases connected with depressive delusion). Positive emotions are no longer connected with ones own self. These scrupulous tendencies correlate with the number of former suicide attempts and are risk factors for suicidal behavior.

The cognitive processing of the own self (rumination) increases the depressive mood and develops into an increasingly dysfunctional mechanism of compensation which is connected with the self-focussed attention and a repetitive focus of ones own negative emotions (Ingram, 1990; Treynor et al., 2003; Rimes and Watkins, 2005). It may be hypothesized that the increased inward focus in depression corresponds with psychodynamic processes, especially introjections and identification of the self with a lost object. The connection between introject and self with negative affects which is postulated in a psychodynamic perspective corresponds to the phenomenological/psychopathological description of the association of the self with negative emotions. Finally, the significance of the actual loss of objects corresponds with the increased cognitive processing of the self because the cognitive processing no longer focuses on the actual loss, but on the loss of objects with which the self is identified ("decreased environmental focus").

NEUROPSYCHODYNAMIC CONCEPT OF PSYCHODYNAMIC DEFENCE MECHANISMS IN DEPRESSION

Neuronal integration characterizes the coordination and modulation of neuronal activity over multiple brain regions. The interaction between brain regions far apart from each other is considered necessary for the development of specific functions such as emotions or cognition (see Price and Friston, 2002; Friston, 2003). It may be hypothesized that defence mechanisms are complex emotional-cognitive interactions that are not localized in specific or isolated brain regions but depend on the interaction between different brain regions, i.e., neuronal integration, or connectivity.

There is a distinction between functional and effective connectivity (see Friston and Price, 2001, p. 277): functional connectivity represents the "correlation between distant neurophysiological events" which may depend either on direct interaction between these events or on different factors which modulate different events. In the first case, the correlation results from the interaction itself; in the second case, the correlation may result by means of different factors, e.g., stimulus-related procedures with common input or stimulus-induced oscillations. In contrast to functional connectivity, effective connectivity describes the directed interaction between brain regions. Effective connectivity relates to the directed influence of one neuronal system to another, either at the synaptic level or at the level of neuronal interaction in different regions (macro-level, see Friston and Price, 2001). In the further course of this article, connectivity at the macro-level is assumed.

On the basis of connectivity, the neuronal activity between brain regions far away from each other can be adapted, coordinated and harmonized. This coordination and adaptation relies on certain principles of neuronal integration (Northoff, 2004; Northoff and Boeker, 2006). These principles represent functional mechanisms which play an important role in the organization and coordination of neuronal activity in different brain regions.

Four of these principles have been investigated in our neuroimaging studies on emotional-cognitive interaction:

1. Top-down/bottom-up modulation and somatization.
2. Reciprocal modulation and introjection.
3. Modulation through functional unit and sensori-motor regression.
4. Self-referential processing, ego-inhibition, and decoupling of the self.

It may be hypothesized that each of these four principles of neuronal integration may be associated with specific mechanisms of defence and compensation.

Top-Down/Bottom-Up Modulation and Somatization

Top-down modulation can be described as modulation of hierarchically lower-level brain regions by higher-level regions. Thus, top-down modulation resembles the concept of "re-entrant circularity" (Tononi and Edelman, 2000) and feedback-modulation (Lamme, 2001). These concepts focus on exchange of information and adaptation of neuronal activity in a certain brain region in accordance with another remote region. As a result, neuronal activity in a lower region can be adapted, filtered and attuned in accordance with neuronal activity in the higher region. Typical examples of top-down modulation are: modulation of neuronal activity in subcortical regions by cortical regions; modulation of subcortical basal ganglia (e.g., nucleus caudatus and striatum)

by premotor/motoric cortical regions (see Masterman and Cummings, 1997; Northoff, 2002a,b); and modulation of the primary visual cortex by prefrontal cortical regions (Lamme, 2004).

Cognition-emotion interactions are crucially regulated via top-down modulation from the medial prefrontal cortex (MPFC) to the amygdala (Davidson, 2002; Pessoa et al., 2002; Pessoa and Ungerleider, 2004) and the insula (Nagai et al., 2004). The insula has a tense and reciprocal relation to other subcortical medial regions, for instance the hypothalamus and the periaqueductal gray (PAG; Panksepp, 1998a,b). Both the amygdala and the subcortical medial regions play an important role in the regulation of internal somatic functions, whereas the medial prefrontal cortical regions are predominantly associated with emotional processing (Phan et al., 2002; Murphy et al., 2003; Northoff and Bermpohl, 2004). All these three regions—the MPFC, the amygdala and subcortical medial regions—have tense and reciprocal connections. Therefore, circular modulation between all these regions may be assumed.

Possibly, there is not only a top-down modulation, but also a bottom-up modulation. A hierarchically lower region modulates the activity in a hierarchically higher region by means of the bottom-up modulation. In this way, subcortical midline regions may, for instance, modulate neuronal activity in the MPFC via the insula. Accordingly, it may be assumed that top-down/bottom-up modulation co-exists in the same region at the same time, which may, from a functional perspective, lead to reciprocal adaptation between emotional processing and processing of internal body functions. The simultaneous occurrence of top-down/bottom-up modulation corresponds to a psychological default-perspective wherein emotional awareness predominates over somatic awareness. The experience and awareness of internally or externally generated emotions comes to the fore, whereas the awareness of the body remains in the background. In this way, a predominating external focus may be explained, in which attention is directed to other persons and events in the outside world. In contrast, the internal focus—that is the attention to one's own body—remains in the background.

The functional equilibrium between the top-down and bottom-up modulation may be disturbed in the course of regressive processes and defence mechanisms connected with these. *Regression* may be understood as a re-actualization of earlier functional levels and the concomitant dominance of somatic reactions instead of emotional and cognitive patterns of reaction. *Somatization* may be characterized as a specific form of mental processing and intensive perception of somatic disturbances. The mechanisms of somatization can be paradigmatically observed in depressive patients who often experience somatic symptoms—especially autonomous-vegetative symptoms—in a subjective way. It may be hypothesized that somatization in depression is correlated with a disturbed equilibrium of top-down/bottom-up modulation between emotional processing and processing of internal body signals.

At a functional level, somatization may point at the predominance of internal processing of the body in contrast to emotional processing. Primary signals of the internal controlling centers of the body are processed, whereas processing of the emotional stimuli originating either internally or externally remains in the background. The balance between internal processing of the body and emotional processing is adapted to a new functional level in the following course. Accordingly, it can be assumed that depressed patients with strong somatization react much more intensively to internal stimuli from the body than to internal or external emotional stimuli. Furthermore, depressed patients show extremely strong autonomous-vegetative reactions (for instance heart rate variability; Bär et al., 2004). Finally, depressed patients show reduced reactions to externally induced emotions, for instance in the context of social interaction. This was already underlined by results from earlier studies on communication in depression (see Coyne, 1976a,b, 1985; Coyne et al., 1987). From the psychological perspective, somatization is reflected by an increased awareness of one's own body and the internal functions of the body. Depressed patients shift their attention away from their own or other's emotions to their own body functions. Depressed patients do not observe their own emotions, but rather their own body functions. They do not observe others' emotions, but rather their own body. At the neuropsychological level, this increased internal focus is reflected in changes in attention and theory of mind, which was shown empirically both in theory of mind tasks (Inoue et al., 2004) and in findings of attention deficits (Paradiso et al., 1997; Murphy et al., 1999, 2001; Sheppard and Teasdale, 2004). Recent neuroimaging studies (Paulus and Stein, 2010; for review Wiebking et al., 2010) support the notion that depressed patient show increased somatization related to altered brain functioning. Wiebking et al. (2010), for example, investigated the neural correlates of interoception in healthy and depressed subjects using the Body Perception Questionnaire (BPQ) and a well-established heartbeat perception task in fMRI. They found that depressed patients showed significantly higher scores in the BPQ and left anterior insula signal changes correlated with depression severity.

Furthermore, Ernst et al. (2013, 2014) investigated the neural correlates of interoception and its relationship to empathy. They found that preceding interoceptive awareness period significantly enhanced neural activity during empathy in bilateral anterior insula and various cortical midline regions. This suggests a close relationship between interoception and empathy; thereby, interoception seems to be implicated to yielding empathy.

Reciprocal Modulation and Introjection

Neuroimaging studies showed a pattern of opposite signal changes in the medial and lateral prefrontal cortex (LPFC) during emotional-cognitive interaction (Goel and Dolan, 2003a,b; Northoff and Bermpohl, 2004; Northoff et al., 2004). These results correspond to the assumption of functional mechanisms of reciprocal modulation and reciprocal reduction during emotional-cognitive interaction. *Reciprocal modulation* is defined as signal changes in opposite directions

(i.e., increases and decreases of signals). It is already known that emotional processing (when an emotional picture is perceived) leads to an increase of signals in the MPFC regions as well as to a decrease of signals in the LPFC (Phan et al., 2002; Murphy et al., 2003; Northoff et al., 2004).

In contrast, cognitive tasks (e.g., judgment or assessment) produce an opposite pattern of signal increases in the LPFC and signal decreases in the MPFC. This corresponds to the functional mechanism of reciprocal modulation (Northoff et al., 2004; Boeker and Northoff, 2018): the experience of the outside world is changed to an experience of the inner self (internal focus). Analogous patterns of reciprocal modulation were also observed in other cortical regions, for instance in the medial and lateral orbitofrontal cortex, in the right and left motor cortex, in the striatal and extra-striatal visual cortex, in the subgenual anterior cingulum and in the right prefrontal cortex, in the sub/pre- and supergenual anterior cingulum as well as in the visual and auditory cortex (overview in Northoff et al., 2004).

On the basis of the mentioned empirical results, it may be assumed that emotional-cognitive interaction is associated with the functional mechanism of reciprocal reduction: if a cognitive task comprises an emotional component (e.g., when assessing an emotional picture), fewer signal decreases result in the MPFC regions and simultaneously fewer signal increases in the LPFC regions. This process was characterized as *attenuation* (synonym: decrease; see Northoff et al., 2004). A reciprocal attenuation can be referred to because this process occurs in the medial as well as in the lateral prefrontal cortical regions in opposite directions (i.e., fewer signal decreases and increases).

It may be assumed that the reciprocal modulation and attenuation can be altered in introjective mechanisms at a neuropsychodynamic level. *Introjection* is—in an operational definition—characterized by the shift of object focus from the outside to the inside in subjective experience. The subject-object relationship is no longer directed to the outside, but to the inside. The experience of the outside is changed into an experience of the inner self.

The defence mechanism of introjection can be paradigmatically observed in depressed patients. These patients tend to internalize their conflicts with others and shift the aggression which was primarily directed towards others, against their own self. It may be hypothesized that this introjection in depression may be associated with the abnormal reciprocal modulation during emotional-cognitive interaction (Deci et al., 1994; Adroer, 1998; Malancharuvil, 2004).

From a functional and psychological perspective, introjective processes in depressed patients may be related to disturbances of emotional-cognitive re-adaptation. Depressed patients are no longer able to adequately assess their own emotional and body experience. The assessment of one's own conditions is "subjectively" distorted and decoupled from "objective" reality. This subjective distortion is seen in a marked negativity of the assessment of one's own emotions and the body, and also of the assessment of others' emotions and the events in the outside world. This extreme negativity corresponds to the "negative or attentional bias" (Elliott et al., 1998, 2000, 2002; Gotlib et al., 2004). The results of a study on the perception of faces (Gotlib et al., 2004), for instance, pointed out that the "negative or attentional bias" may be connected to interpersonal dysfunction in depressed patients. Further studies are necessary to explain how and why the "negative or attentional bias" apparently induces a decoupling of the "subjective" assessment from the "objective" reality.

On the basis of the generated empirical results, it may be assumed that the disturbed reciprocal modulation and attenuation during emotional-cognitive interaction in depression is of outstanding importance for the development of introjective defence and compensation mechanisms. This notion has been supported by several neuroimaging studies (Mayberg et al., 1999; Brody et al., 2001; Drevets, 2001) which showed that depressive patients show both increased neural activity in the ventromedial prefrontal cortex (VMPFC) and decreased neural activity in the dorsolateral prefrontal cortex (DLPFC) as compared to healthy subjects. Thus, maladjustment of reciprocal modulation and attenuation might account for both emotional and cognitive deficits in depressive patients. Furthermore, Zimmermann et al. (2015), in their seminal psychotherapy study, applied multilevel mediation analyses; the results showed that post-treatment differences in interpersonal problems and introject affiliation were mediated by the higher number of sessions; and follow-up differences in depressive symptoms were mediated by the more pronounced application of psychoanalytic techniques. Furthermore, they also found some evidence for indirect treatment effects via psychoanalytic techniques on changes in introject affiliation during follow-up. They concluded that these effects provide support for the prediction that both a high dose and the application of psychoanalytic techniques facilitate therapeutic change in patients with major depression.

Modulation Through Functional Unit and Sensori-Motor Regression

A further example of functional mechanisms of emotional-cognitive interaction is the development of functional units in different brain regions over time. Such transient functional units could be identified on the basis of psychophysiological features or functional connectivity in the involved regions (Friston, 1998, 2003; Friston et al., 1998a,b, 2003; Friston and Price, 2003). The cortical midline structures (CMS, Northoff and Bermpohl, 2004), for instance, show a continuously high level of neuronal activity also under resting state conditions (e.g., when passively regarding a fixation cross; Gusnard and Raichle, 2001; Gusnard et al., 2001; Mazoyer et al., 2001; Raichle, 2001; Raichle et al., 2001). Furthermore, the regions within the cortical midline structures are characterized by dense anatomical connections. In addition, investigations on the functional activity in the CMS found an increase in functional activity in the CMS between anterior and posterior CMS regions in the resting state, whereas this connectivity decreased during active cognitive tasks.

The participation of both anterior and posterior midline structures is in line with results from further studies on cognitive, emotional and social processing (overview in Northoff and Bermpohl, 2004). Furthermore, signal decreases were found both in the orbito-medial prefrontal cortex (OMPFC) and the parietal cortex (PC) during cognitive tasks requiring attention. In addition, these regions show an increased circular connectivity (Greicius et al., 2003, 2007; Raichle, 2003). In summary, these empirical results deliver convincing evidence for the existence of the CMS and a functional unit, which is particularly active and cohesive in the resting state (Greicius et al., 2003; Wicker et al., 2003a,b,c).

With this in mind, it may be assumed that modulation through functional unit is altered in regressive processes involving sensori- and motor functions. Sensori-motor regression can be defined as a defence and compensation mechanism, which is activated when conflicts and anxieties can no longer be solved by means of cognitive and emotional functions and when somatic and particularly sensori-motor functions are involved. The defence mechanism or the sensori-motor regression can be paradigmatically observed in patients with catatonia ("scared stiff"; Böker, 2000a,b, 2001; Böker et al., 2000a,b). It may be hypothesized that the sensori-motor regression in catatonia is connected with altered modulation by functional unit in the CMS (overview in Böker et al., 2000a,b; Northoff et al., 2003, 2004). This hypothesis has been investigated in an fMRI study in catatonic patients with an underlying affective or schizoaffective psychosis (Northoff et al., 2002). They found significantly altered activation patterns in orbitofrontal and premotor cortex during negative emotional stimulation which correlated significantly with affective, behavioral, and motor alterations in catatonia. It was concluded that orbitofrontal cortical dysfunction and related alterations in medial prefrontal and premotor cortical activity may account for lack of emotional control with consecutive sensori-motor regression as an "immobilization by anxieties" in catatonia (both in depression and schizophrenia), where regression to somatic defense mechanisms is paradigmatically observed.

Self-Referential Processing, Ego-Inhibition and Decoupling of the Self

Certain sensory stimuli are related to one's own person, contrary to other stimuli which are rather related to other persons and the outside world. Accordingly, self-referential stimuli can be differentiated from non-self-referential stimuli (Northoff and Bermpohl, 2004; Northoff and Boeker, 2006). This differentiation is valid not only for sensory stimuli, but also for emotional and cognitive stimuli. From a functional perspective, self-referential processing points at a simple distinguishing process, the distinction between self and non-self. This process is decisive for the distinction between one's own stimuli and those from others, and therefore for the distinction between self and the outside world. Moreover, self-referential processing may be a pre-requisite condition for the development of a concept of one's own self, the so-called mental or phenomenal self as a subject of experience (Northoff et al., 1997, 2000, 2005; Panksepp, 1998a,b; Damasio, 1999; Northoff, 2004).

From a psychological perspective, self-referential processing may be manifest in the possibility of a subjective experience of one's own self or ego (both terms are used synonymously in the following; see Freud, 1914; Kohut, 1977; Dennecker, 1989). By marking certain stimuli as self-referential, they can be experienced subjectively, i.e., from the individual subject's or ego perspective (Northoff and Boeker, 2006). Owing to the fact that, besides the internal and sensory stimuli of one's own body, emotions and cognitions are also examined with regard to their self-reference, emotions and cognitions can be attributed to one's own self. The subject constituted primarily by one's own body is "filled", so to speak, with certain related emotions and cognitions.

The development of neuropsychodynamic hypotheses of altered self-reference in depression is based on the investigation of the emotional-cognitive interaction in depressed patients, which focussed on the neurophysiological correlates of depressive inhibition and the neurophysiological substrates of negative cognitive schemes and the neuropsychological deficits (overview in Northoff, 2002a,b; Northoff et al., 2005, 2007; Böker and Northoff, 2005, 2010; Grimm et al., 2006, 2008, 2009; Walter et al., 2009; Boeker et al., 2012). In addition to the emotional-cognitive interaction, semantic representations (and their neural correlates) play an important role in depression. Beyond the concept of cognitive control, psychodynamic (and neuropsychodynamic) models of depression focus on the development of the individuals' capacity to regulate their emotional states in significant interactive relationships during childhood and through the re-construction of the representation of the self, of significant others, and relationships (see Messina et al., 2015, 2016a,b). Furthermore, consistent with psychodynamic (and neuropsychodynamic) models of depression, psychological functions associated with the default mode system include self-related processing, semantic processes, and implicit forms of emotion regulation (Messina et al., 2016a).

Rumination is a form of self-referential processing, which is the process of relating information to the self. In a meta-analysis of neuroimaging studies focused on self-referential processing, Northoff et al. (2006) found that commonly activated regions lie in dorsal and ventral areas of the medial prefrontal and anterior cingulate cortices, as well as the posterior cingulate cortex and precuneus. These regions have been termed cortical midline structures (Northoff and Bermpohl, 2004) and somewhat overlap with the intrinsic default mode network (DMN; Raichle et al., 2001). A recent review (Nejad et al., 2013) of neuroimaging studies on rumination, self-related processing, and depression found that the anterior cortical midline structures play an important role in maladaptive rumination in major depression.

To sum up, depression may be characterized by reduced neuronal activity in the left DLPFC and increased activity in the right DLPFC. The neuronal activity in the left

DLPFC cannot be modified by emotional valence. The severity of depression correlates with the activity in the right DLPFC. Connected with the reduced deactivation in the pregenual ACC (DMN), depressed persons cannot shift their attention from themselves to the outside world (Grimm et al., 2008). The degree of helplessness and the severity of depressive symptoms correlate with the reduced deactivation in the perigenual anterior cingulate cortex (PACC) and posterior cingulate cortex (PCC). The signal intensities in different subcortical and cortical midline regions (DMPFC, supragenual anterior cingulate cortex (SACC), precuneus, ventral striatum (VS), DMT) were reduced significantly. On the basis of these empirical results, it may be concluded that the increased negative self-attributions—as typical characteristics of an increased self-focus in depression—may result from altered neuronal activity in subcortical-cortical midline structures in the brain[1] (especially from hyperactivity in the cortical-subcortical midline regions and hypoactivity in the lateral regions). On the basis of neuropsychological, neurophysiological and neurochemical findings and, as we mentioned, psychodynamic dimensions of depression, neuropsychodynamic hypotheses on the disturbed self-reference in depression were developed and related to psychodynamic and specific neuronal mechanisms of depression.

Finally, the decoupling of the self characterizes the extreme form of the altered self-related processes in depression, including complete loss of self. A typical example of decoupled self experience may be encountered in severely depressed patients with psychotic symptoms, e.g., nihilistic delusion (Cotard Syndrome).

DYSBALANCE OF RESTING STATE ACTIVITY IN DMN AND MENTAL REACTIVATION OF EARLY OBJECT LOSS

In the neuropsychodynamic framework presented here, it may be hypothesized that altered resting state activity[2] in depression is a pre-disposition for reactivation of early object loss experiences in the subject. There is ample evidence for resting state abnormalities in depression. For example, PET-studies in major depression found decreased resting state activity, especially in the lateral anterior cortical midline regions (PACC, VMPFC, compare Mayberg et al., 1999; Mayberg, 2002, 2003a,b; Phillips et al., 2003). Alterations in neural activity were shown in ventral regions of the so-called DMN in depressed patients (reduced deactivation, that is negative BOLD-reactions, see Greicius et al., 2007; Grimm et al., 2009; Sheline et al., 2009). Furthermore, a translational meta-analysis of resting state studies in depressed patients and in animal models confirm resting state *hyperactivity* in ventral, cortical midline regions (PACC, VMPFC; Drevets and Raichle, 1998; Drevets, 2000, 2001; Fitzgerald et al., 2007; Drevets et al., 2008; Alcaro et al., 2010; Price and Drevets, 2010). In contrast to the anterior midline regions, posterior midline regions (PCC, precuneus/cuneus) and the superior temporal gyrus (STG) show *hypoactivity* in the resting state (Heinzel et al., 2009; Alcaro et al., 2010). The hyperactivity in the anterior midline regions and the hypoactivity in the posterior midline regions result from a disturbed balance between anterior and posterior midline regions in acute depression and a disturbance in the DMN in depression (Raichle et al., 2001; Buckner et al., 2008).

How can these results be related to psychodynamic mechanisms, especially the reactivation of early loss in childhood? Early traumatization causes alterations in developing processes which may contribute to the development of early immature defence mechanisms (Feinberg, 2011). Traumatization in early childhood was found in a large subgroup of depressed patients (experiences of loss, divorce of parents, physical or sexual abuse; see Böker, 2000a,b; Nemeroff et al., 2003; Gabbard, 2005, 2014). Traumatic life-events may cause biological alterations on the genetic, hormonal or anatomic-structural level (Feder et al., 2009). It may be hypothesized that traumatic life experiences interfere with the development of the VMPC and especially the ventral anterior subcortical-cortical midline regions as an essential part of the DMN. Anterior midline regions are especially involved in the processing of the degree of self-reference of different stimuli, whereas the posterior regions are likely to be involved in the processing of social and non-self-related stimuli (Qin and Northoff, 2011).

Furthermore, it may be assumed that early traumatic experience of object loss is associated with the desperate attempt to relate the self to the lost object in order to develop a self-object relationship and to experience the lost object as a self-object. In connection with this, possible hyperactivation, especially in the anterior midline regions, may be induced, which finally contributes to a disbalance in the posterior midline regions.

The retrieval of early traumatic experiences in the context of current experiences of object loss triggers a reactivation of the same neuronal patterns used in the early development of a relationship to the object with a consecutive hyperactivity in the anterior midline regions and a disbalance in the posterior regions and in the DMN.

In view of the early object loss, depressed patients develop a psychological pre-disposition to attribute a high degree of self-reference to lost or disappointing objects. Therefore, a neuronal pre-disposition for the development of hyperactivity in the resting state in anterior midline regions, when object loss is experienced in adulthood, is induced. Accordingly, it can be hypothesized that the psychological and neuronal predisposition correspond with the psychodynamic predisposition, the reactivation of early object loss. When actual stimuli induce less stimulus-induced activity in the anterior midline regions

[1] We do not understand the cortical midline areas as an unitary neural system but as an important component of neural integration which characterizes the coordination and modulation of neuronal activity over multiple brain regions. We desribed functional and effective connectivity and four principles of neural integration in the third section of the article (see Fox et al., 2005).

[2] Resting state activity in the brain represents the intrinsic activity of the brain and should be differentiated from the brain's activity induced by somatic stimuli or outside stimuli.

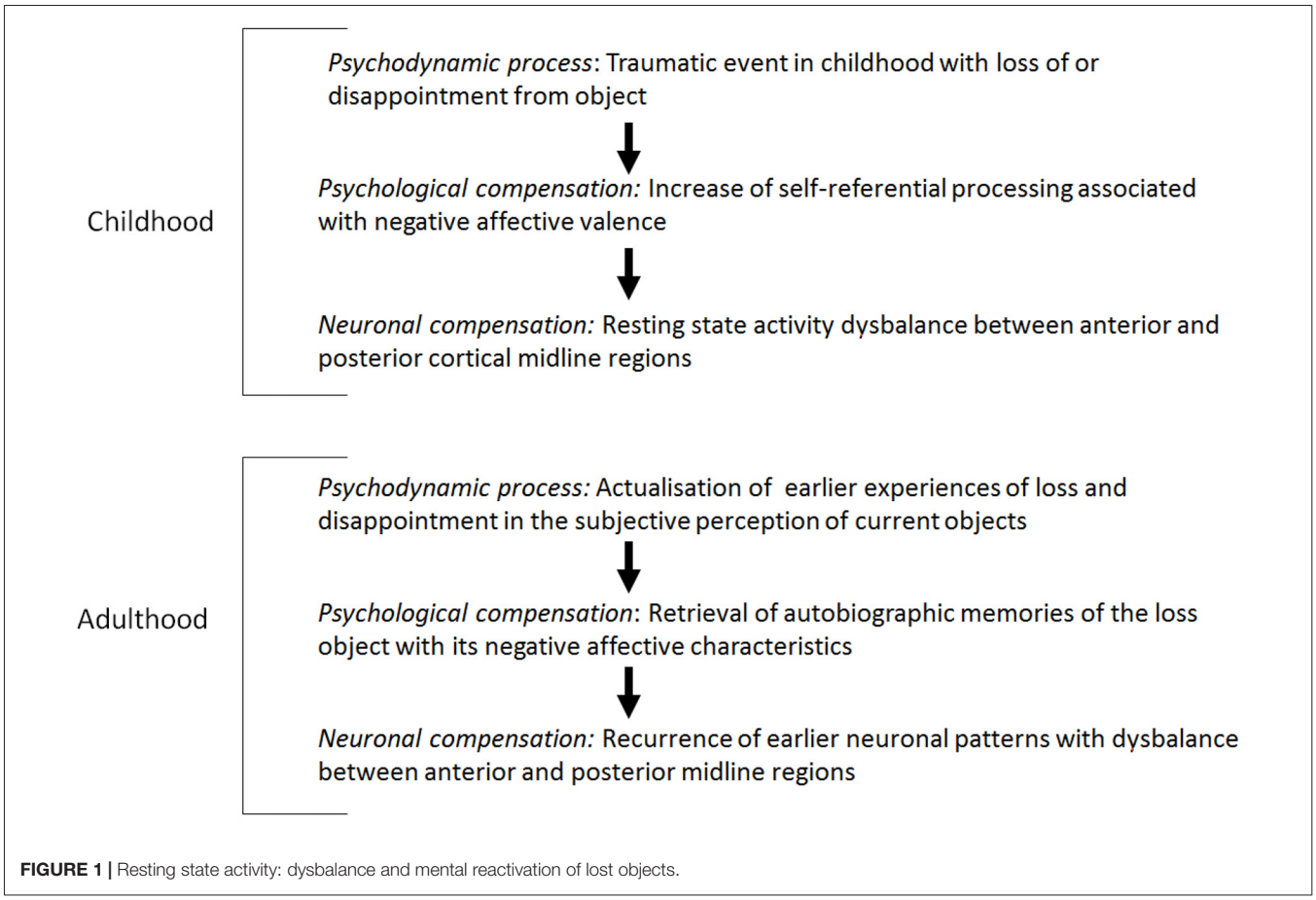


FIGURE 1 | Resting state activity: dysbalance and mental reactivation of lost objects.

because of the abnormally increased resting state activity, the brain keeps predominantly occupied with itself, i.e., that the earlier experienced contents and the objects are reactivated by the increased resting state activity accordingly or that the representations of the earlier objects are represented in the actual context (see **Figure 1**; see Boeker and Northoff, 2018).

Reduced Resting State-Stimulus-Interaction and Introjection in Correlation With Negative Emotions

Resting state-stimulus-interaction includes the interaction between two different modes of neural activity: the intrinsic activity of the brain and the stimulus-induced activity (induced by stimuli from the outside world and/or the own body). It may be hypothesized that resting state-stimulus-interaction in depression is reduced because of increased resting state activity and that the resting state-stimulus-interaction is associated with introjective processes in the interaction between self and the object world connected with negative emotions. Functional activation paradigms (emotional, cognitive) showed dysfunctional activation patterns, especially hyperactivity, in the ventral cortical midline regions in patients with major depression during resting state and emotional stimulation (Elliott et al., 1998, 2002; Mayberg et al., 1999; Davidson, 2002; Mayberg, 2002, 2003a,b; Davidson et al., 2003; Canli et al., 2004; Fu et al., 2004). In other brain regions, especially in the reward system (VS/n.accumbens, right and left amygdala), dysfunctional activation patterns were found during positive and/or negative emotional stimulation in major depressive disorder (MDD; Kumari et al., 2003; Canli et al., 2004; Lawrence et al., 2004; Surguladze et al., 2004). These dysfunctional activation patterns may be interpreted as the neurophysiological basis of the "negative affective bias," that is the focussing of negative emotions which is related to the inability to process positive emotions (Mayberg, 2003a,b; Phillips et al., 2003; Grimm et al., 2009; Heinzel et al., 2009; Heller et al., 2009). The reduced deactivation in cortical-subcortical regions was correlated with the severity of depression and the degree of hopelessness. A direct association between reduced resting state-stimulus-interaction and the severity of depression may be assumed (Grimm et al., 2009).

Further studies focussed on the biochemical basis of the reduced resting state stimulus interaction. It could be shown that increased resting state activity in the PACC is associated with the concentration of the neurotransmitter glutamate (Zarate et al., 2006; Maeng and Zarate, 2007; Northoff et al., 2007; Maeng et al., 2008; Walter et al., 2009; Alcaro et al., 2010;

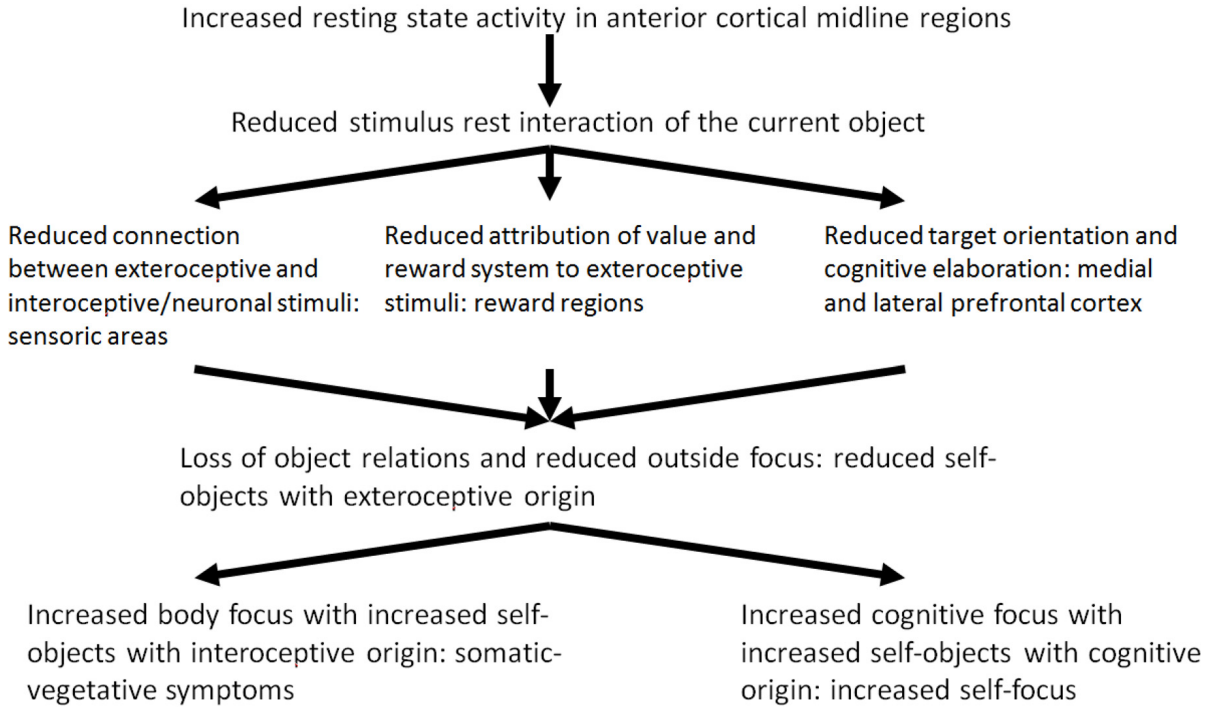


FIGURE 2 | Reduced stimulus-rest-interaction, reduced outside focus and increased self-focus.

Sanacora, 2010). A disbalance between neuronal inhibition and excitation in the anterior midline regions in depressed patients may be assumed.

The induced resting state activity in the brain inhibits the neuronal processing of stimuli from the outside world. Stimuli from the outside world cannot be related to one's own self or connected with emotional valence. Nevertheless, these psychological mechanisms are still active and are mediated by the induced resting state activity. From a psycho-energetic perspective, the energy which is usually used for the development of self-relatedness and the connection with emotions (emotional valence) is related to early stimuli which are related to early object loss and the induced resting state activity.

The change from current to early stimuli may contribute to an increase of introjective processes in a neuropsychodynamic perspective. The reactivated stimuli from the past are related to the self and negative emotional valence. Stimuli which are connected with early object loss are introjected and related with negative emotions. It may be assumed that this process corresponds with an introjective type of depression (Blatt, 1998) which is characterized by an increased interpersonal relatedness.

Reduced Stimulus-Resting State-Interaction and the Loss of Current Object Relations

It may be hypothesized that the modulation of the resting state activity by means of stimulus-induced activity and the stimulus resting state interaction in depression is reduced because of the increased resting state activity. Reduced stimulus resting state interaction probably leads to dysfunctional development of the neuronal structure and organization which is associated with dysfunctional processing of current experiences of loss. The reduced stimulus resting state interaction can be seen in three different patterns: (1) interoceptive stimuli no longer modify the resting state or baseline activity of the brain (Wiebking et al., 2010); (2) exteroceptive stimuli are no longer associated with value and reward (Kumar et al., 2008; Dichter et al., 2009; Pizzagalli et al., 2009; Smoski et al., 2009; Sajonz et al., 2010); and (3) exteroceptive stimuli no longer induce or constitute cognitive processing (Goel and Dolan, 2003a,b; Northoff et al., 2004; Grimm et al., 2006; see **Figure 2**, see Boeker and Northoff, 2018).

On the basis of these empirical results, Phillips et al. (2003) and Mayberg (2002, 2003a) developed a model of the altered reciprocal functional interaction between ventromedial and DLPFC in MDD (model of ventro-dorsal dissociation) where reciprocal modulation of neural activity in depression is reduced because of reduced deactivation in the medial regions and reduced activation of the DLPFC (Carhart-Harris et al., 2008; Grimm et al., 2008). The disturbed modulation of the lateral prefrontal cortical resting state most probably contributes to a reduced stimulus-induced activity triggered by cognitive stimuli. From a neuropsychodynamic perspective, the reduced stimulus resting state activity and the reduced exteroceptive neuronal interaction contributes to a reduced constitution of objects which also results from

the reduced emotional valence and reward. Current object relationship experiences lose their emotional significance. Reduced reciprocal modulation—as the third part of the reduced stimulus resting state interaction—contributes to a reduced activation of cognitive processes by exteroceptive stimuli. In this way, the "object cathexis" is reduced (Carhart-Harris et al., 2008). Furthermore, it may be assumed that the disturbed reciprocal modulation may be an adaptive mechanism by which the depressive self is finally disconnected from the significance of current object relationship experiences. From a psycho-energetic perspective, the result is a further reduction of object cathexis. The depressed patient attempts to constitute and cathect compensational objects from his inner world. The inner world encompasses interoceptive stimuli of the body and cognitive stimuli instead of external objects.

Reduced Interaction of Exteroceptive Stimuli

Wiebking et al. (2010) studied the neuronal activity during exteroceptive and interoceptive perception (heartbeat and counting of the cardiac frequency) in relation to the resting state activity of the brain. Exteroceptive stimuli (heartbeat) contributed to a neuronal activation in the bilateral anterior insula in depressed patients, if it was related to the previous resting state activity of the brain. But if the exteroceptive-induced activity was viewed independently from the previous resting state activity, significant differences were found between healthy persons and depressed patients. The resting state activity in depressed was increased compared to healthy persons, as the reduced deactivation during stimulus-induced activity had shown already. Thus, the increased resting state activity in the bilateral anterior insula contributed to a reduced interaction of the exteroceptive stimulus with the previously increased resting state activity. Analogous results were not found during the interoceptive stimuli (counting of the heartbeat), by means of which the specificity of the reduced stimulus-resting state-interaction during exteroceptive stimuli was underlined.

The importance of the increased resting state activity in the bilateral anterior insula was further supported through its correlation with the severity of depression: the higher the resting state activity in these regions, the more severe the depression was experienced in the self-assessment beck depression inventory (BDI). Furthermore, depressed patients showed increased scores for body perception and stress (BPQ). This result is consistent with the increased perception and attention to one's own body and the unspecific somatic symptoms, which are characteristic of depression. Whereas the BPQ-scores in healthy persons correlated with the resting state activity in the insula significantly, this correlation was not found in depressed patients: therefore, it could be concluded that the increased resting state activity in depressed was decoupled from the perception and experience of one's own body. The increased resting state activity and the consecutively reduced stimulus-rest-interaction are psychologically and psychopathologically of great importance.

The second component of the reduced stimulus-rest-interaction relates to the processing of value and reward. The reward network includes central regions the ventral tegmental area (VTA), the VS, and the VMPFC. Actual studies underline a reduced activity during the processing of reward tasks through exteroceptive stimuli just in these regions of depressed patients (Kumar et al., 2008; Dichter et al., 2009; Pizzagalli et al., 2009; Smoski et al., 2009).

Reduced Stimulus-Rest-Interaction and Cognitive Processing

The third component of the reduced stimulus-rest-interaction relates to the reciprocal pattern of neuronal activity between the medial and LPFC which could be shown in different studies (Goel and Dolan, 2003b; Northoff et al., 2004; Grimm et al., 2006) and which were described as reciprocal modulation (Northoff et al., 2004). In healthy persons, exteroceptive stimuli lead to a deactivation, i.e., to negative BOLD-answers, in the anterior medial cortical regions, whereas they lead to an increased neuronal activity in the lateral prefrontal cortical regions (e.g., in the DLPFC) during cognitive and emotional stimulation. Contrary, in depressed patients—as already mentioned—not only a hyperactivity in the ventral cortical midline regions was found, but also a hypoactivity in the left DLPFC as well during emotional as during cognitive processing either (Davidson et al., 2003; Lawrence et al., 2004; Keedwell et al., 2005). On the basis of these results, Phillips et al. (2003) and Mayberg (2003b) proposed a model of altered reciprocal functional connections between ventromedial and DLPFC in major depression (model of the ventro-dorsal dissociation in major depression). The reciprocal modulation is reduced in depression because of the decreased deactivation in the medial regions and the decreased activation of the DLPFC (Grimm et al., 2008; Carhart-Harris and Friston, 2010), i.e., there is an opposite activity in the medial and LPFC. When the medial regions are strongly deactivated, a strong activation in the lateral regions results, when the lateral regions are less activated, a less deactivation results in the medial regions. Therefore, exteroceptive stimuli do not lead to a decreased deactivation in the medial cortical regions, but also to a decreased activation in the lateral regions (DLPFC), which are especially associated with cognitive processing (Grimm et al., 2006, 2008, 2009). The disturbed modulation of the lateral prefrontal cortical rest activity probably leads to a decreased stimulus-induced activity, which is triggered by cognitive stimuli.

Of what significance are these three different components of the reduced stimulus-rest-interaction in a psychodynamic context? In depression, exteroceptive stimuli do not induce the existing resting state activity of the brain any longer. The reduced stimulus-resting state activity contributes to a reduced exteroceptive-neuronal interaction. It may be assumed accordingly, that the exteroceptive stimuli and the objects with are related to them are introjected with less probability. The

consecutive reduced constituting of the objects also results from the second component of the reduced stimulus-rest-interaction, the reduced processing of value and reward. The neuronal activity of the reward system—as the basis of processing of value induced by stimuli—is extremely reduced in depression. In a psychodynamic context it can be assumed that the selection of objects and the possibility to identify with them is more and more reduced because of the reduced ability of processing of value of stimuli. Actual object relation experiences get increasingly unimportant.

The reduced reciprocal modulation—as third component of the reduced stimulus-rest-interaction—implies that exteroceptive stimuli no longer induce the activation of cognitive processes (e.g., goal-oriented cognitions). This interferes with the "*object cathexis*," which Carhart-Harris and Friston (2010) associate in a neuropsychological perspective with goal-oriented cognition and activity within the DLPFC. The important thing here is that the reciprocal modulation itself is not disturbed in depression, but rather the causes of the reduced medial deactivation have to be explored. These may consist in the reduced rest activity and the reduction of exteroceptive stimuli, in which the latter is connected with the reduction of the previous exteroceptive-neuronal processing of values. Neuronal activity is not induced in the medial cortical regions by the incoming exteroceptive stimuli. In this perspective, the apparent abnormal reciprocal modulation in depression represents a process of compensation aiming at adapting the brain with regard to the processing of exteroceptive stimuli. Accordingly, the neurophysiologic problem in depression is not a lesion or a deficit of the reciprocal modulation, but the maintenance and the adaptive function of this mechanism. The depressive self is uncoupled from the experienced significance of actual object relation experiences finally. In a psych energetic perspective, a reduction of the object cathexis results.

Which are the mechanisms of compensation which are developed by the depressed patient in this situation? To answer this question Freud's metaphor of an open wound may be picked up: The depressed tries to constitute compensatory objects and to cathect them. In view of the inability to constitute objects of exteroceptive origin, i.e., from the outside, and to introject them, the depressed patient constitutes and introjects objects from the inside. The internal environment includes interoceptive stimuli from the body and cognitive stimuli. Instead of exteroceptive-interoceptive and exteroceptive-cognitive connections, neuronal-interoceptive and interoceptive-cognitive connections are developed from now on. By this, the depressed attempts to compensate the loss of exteroceptive stimuli. In a psychodynamic perspective external objects, i.e., objects of exteroceptive origin from the outside, are replaced by internal objects, i.e., objects of interoceptive and cognitive origin. The outstanding aim is to constitute objects and to develop object relations. Therefore, in a self-psychological perspective, this can be understood as a compensation of the loss of external or sensory self objects by internal or somatic and cognitive self objects.

Regarding psychopathological symptoms, the constitution of internal or somatic and cognitive self objects contributes to the development of somatic symptoms. The body is perceived in an altered way (see Wiebking et al., 2010). If the constitution of cognitive self objects dominates, the depressed suffers from distinctly distorted, negative cognitive schemes and ruminations, which are experienced as painful and tormenting. Because of the loss of exteroceptive objects the focus of attention is directed to one's own self and the self objects of cognitive origin. In a phenomenological perspective this was described by us as increased cognitive processing of one's own self with ruminations and a disbalance between the experiential and the analytical self-focus.

NEUROPSYCHODYNAMIC APPROACH TO TREATMENT OF DEPRESSION

How can we use the neuropsychodyamic model of depression for psychotherapeutic interventions in the treatment of depressed patients? Due to the multidimensionality and heterogeneity of depressive disorders, it is of essential importance to adapt the applicable somatotherapeutic and psychotherapeutic interventions to the specific conditions of each single case. The concept of depression as psychosomatosis of emotion regulation and the neuropsychodynamic model of depression may promote this individualized procedure (see Böker, 2017). The main aim of the psychotherapy of depression is to overcome the defensive strategies of the depressed patients and their intrapsychic, interpersonal, and psychosomatic vicious circles (Mentzos, 1995; Böker, 2002, 2006, 2009, 2017). Further therapeutic consequences of the neuropsychodynamic approach to depression involve the necessary emotional attunement in psychoanalytic psychotherapy of depressed patients and the adequate timing of therapeutic interventions (see Stern, 1983, 1985; Böker, 2003a,b; Boeker et al., 2013; see **Table 1**).

A stepwise adapted therapeutic focus, which takes state-variables of depression as well as trait-variables into account, is necessary. Particularly with regard to the actual emotional and cognitive state (see Böker and Grimm, 2012) and to the recidivism and chronification in the long-time course either, the importance of the hyperarousal of depressed patients, as subjective and clinical expression of the hyperactivity of the cortical midline structures, which was pointed out in this contribution, has to be kept in mind. Agitation and anxiety of the depressed patient require an appropriate containment, especially in the beginning of the treatment. In the long-time treatment course structural aspects of the personality of the patients move more and more into the center (e.g., dependency in relationships), furthermore the effects of experienced traumatization in another subgroup. The synergistic effects of pharmaco- and psychotherapy (as an expression of top-down- and bottom-up-mechanisms) are often the starting point for a combination therapy.

Psychoanalytic psychotherapy focusses primarily on the conflictuous forms of self-worth regulation and relationship expectations, especially in the long-time course. Generally, due

TABLE 1 | Neuropsychodynamic approach, psychotherapeutic attitude and therapeutic focus.

Depression
- Dysfunction of cortical midline structures (CMS)
- Arousal (Hyperactivity CMS)
- Disturbed self-referential processing
- Intensified processing of the body
Therapy:
- Acute and severe depression: state variables
- Longer course: trait variables
Neuropsychodynamic psychotherapy:
- Phase typical, stepwise adapted focus
- Beginning:
- Containment
- Being aware of anxiety, agitation and cognitive dysfunction
- Course:
- Increasing focus on conflictuous self-worth regulation and relationship expectations
- Long-time course (recidivism, double depression, loss of psychosocial functions, chronicity): psychotherapeutic maintenance strategies

to network dynamics and gene-expression, a sufficiently long duration of the treatment is necessary, and "psychotherapeutic maintenance strategies" are often necessary (Schauenburg and Clarkin, 2003).

The adequate timing of therapeutic interventions (in the sense of "now moments", see Stern, 1983) is especially important in the treatment of depressed patients. In this context, a specific problem of treatment technique derives from the encounter with different levels of symbolization and a possibly discontinuous process of de- and re-symbolization, which may be connected with a temporal decoupling of the psychic process and a reoccurrence of manifest depressive symptoms (see Böker, 2003a,b; Böker and Grimm, 2012; Böker, 2017). This discontinuity may also contribute to difficult countertransference feelings (e.g., guilt, shame, aggression, doubtfulness, self-criticism), similar to those feelings the depressed patient is suffering from. Furthermore, this may hinder the psychotherapist in his/her necessarily supportive and confident attitude. The insight into the neuronal and neuropsychodynamic mechanisms of depression (e.g., resting state hyperactivity, reduced rest-stimulus interaction) may help the psychotherapist to get along with this specific challenge in the therapeutic relationship and to use the countertransference feelings for therapeutic interventions in the further course.

Emotional experience evolves during the course of a psychoanalytic psychotherapy of depressed patients in the sense of a re-symbolization from the participation in a sensomotor affect through a trans modal change to an experienced emotion ("semiotic progression," see Böhme-Bloem, 1999) by discovering the otherness of the other and being able to mourn the separation: "The capacity to experience loss and the wish to recreate the object within oneself gives the individual the unconscious freedom in the use of symbols" (Segal, 1957, p. 394). Segal concluded: "The process of symbol formation is, ..., a continuous process of bringing together and integrating the internal with the external, the subject with the object, and the earlier experiences with the later ones" (p. 397).

The hypotheses which have been developed in the context of the neuropsychodynamic model of depression may be used for more specific psychotherapeutic interventions, aiming at specific mechanisms of compensation and defence, which are related to the increased resting state activity and the disturbed resting state-stimulus-interaction. Moreover, in a future "brain-based psychodynamic psychotherapy" of depression, the enabled processes of development and separation will be based on new experiences in the context of the therapeutic relationship.

Finally, the neurobiological effects of psychotherapy, though one of the most interesting and important challenges of a multidimensional psychotherapy research (for a methodological discussion, see Boeker et al., 2013), was not in the focus of the article. Because of the importance of this issue, we shortly mention recent neurobiological literature concerning neural effects of psychotherapy. A recent meta-analysis on neuroimaging findings of neural change in brain networks associated to emotion regulation after psychotherapy of depression by Messina et al. (2013) detected consistent changes in the DMPFC and in the posterior cingulated gyrus/precuneus, and in several areas in the temporal lobes in depression. A further meta-analysis by Kalsi et al. (2017) compared the effects of psychotherapy compared to antidepressant therapy on brain activity in depression. They found that patients undergoing psychotherapy showed an increase in the right paracingulate activity while pharmacological treatment led to a decrease of activation of this area. They interpreted this finding as supporting the hypothesis that psychotherapy increases top-down emotional regulation through self-knowledge and meaning processing. In a recent neuroimaging study in depressed patients undergoing psychodynamic psychotherapy, Buchheim et al. (2012) recently showed that psychodynamic psychotherapy in depressed patients reduces activation in the left anterior hippocampus/amygdala, subgenual cingulate and MPFC after 15 months.

CONCLUSIONS AND OUTLOOK

A neuropsychodynamic approach to depression may be summarized as follows: the self and the changes in self-experience are core dimensions in depression and of psychoanalytical theories of depression. The experience of self-related depression

can be characterized as the experience of the loss of the self. A mechanism-based approach was developed, focussing on the psychodynamic, psychological and neuronal mechanisms in healthy and depressed persons. On the basis of empirical results concerning emotional-cognitive interaction in depression, neuropsychodynamic hypotheses of the self in depression were developed.

In particular, it may be assumed that the empirically validated *increased resting state activity* in depression is a pre-disposition for the reactivation of experiences of early loss. The term "experiences of object loss" focuses not only on traumatic relationship experiences, but also encompasses the loss of the self in a significant relationship structure. Further, it may be hypothesized that the *resting state-stimulus-interaction* in depression is reduced because of the increased resting state activity and that it corresponds with introjective processes of the self in the relationship with objects (correlated with negative emotions).

The increased resting state activity in depression is especially associated with an increased resting state activity in the DMN. By means of this, changes in the complete spatial temporal structure of the intrinsic activity of the brain and the disbalance between DMN and executive network (EN) are induced. The reciprocal or negative interaction between DMN and EN is shifted in the direction of the DMN. This disbalance causes an abnormal increase in the internal mental contents, whereas externally oriented actions are decreased. The increased inward focus (with strong ruminations) and a reduced outward focus (with a reduced relationship to the outside world) are core symptoms in depression. The depressed patient is no longer able to differentiate between external stimuli and his own self (caused by the increased resting state activity in the DMN which cannot be modified by external stimuli).

The question of why adaptive mechanisms are activated in the disturbed context of the increased resting state activity may be answered by mentioning the central aim of these neuropsychodynamic mechanisms: to maintain at all costs the subjective existence of the self in view of the experienced threat of loss of the self. It is neither lesions nor disturbances of adaptive neuronal mechanisms which generate depressive symptoms, but rather increasingly dysfunctional mechanisms of compensation on the basis of the increased resting state activity.

As has been shown, different kinds of cognitive symptoms in depression may be connected to different neuropsychological functions, which in turn can be attributed to different forms of processing in the prefrontal cortex. These different forms of processing in the prefrontal cortex can be characterized by spatiotemporal patterns of neuronal activity, which are altered in a specific way during depression. In depression, there is hypofunction in the medial orbitofrontal cortex with consecutive changes in feedforward, feedback and re-entrant processing in the prefrontal cortex, anterior cingulate, DLPFC and VLPFC, respectively. The changes in prefrontal processing in depression are mostly related to an abnormal increase and synchronization in feedforward processing from the VMPFC, as well as to the resulting abnormal reduction of feedback and re-entrant processing.

Psychotherapeutic interventions in depression should focus on restoring these various forms of processing in the prefrontal cortex. In this context, emotional, cognitional and motor imagination, as well as working memory training, chronometrically oriented cognitive therapy and awareness of the time dimension play an important role in the psychotherapy of depression. These various inputs, based on neurophysiological mechanisms, could well complement existing psychotherapeutic approaches such as Psychodynamic Psychotherapy, Cognitive Behavioral Therapy (CBT), Interpersonal Therapy (IPT), Mindfulness-Based Cognitive Therapy (MBCT) and Cognitive Behavioral Analysis of Psychotherapy (CBASP). Considering the cognitive phenomenology described above and the underlying physiological mechanisms, new psychotherapeutic approaches may be developed in the future on the basis of the specific change in processing in the prefrontal cortex, in the sense of "phenomenologically and physiologically based neuropsychodynamic psychotherapy".

The role of attribution, i.e., the subjective interpretation of events, has been widely studied within the context of depression (for a recent review see Rubenstein et al., 2016). However, neuropsychodynamic psychiatry (see Boeker and Northoff, 2018) encompasses a novel approach to psychopathology and its psychodynamic dimensions. Neuropsychodynamic psychiatry aims to complement and extend phenomenological psychopathology beyond the phenomenal boundaries of experience and thus towards the brain. Methodologically, this requires two-fold access: the neuropsychodynamic psychiatrist and psychoanalyst needs access to subjects' experience while, at the same time, she/he requires access to the brain's spontaneous activity. Furthermore, the knowledge about the neuropsychodynamic mechanisms of depression may support the psychotherapist to recognize and use her/his countertransference feelings for therapeutic interventions. In the neuropsychodynamic approach to depression, therapeutic relationship (empathy, countertransference, therapeutic alliance) is of outstanding importance. In fact, one of the authors, HB, underlined the importance of the therapeutic relationship in the psychotherapy of depressed patients in a recent publication (Boeker, 2017). We hope that the neuropsychodynamic approach may assist the therapist/psychoanalyst perceiving, considering, and understanding some of the specific characteristics of the "affect communication" between the depressed patient and the therapist, e.g., increased self-focus, increased body-focus, agitation in the context of resting state dysfunctions. Therefore, we underlined the importance of the emotional attunement in psychoanalytic psychotherapy of depressed patients and the adequate timing of therapeutic interventions (see "Neuropsychodynamic Approach to Treatment of Depression" section). The knowledge on neurobiological/neuropsychodynamic mechanisms (e.g., increased resting state activity) may help the psychotherapist to use her/his countertransference and to enable an appropriate containmemt (especially in the beginning of the therapy) and to adapt the therapeutical interventions in the long-time

treatment course considering structural aspects of the personality of the depressed patient. This is strongly supported by recent evidence from therapeutic outcome studies in major depression (Blatt et al., 2010; Zimmermann et al., 2015) which showed that therapeutic relationship facilitates changes in negative self-representation ("introjective pole of depressive psychopathology") and structural organization of patients' inter-personal schemas ("anaclitic pole of depressive psychopathology"), leading to sustained therapeutic change.

Furthermore, semantic representations of the relationships represent an important inter-individual process in the therapeutic relationship and in the development of the patients' capacities to regulate their emotional states through the construction of the self, others and relationships. On this way the therapeutic relationship is "a key tool for revisiting impaired or distorted representations of the self and relational objects" (Messina et al., 2016a). Some limitations of this neuropsychodynamic approach to depression concern the problem of investigating psychodynamic dimensions of depression by means of operationalized studies (see Böker and Northoff, 2010; Boeker et al., 2013). Further studies are necessary to validate the increased resting state activity in depression.

AUTHOR CONTRIBUTIONS

HB: main author, empirical studies on depression, development of hypotheses and concepts. RK: co-author, neuroscientific research, critical discussion of literature and concepts.

ACKNOWLEDGMENTS

The neuroscientific results, which are presented in this article, and the development of a neuropsychodynamic model of depression would not have been possible without the cooperation with the members of the research group "Therapy and Process Research/TPR" at the Hospital of Psychiatry, Psychotherapy, and Psychosomatic Medicine, University of Zurich/Switzerland, and with further international partners. I would particularly like to thank Priv. Doz. Dr. rer.nat. Simone Grimm, Dr. rer.nat. Jutta Ernst, Dr. Holger Himmighoffen, MD, Dr. Andre Richter, MD, Dr. Dr. rer.nat. Milan Scheidegger, MD, Dipl. Psych Laura Bohleber, Dipl. Psych Johannes Vetter and Dipl. Psych. Isabel Berwian. My special thanks go to Prof. Dr. phil.habil. Georg Northoff, MD in Ottawa/Canada and Prof. Dr. Peter Hartwich/Frankfurt/M./Germany for the inspiring cooperation over decades.

REFERENCES

Adroer, S. (1998). Some considerations in the structure of the self and its pathology. *Int. J. Psychoanal.* 79, 681–696.

Alcaro, A., Panksepp, J., Witczak, J., Hayes, D. J., and Northoff, G. (2010). Is subcortical-cortical midline activity in depression mediated by glutamate and GABA? A cross-species translational approach. *Neurosci. Biobehav. Rev.* 34, 592–605. doi: 10.1016/j.neubiorev.2009.11.023

Bär, K. J., Greiner, W., Jochum, T., Friedrich, M., Wagner, G., and Sauer, H. (2004). The influence of major depression and its treatment on heart rate variability and pupillary light reflex parameters. *J. Affect. Disord.* 82, 245–252. doi: 10.1016/j.jad.2003.12.016

Blatt, S. J. (1998). Contributions of psychoanalysis to the understanding and treatment of depression. *J. Am. Psychoanal. Assoc.* 46, 723–752. doi: 10.1177/000306519804600301

Blatt, S. J., Zuroff, D. C., Hawley, L. L., and Auerbach, J. S. (2010). Predictors of sustained therapeutic change. *Psychother. Res.* 20, 37–54. doi: 10.1080/10503300903121080

Boeker, H. (2004). "Persons with depression, mania and schizoaffective Psychosis–investigations of cognitive complexity, self-esteem, social perception and object relations by means of the Repertory Grid-Technique," in *Role Repertory Grid and Body Grid–Construct Psychological Approaches in Psychosomatic Research*, ed. B. F. Klapp (Frankfurt/M: VAS–Verlag für Akademische Schriften, Reihe Klinische Psycholinguistik), S3–S20.

Boeker, H. (2017). *Psychodynamische Psychotherapie Depressiver Störungen. Theorie und Praxis.* Giessen: Psychosozial-Verlag.

Boeker, H., and Northoff, G. (2018). "Depressive syndromes," in *Neuropsychodynamic Psychiatry*, eds H. Boeker, P. Hartwich and G. Northoff (New York, NY: Springer), XVII–650.

Boeker, H., Richter, A., Himmighoffen, H., Ernst, J., Bohleber, L., Hofmann, E., et al. (2013). Essentials of psychoanalytic process and change: how can we investigate the neural effects of psychodynamic psychotherapy in individualised neuro-imaging? *Front. Hum. Neurosci.* 7:355. doi: 10.3389/fnhum.2013.00355

Boeker, H., Schulze, J., Richter, A., Nikisch, G., Schuepbach, D., and Grimm, S. (2012). Sustained cognitive impairments after clinical recovery of severe depression. *J. Nerv. Ment. Dis.* 200, 773–776. doi: 10.1097/NMD.0b013e318266ba14

Böhme-Bloem, C. (1999). "Gleiches und Trennendes bei der Affektabstimmung als Vorbereitung auf die Symbolbildung in der menschlichen Entwicklung und im psychoanalytischen Prozeß," in *Trennungen*, eds A. Sclösser and K. Höhfeld (Giessen: Psychosozial-Verlag), 171–186.

Böker, H. (1999). *Selbstbild und Objektbeziehungen bei Depressionen: Untersuchungen mit der Repertory Grid-Technik und dem Gießen-Test an 139 PatientInnen mit depressiven Erkrankungen. Monographien aus dem Gesamtgebiete der Psychiatrie.* Darmstadt: Steinkopff-Springer.

Böker, H. (2000a). *Depression, Manie und Schizoaffektive Psychosen: Psychodynamische Theorien, Einzelfallorientierte Forschung und Psychotherapie.* Giessen: Psychosozial-Verlag.

Böker, H. (2000b). "Subjective experience of catatonia: construct-analytical findings by means of modified landfield categories," in *The Person in Society: Challenges to a Constructivist Theory*, ed. J. W. Scheer (Giessen: Psychosozial-Verlag), 303–316.

Böker, H. (Ed.). (2001). *Depression, Manie und Schizoaffektive Psychosen: Psychodynamische Theorien, Einzelfallorientierte Forschung und Psychotherapie.* Giessen: Psychosozial-Verlag.

Böker, H. (2002). "Depressionen: psychosomatische erkrankungen des gehirns?" in *Therapie der Affektiven Störungen*, eds H. Böker and D. Hell (Schattauer, Stuttgart, New York, NY: Psychosoziale und neurobiologische Perspektiven), 183–205.

Böker, H. (2003a). Sind Depressionen psychosomatische Erkvankungen? *Vierteljahresschr. Naturforschenden Ges. Zür.* 148, 1–16. Available online at: http://www.ngzh.ch/archiv/2003_148/148_1/148_2.pdf

Böker, H. (2003b). "Symbolisierungsstörungen bei schweren depressionen: zur bedeutung psychosomatischer circuli vitiosi bei depressiv erkrankten," in *Symbolisierung und ihre Störungen*, ed. H. Lahme-Gronostaj (Frankfurt/M: Deutsche Psychoanalytische Vereinigung), 149–164.

Böker, H. (Ed.). (2005). "Melancholie, depression und affektive störungen: zur entwicklung der psychoanalytischen depressionsmodelle und deren rezeption in der klinischen psychiatrie," in *Psychoanalyse und Psychiatrie–Historische Entwicklung, Krankheitsmodelle und Therapeutische Praxis* (Springer, Berlin, Heidelberg, New York, NY: Springer), 115–158.

Böker, H. (2006). *Psychoanalyse und Psychiatrie.* Springer, Heidelberg: Geschichte, Krankheitsmodelle und Therapiepraxis.

Böker, H. (2009). Selbst und körper in der depression: herausforderungen an die therapie. *Schweiz. Archiv. Neurologie Psychiatr.* 160, 188–199. doi: 10.4414/sanp.2009.02074

Böker, H. (2017). *Psychodynamische Psychotherapie Depressiver Störungen. Theorie und Praxis.* Giessen: Psychosozial-Verlag.

Böker, H., and Grimm, S. (2012). "Emotion und kognition bei depressiv erkrankten," in *Psychotherapie und Neurowissenschaften*, eds H. Böker and E. Seifritz (Verlag Hans Huber, Bern: Integration–Kritik–Zukunftsaussichten), 309–351.

Böker, H., Hell, D., Budischewski, K., Eppel, A., Härtling, F., Rinnert, H., et al. (2000a). Personality and object relations in patients with affective disorders: idiographic research by means of the repertory grid technique. *J. Affect. Disord.* 60, 53–59. doi: 10.1016/s0165-0327(99)00161-5

Böker, H., Northoff, G., Lenz, C., Von Schmeling, C., Eppel, A., Hartling, F., et al. (2000b). Die Rekonstruktion der Sprachlosigkeit. Untersuchungen des subjektiven Erlebens ehemals katatoner PatientInnen mittels modifizierter Landfield-Kategorien. *Psychiat. Prax.* 27, 389–396.

Böker, H., and Northoff, G. (2005). Desymbolisierung in der schweren Depression und das Problem der Hemmung: Ein neuropsychoanalytisches Modell der Störung des emotionalen Selbstbezugs Depressiver. *Psyche Z Psychoanal.* 59, 964–989.

Böker, H., and Northoff, G. (2010). Die Entkopplung des Selbst in der Depression: Empirische Befunde und neuropsychodynamische Hypothesen. *Psyche Z Psychoanal.* 64, 934–976.

Bowlby, J. (1980). *Attachment and Loss: Sadness and Depression (Vol. 3).* New York, NY: Basic Books.

Brenner, C. (1991). A psychoanalytic perspective on depression. *J. Am. Psychoanal. Assoc.* 39, 25–43. doi: 10.1177/000306519103900102

Brody, A. L., Saxena, S., Stoessel, P., Gillies, L. A., Fairbanks, L. A., Alborzian, S., et al. (2001). Regional brain metabolic changes in patients with major depression treated with either paroxetine or interpersonal therapy: preliminary findings. *Arch. Gen. Psychiatry* 58, 631–640. doi: 10.1001/archpsyc.58.7.631

Buchheim, A., Viviani, R., Kessler, H., Kächele, H., Cierpka, M., Roth, G., et al. (2012). Changes in prefrontal-limbic function in major depression after 15 months of long-term psychotherapy. *PLoS One* 7:e33745. doi: 10.1371/journal.pone.0033745

Buckner, R. L., Andrews-Hanna, J. R., and Schacter, D. L. (2008). The brain's default network: anatomy, function and relevance to disease. *Ann. N Y Acad. Sci.* 1124, 1–38. doi: 10.1196/annals.1440.011

Canli, T., Sivers, H., Thomason, M. E., Whitfield-Gabrieli, S., Gabrieli, J. D., and Gotlib, I. H. (2004). Brain activation to emotional words in depressed vs. healthy subjects. *Neuroreport* 15, 2585–2588. doi: 10.1097/00001756-200412030-00005

Carhart-Harris, R. L., and Friston, K. J. (2010). The default-mode, ego-function and free energy; a neurobiological account of Freudian ideas. *Brain* 133, 1265–1283. doi: 10.1093/brain/awq010

Carhart-Harris, R. L., Mayberg, H. S., Malizia, A. L., and Nutt, D. (2008). Mourning and melancholia revisited: correspondences between principles of Freudian metapsychology and empirical findings in neuropsychiatry. *Ann. Gen. Psychiatry* 24, 7–9. doi: 10.1186/1744-859X-7-9

Coyne, J. C. (1976a). Depression and response of others. *J. Abnorm. Psychol.* 85, 186–193. doi: 10.1037/0021-843x.85.2.186

Coyne, J. C. (1976b). Toward an interactional description of depression. *Psychiatry* 39, 28–40. doi: 10.1080/00332747.1976.11023874

Coyne, J. C. (1985). Studying depressed persons' interactions with strangers and spouses. *J. Abnorm. Psychol.* 94, 231–232. doi: 10.1037/0021-843x.94.2.231

Coyne, J. C., Kessler, R. C., Tal, M., Turnbull, J., Wortman, C. B., and Greden, J. F. (1987). Living with a depressed person. *J. Consult. Clin. Psychol.* 55, 347–352. doi: 10.1037/0022-006x.55.3.347

Damasio, A. R. (1999). How the brain creates the mind. *Sci. Am.* 281, 112–117. doi: 10.1038/scientificamerican1299-112

Davidson, R. J. (2002). Anxiety and affective style: role of prefrontal cortex and amygdala. *Biol. Psychiatry* 51, 68–80. doi: 10.1016/s0006-3223(01)01328-2

Davidson, R. J., Irwin, W., Anderle, M. J., and Kalin, N. H. (2003). The neural substrates of affective processing in depressed patients treated with venlafaxine. *Am. J. Psychiatry* 160, 64–75. doi: 10.1176/appi.ajp.160.1.64

Deci, E. L., Eghrari, H., Patrick, B. C., and Leone, D. R. (1994). Facilitating internalization: the self-determination theory perspective. *J. Pers.* 62, 119–142. doi: 10.1111/j.1467-6494.1994.tb00797.x

Dennecker, F. W. (1989). Das selbst-system. *Psyche* 43, 577–608.

Dichter, G. S., Felder, J. N., Petty, C., Bizzell, J., Ernst, M., and Smoski, M. J. (2009). The effects of psychotherapy on neural responses to rewards in major depression. *Biol. Psychiatry* 66, 886–897. doi: 10.1016/j.biopsych.2009.06.021

Drevets, W. C. (2000). Neuroimaging studies of mood disorders. *Biol. Psychiatry* 48, 813–829. doi: 10.1016/S0006-3223(00)01020-9

Drevets, W. C. (2001). Neuroimaging and neuropathological studies of depression: implications for the cognitive-emotional features of mood disorders. *Curr. Opin. Neurobiol.* 11, 240–249. doi: 10.1016/s0959-4388(00)00203-8

Drevets, W. C., Price, J. L., and Furey, M. L. (2008). Brain structural and functional abnormalities in mood disorders: implications for neurocircuitry models of depression. *Brain Struct. Funct.* 213, 93–118. doi: 10.1007/s00429-008-0189-x

Drevets, W. C., and Raichle, M. (1998). Reciprocal suppression of rCBF during emotional versus higher cognitive processes. *Cogn. Emot.* 12, 353–835. doi: 10.1080/026999398379646

Elliott, R., Rubinsztein, J. S., Sahakian, B. J., and Dolan, R. J. (2000). Selective attention to emotional stimuli in a verbal go/no-go task: an fMRI study. *Neuroreport* 11, 1739–1744. doi: 10.1097/00001756-200006050-00028

Elliott, R., Rubinsztein, J. S., Sahakian, B. J., and Dolan, R. J. (2002). The neural basis of mood-congruent processing biases in depression. *Arch. Gen. Psychiatry* 59, 597–604. doi: 10.1001/archpsyc.59.7.597

Elliott, R., Sahakian, B. J., Michael, A., Paykel, E. S., and Dolan, R. J. (1998). Abnormal neural response to feedback on planning and guessing tasks in patients with unipolar depression. *Psychol. Med.* 28, 559–571. doi: 10.1017/s0033291798006709

Ernst, J., Böker, H., Hättenschwiler, J., Schüpbach, D., Northoff, G., Seifritz, E., et al. (2014). The association of interoceptive awareness and alexithymia with neurotransmitter concentrations in insula and anterior cingulate. *Soc. Cogn. Affect. Neurosci.* 9, 857–863. doi: 10.1093/scan/nst058

Ernst, J., Northoff, G., Böker, H., Seifritz, E., and Grimm, S. (2013). Interoceptive awareness enhances neural activity during empathy. *Hum. Brain Mapp.* 34, 1615–1624. doi: 10.1002/hbm.22014

Feder, A., Nestler, E. J., and Charney, D. S. (2009). Psychobiology and molecular genetics of resilience. *Nat. Rev. Neurosci.* 10, 446–457. doi: 10.1038/nrn2649

Feinberg, T. E. (2011). Neuropathologies of the self: clinical and anatomical features. *Conscious. Cogn.* 20, 75–81. doi: 10.1016/j.concog.2010.09.017

Fitzgerald, P. B., Sritharan, A., Daskalakis, Z. J., de Castella, A. R., Kulkarni, J., and Egan, G. (2007). A functional magnetic resonance imaging study of the effects of low frequency right prefrontal transcranial magnetic stimulation in depression. *J. Clin. Psychopharmacol.* 27, 488–492. doi: 10.1097/jcp.0b013e318151521c

Fonagy, P., Gergely, G., and Target, M. (2007). The parent-infant dyad and the construction of the subjective self. *J. Child Psychol. Psychiatry* 48, 288–328. doi: 10.1111/j.1469-7610.2007.01727.x

Force, O. T. (Ed.). (2008). *Operationalized Psychodynamic Diagnosis OPD-2: Manual of Diagnosis and Treat-Ment Planning.* Göttingen: Hogrefe & Huber Publishers.

Fox, M. D., Snyder, A. Z., Vincent, J. L., Corbetta, M., Van Essen, D. C., and Raichle, M. E. (2005). The human brain is intrinsically organized into dynamic, anti-correlated functional networks. *Proc. Natl. Acad. Sci. U S A* 102, 9673–9678. doi: 10.1073/pnas.0504136102

Freud, S. (1914). On narcissism: an introduction. *SE* XIV, 30–59.

Freud, S. (1917). Mourning and melancholia. *SE* XIV, 239–260.

Friston, K. J. (1998). Imaging neuroscience: principles or maps? *Proc. Natl. Acad. Sci. U S A* 95, 796–802. doi: 10.1073/pnas.95.3.796

Friston, K. J. (2003). Learning and inference in the brain. *Neural Netw.* 16, 1325–1352. doi: 10.1016/j.neunet.2003.06.005

Friston, K. J., Fletcher, P., Josephs, O., Holmes, A., Rugg, M. D., and Turner, R. (1998a). Event-related fMRI: characterizing differential responses. *Neuroimage* 7, 30–40. doi: 10.1006/nimg.1997.0306

Friston, K. J., Josephs, O., Rees, G., and Turner, R. (1998b). Nonlinear event-related responses in fMRI. *Magn. Reson. Med.* 39, 41–52. doi: 10.1002/mrm.1910390109

Friston, K. J., Harrison, L., and Penny, W. (2003). Dynamic causal modelling. *Neuroimage* 19, 1273–1302. doi: 10.1016/S1053-8119(03)00202-7

Friston, K. J., and Price, C. J. (2001). Dynamic representations and generative models of brain function. *Brain Res. Bull.* 54, 275–285. doi: 10.1016/s0361-9230(00)00436-6

Friston, K. J., and Price, C. J. (2003). Degeneracy and redundancy in cognitive anatomy. *Trends Cogn. Sci.* 7, 151–152. doi: 10.1016/s1364-6613(03)00054-8

Fu, C. H., Williams, S. C., Cleare, A. J., Brammer, M. J., Walsh, N. D., Kim, J., et al. (2004). Attenuation of the neural response to sad faces in major depression by antidepressant treatment: a prospective, event-related functional magnetic resonance imaging study. *Arch. Gen. Psychiatry* 61, 877–889. doi: 10.1001/archpsyc.61.9.877

Gabbard, G. O. (2005). *Psychodynamic Psychiatry in Clinical Practice.* Arlington, VA: American Psychiatric Press Inc.

Gabbard, G. O. (2014). *Psychodynamic Psychiatry in Clinical Practice.* 5th Edn. Washington, DC: American Psychiatric Publishing.

Goel, V., and Dolan, R. J. (2003a). Explaining modulation of reasoning by belief. *Cognition* 87, B11–B22. doi: 10.1016/s0010-0277(02)00185-3

Goel, V., and Dolan, R. J. (2003b). Reciprocal neural response within lateral and ventral medial prefrontal cortex during hot and cold reasoning. *Neuroimage* 20, 2314–2321. doi: 10.1016/j.neuroimage.2003.07.027

Gotlib, I. H., Krasnoperova, E., Yue, D. N., and Joormann, J. (2004). Attentional biases for negative interpersonal stimuli in clinical depression. *J. Abnorm. Psychol.* 113, 121–135. doi: 10.1037/0021-843X.113.1.121

Greicius, M. D., Flores, B. H., Menon, V., Glover, G. H., Solvason, H. B., Kenna, H., et al. (2007). Resting-state functional connectivity in major depression: abnormally increased contributions from subgenual cingulate cortex and thalamus. *Biol. Psychiatry* 62, 429–437. doi: 10.1016/j.biopsych.2006.09.020

Greicius, M. D., Krasnow, B., Reiss, A. L., and Menon, V. (2003). Functional connectivity in the resting brain: a network analysis of the default mode hypothesis. *Proc. Natl. Acad. Sci. U S A* 100, 253–258. doi: 10.1073/pnas.0135058100

Grimm, S., Beck, J., Schuepbach, D., Hell, D., Boesiger, P., Bermpohl, F., et al. (2008). Imbalance between left and right dorsolateral prefrontal cortex in major depression is linked to negative emotional judgment: an fMRI study in severe major depressive disorder. *Biol. Psychiatry* 63, 369–376. doi: 10.1016/j.biopsych.2007.05.033

Grimm, S., Ernst, J., Boesiger, P., Schuepbach, D., Hell, D., Boeker, H., et al. (2009). Increased self-focus in major depressive disorder is related to neural abnormalities in subcortical midline structures. *Hum. Brain Mapp.* 30, 2617–2627. doi: 10.1002/hbm.20693

Grimm, S., Schmidt, C. F., Bermpohl, F., Heinzel, A., Dahlem, Y., Wyss, M., et al. (2006). Segregated neural representation of distinct emotion dimensions in the prefrontal cortex–an fMRI study. *Neuroimage* 30, 325–340. doi: 10.1016/j.neuroimage.2005.09.006

Gündel, H., O'Connor, M. F., and Nolen-Hoeksema, S. (2003). Functional neuroanatomy of grief: an FMRI study. *Am. J. Psychiatry* 160, 1946–1953. doi: 10.1176/appi.ajp.160.11.1946

Gusnard, D. A., Akbudak, E., Shulman, G. L., and Raichle, M. E. (2001). Medial prefrontal cortex and self-referential mental activity: relation to a default mode of brain function. *Proc. Natl. Acad. Sci. U S A* 98, 4259–4264. doi: 10.1073/pnas.071043098

Gusnard, D. A., and Raichle, M. E. (2001). Searching for a baseline: functional imaging and the resting human brain. *Nat. Rev. Neurosci.* 2, 685–694. doi: 10.1038/35094500

Gut, E. (1989). *Productive and Unproductive Depression.* London: Tavistock and Routledge.

Heinzel, A., Grimm, S., Beck, J., Schuepbach, D., Hell, D., Boesiger, P., et al. (2009). Segregated neural representation of psychological and somatic-vegetative symptoms in severe major depression. *Neurosci. Lett.* 456, 49–53. doi: 10.1016/j.neulet.2009.03.097

Heller, A. S., Johnstone, T., Shackman, A. J., Light, S. N., Peterson, M. J., Kolden, G. G., et al. (2009). Reduced capacity to sustain positive emotion in major depression reflects diminished maintenance of fronto-striatal brain activation. *Proc. Natl. Acad. Sci. U S A* 106, 22445–22450. doi: 10.1073/pnas.0910651106

Ingram, R. E. (1990). Self-focused attention in clinical disorders: review and a conceptual model. *Psychol. Bull.* 107, 156–176. doi: 10.1037/0033-2909.107.2.156

Inoue, Y., Tonooka, Y., Yamada, K., and Kanba, S. (2004). Deficiency of theory of mind in patients with remitted mood disorder. *J. Affect. Disord.* 82, 403–409. doi: 10.1016/j.jad.2004.04.004

Jacobson, E. (1971). *Depression. Comparative Studies of Normal, Neurotic and Psychotic Conditions.* New York, NY: New Intern Universities Press.

Kalsi, N., Altavilla, D., Tambelli, R., Aceto, P., Trentini, C., Di Giorgio, C., et al. (2017). Neural correlates of outcome of the psychotherapy compared to antidepressant therapy in anxiety and depression disorders: a meta-analysis. *Front. Psychol.* 8:927. doi: 10.3389/fpsyg.2017.00927

Keedwell, P. A., Andrew, C., Williams, S. C., Brammer, M. J., and Phillips, M. L. (2005). The neural correlates of anhedonia in major depressive disorder. *Biol. Psychiatry* 58, 843–853. doi: 10.1016/j.biopsych.2005.05.019

Kernberg, O. (1976). *Object-Relations Theory and Clinical Psychoanalysis.* New York, NY: Jason Aronson.

Kohut, H. (1977). *The Restoration of the Self.* New York, NY: International Universities Press. (Deutsch, 1979. Die Heilung des Selbst. Suhrkamp, Frankfurt/M).

Kumari, V., Mitterschiffthaler, M. T., Teasdale, J. D., Malhi, G. S., Brown, R. G., Giampietro, V., et al. (2003). Neural abnormalities during cognitive generation of affect in Treatment-Resistant depression. *Biol. Psychiatry* 54, 777–791. doi: 10.1016/s0006-3223(02)01785-7

Kumar, P., Waiter, G., Ahearn, T., Milders, M., Reid, I., and Steele, J. D. (2008). Abnormal temporal difference reward-learning signals in major depression. *Brain* 131, 2084–2093. doi: 10.1093/brain/awn136

Lamme, V. A. (2001). Blindsight: the role of feedforward and feedback corticocortical connections. *Acta Psychol.* 107, 209–228. doi: 10.1016/s0001-6918(01)00020-8

Lamme, V. A. (2004). Separate neural definitions of visual consciousness and visual attention; a case for phenomenal awareness. *Neural Netw.* 17, 861–872. doi: 10.1016/j.neunet.2004.02.005

Lawrence, N. S., Williams, A. M., Surguladze, S., Giampietro, V., Brammer, M. J., Andrew, C., et al. (2004). Subcortical and ventral prefrontal cortical neural responses to facial expressions distinguish patients with bipolar disorder and major depression. *Biol. Psychiatry* 55, 578–587. doi: 10.1016/j.biopsych.2003.11.017

Lichtenberg, J. D. (1983). *Psychoanalysis and Infant Research.* Hillsdale, NY: The Analytic Press.

Maeng, S., and Zarate, C. A. Jr. (2007). The role of glutamate in mood disorders: results from the ketamine in major depression study and the presumed cellular mechanism underlying its antidepressant effects. *Curr. Psychiatry Rep.* 9, 467–474. doi: 10.1007/s11920-007-0063-1

Maeng, S., Zarate, C. A. Jr., Du, J., Schloesser, R. J., McCammon, J., Chen, G., et al. (2008). Cellular mechanisms underlying the antidepressant effects of ketamine: role of α-amino-3-hydroxy-5-methylisoxazole-4-propionic acid receptors. *Biol. Psychiatry* 63, 349–352. doi: 10.1016/j.biopsych.2007.05.028

Malancharuvil, J. M. (2004). Projection, introjection and projective identification: a reformulation. *Am. J. Psychoanal.* 64, 375–382. doi: 10.1007/s11231-004-4325-y

Masterman, D. L., and Cummings, J. L. (1997). Frontal-subcortical circuits: the anatomic basis of executive, social and motivated behaviors. *J. Psychopharmacol.* 11, 107–114. doi: 10.1177/026988119701100203

Mayberg, H. S. (2002). Depression, II: localization of pathophysiology. *Am. J. Psychiatry* 159:1979. doi: 10.1176/appi.ajp.159.12.1979

Mayberg, H. S. (2003a). Modulating dysfunctional limbic-cortical circuits in depression: towards development of brain-based algorithms for diagnosis and optimised treatment. *Br. Med. Bull.* 65, 193–207. doi: 10.1093/bmb/65.1.193

Mayberg, H. S. (2003b). Positron emission tomography imaging in depression: a neural systems perspective. *Neuroimaging Clin. N. Am.* 13, 805–815. doi: 10.1016/s1052-5149(03)00104-7

Mayberg, H. S., Liotti, M., Brannan, S. K., McGinnis, S., Mahurin, R. K., Jerabek, P. A., et al. (1999). Reciprocal limbic-cortical function and negative mood: converging PET findings in depression and normal sadness. *Am. J. Psychiatry* 156, 675–682.

Mazoyer, B., Zago, L., Mellet, E., Bricogne, S., Etard, O., Houdé, O., et al. (2001). Cortical networks for working memory and executive functions sustain the conscious resting state in man. *Brain Res. Bull.* 54, 287–298. doi: 10.1016/s0361-9230(00)00437-8

Mentzos, S. (1995). *Depression und Manie; Psychodynamik und Psychotherapie Affektiver Störungen*. Zürich, Göttingen: Vandenhoeck & Ruprecht.

Mentzos, S. (2009). *Lehrbuch der Psychodynamik*. 5th Edn. Göttingen: Vandenhoeck & Ruprecht.

Messina, I., Bianco, F., Cusinato, M., Calvo, V., and Sambin, M. (2016a). Abnormal default system functioning in depression: implications for emotion regulation. *Front. Psychol.* 7:858. doi: 10.3389/fpsyg.2016.00858

Messina, I., Sambin, M., Beschoner, P., and Viviani, R. (2016b). Changing views of emotion regulation and neuro-biological models of the mechanism of action of psychotherapy. *Cogn. Affect. Behav. Neurosci.* 16, 571–587. doi: 10.3758/s13415-016-0440-5

Messina, I., Bianco, S., Sambin, M., and Viviani, R. (2015). Executive and semantic processes in reappraisal of negative stimuli: insights from a meta-analysis of neuroimaging studies. *Front. Psychol.* 6:956. doi: 10.3389/fpsyg.2015.00956

Messina, I., Sambin, M., Palmieri, A., and Viviani, R. (2013). Neural correlates of psychotherapy in anxiety and depression: a meta-analysis. *PLoS One* 8:e74657. doi: 10.1371/journal.pone.0074657

Murphy, F. C., Nimmo-Smith, I., and Lawrence, A. D. (2003). Functional neuroanatomy of emotions: a meta-analysis. *Cogn. Affect. Behav. Neurosci.* 3, 207–233. doi: 10.3758/cabn.3.3.207

Murphy, F. C., Rubinsztein, J. S., Michael, A., Rogers, R. D., Robbins, T. W., Paykel, E. S., et al. (2001). Decision-making cognition in mania and depression. *Psychol. Med.* 31, 679–693. doi: 10.1017/s003329171001003804

Murphy, F. C., Sahakian, B. J., Rubinsztein, J. S., Michael, A., Rogers, R. D., Robbins, T. W., et al. (1999). Emotional bias and inhibitory control processes in mania and depression. *Psychol. Med.* 29, 1307–1321. doi: 10.1017/s0033291799001233

Nagai, Y., Critchley, H. D., Featherstone, E., Trimble, M. R., and Dolan, R. J. (2004). Activity in ventromedial prefrontal cortex covaries with sympathetic skin conductance level: a physiological account of a "default mode" of brain function. *Neuroimage* 22, 243–251. doi: 10.1016/j.neuroimage.2004.01.019

Najib, A., Lorberbaum, J. P., Kose, S., Bohning, D. E., and George, M. S. (2004). Regional brain activity in women grieving a romantic relationship breakup. *Am. J. Psychiatry* 161, 2245–2256. doi: 10.1176/appi.ajp.161.12.2245

Nejad, A. B., Fossati, P., and Lemogne, C. (2013). Self-referential processing, rumination, and cortical midline structures in major depression. *Front. Hum. Neurosci.* 7:666. doi: 10.3389/fnhum.2013.00666

Nemeroff, C. B., Heim, C. M., Thase, M. E., Klein, D. N., Rush, A. J., Schatzberg, A. F., et al. (2003). Differential responses to psychotherapy versus pharmacotherapy in patients with chronic forms of major depression and childhood trauma. *Proc. Natl. Acad. Sci. U S A* 100, 14293–14296. doi: 10.1073/pnas.2336126100

Northoff, G. (2000). *Das Gehirn: Eine Neurophilosophische Bestandesaufnahme*. Paderborn: Mentes-Verlag.

Northoff, G. (2002a). Catatonia and neuroleptic malignant syndrome: psychopathology and pathophysiology. *J. Neural Transm.* 109, 1453–1467. doi: 10.1007/s00702-002-0762-z

Northoff, G. (2002b). What catatonia can tell us about "top-down" modulation: a neuropsychiatric hypothesis. *Behav. Brain Sci.* 25, 555–577; discussion 578–604. doi: 10.1017/s0140525x02000109

Northoff, G. (2004). *Philosophy of the Brain. The Brain Problem*. Amsterdam: John Benjamin Publishing.

Northoff, G. (2013). *Unlocking the Brain. Volume 2, Consciousness*. Oxford, NY: Oxford University Press.

Northoff, G., and Bermpohl, F. (2004). Cortical midline structures and the self. *Trends Cogn. Sci.* 8, 102–107. doi: 10.1016/j.tics.2004.01.004

Northoff, G., and Boeker, H. (2006). Principles of neuronal integration and defense mechanisms: neuropsychoanalytic hypothesis. *Neuropsychoanalysis* 8, 69–84. doi: 10.1080/15294145.2006.10773514

Northoff, G., Boeker, H., Richter, A., Tempelmann, C., Bogerts, B., and Heinze, H. J. (2003). Emotional-behavioral disturbances in catatonia: a combined study of psychological self-evaluation and fMRI. *Neuropsychoanalysis* 3, 151–167.

Northoff, G., Eckert, J., and Fritze, J. (1997). Glutamatergic dysfunction in catatonia? Successful treatment of three acute akinetic catatonic patients with the NMDA antagonist amantadine. *J. Neurol. Neurosurg. Psychiatry* 62, 404–406. doi: 10.1136/jnnp.62.4.404

Northoff, G., Heinzel, A., Bermpohl, F., Niese, R., Pfennig, A., Pascual-Leone, A., et al. (2004). Reciprocal modulation and attenuation in the prefrontal cortex: an fMRI study on emotional-cognitive interaction. *Hum. Brain Mapp.* 21, 202–212. doi: 10.1002/hbm.20002

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., and Panksepp, J. (2006). Self-referential processing in our brain—a meta-analysis of imaging studies on the self. *Neuroimage* 31, 440–457. doi: 10.1016/j.neuroimage.2005.12.002

Northoff, G., Richter, A., Baumgart, F., Leschinger, von Schmeling, C., Lenz, C., et al. (2002). Orbitofrontal cortical dysfunction and "sensori-motor regression": a combined study of fMRI and personal constructs in catatonia. *Neuropsychoanalysis* 4, 151–171. doi: 10.1080/15294145.2002.10773394

Northoff, G., Richter, A., Bermpohl, F., Grimm, S., Martin, E., Marcar, V. L., et al. (2005). NMDA hypofunction in the posterior cingulate as a model for schizophrenia: an exploratory ketamine administration study in fMRI. *Schizophr. Res.* 72, 235–248. doi: 10.1016/j.schres.2004.04.009

Northoff, G., Richter, A., Gessner, M., Schlagenhauf, F., Fell, J., Baumgart, F., et al. (2000). Functional dissociation between medial and lateral spatiotemporal activation in negative and positive emotions: a combined FMRI/MEG study. *Cereb. Cortex* 10, 93–107. doi: 10.1093/cercor/10.1.93

Northoff, G., Walter, M., Schulte, R. F., Beck, J., Dydak, U., Henning, A., et al. (2007). Gaba concentrations in the human anterior cingulate cortex predict negative BOLD responses in fMRI. *Nat. Neurosci.* 10, 1515–1517. doi: 10.1038/nn2001

O'Connor, M. F., Allen, J. J., and Kaszniak, A. W. (2002). Autonomic and emotion regulation in bereavement and depression. *J. Psychosom. Res.* 52, 183–185. doi: 10.1016/s0022-3999(02)00292-1

O'Connor, M. F., Wellisch, D. K., Stanton, A. L., Eisenberger, N. I., Irwin, M. R., and Lieberman, M. D. (2008). Craving love? Endur-ing grief activates brain's reward center. *Neuroimage* 42, 969–972. doi: 10.1016/j.neuroimage.2008.04.256

Panksepp, J. (1998a). *Affective Neuroscience: The Foundations of Human and Animal Emotions*. New York, NY: Oxford University Press.

Panksepp, J. (1998b). The periconscious substrates of consciousness: affective states and the evolutionary origins of the self. *J. Conscious. Stud.* 5, 566–582.

Paradiso, S., Lamberty, G. J., Garvey, M. J., and Robinson, R. G. (1997). Cognitive impairment in the euthymic phase of chronic unipolar depression. *J. Nerv. Ment. Dis.* 185, 748–754. doi: 10.1097/00005053-199712000-00005

Paulus, M. P., and Stein, M. B. (2010). Interoception in anxiety and depression. *Brain Struct. Funct.* 214, 451–463. doi: 10.1007/s00429-010-0258-9

Pelosi, L., Slade, T., Blumhardt, L. D., and Sharma, V. K. (2000). Working memory dysfunction in depression: an event-related potential study. *Clin. Neurophysiol.* 111, 1531–1543. doi: 10.1016/s1388-2457(00)00354-0

Pessoa, L., McKenna, M., Gutierrez, E., and Ungerleider, L. G. (2002). Neural processing of emotional faces requires attention. *Proc. Natl. Acad. Sci. U S A* 99, 11458–11463. doi: 10.1073/pnas.172403899

Pessoa, L., and Ungerleider, L. G. (2004). Neuroimaging studies of attention and the processing of emotion-laden stimuli. *Prog. Brain Res.* 144, 171–182. doi: 10.1016/s0079-6123(03)14412-3

Phan, K. L., Wager, T., Taylor, S. F., and Liberzon, I. (2002). Functional neuroanatomy of emotion: a meta-analysis of emotion activation studies in PET and fMRI. *Neuroimage* 16, 331–348. doi: 10.1006/nimg.2002.1087

Phillips, M. L., Drevets, W. C., Rauch, S. L., and Lane, R. (2003). Neurobiology of emotion perception II: implications for major psychiatric disorders. *Biol. Psychiatry* 54, 515–528. doi: 10.1016/s0006-3223(03)00171-9

Pizzagalli, D. A., Holmes, A. J., Dillon, D. G., Goetz, E. L., Birk, J. L., Bogdan, R., et al. (2009). Reduced caudate and nucleus accumbens response to rewards in unmedicated individuals with major depressive disorder. *Am. J. Psychiatry* 166, 702–710. doi: 10.1176/appi.ajp.2008.08081201

Price, C. J., and Friston, K. J. (2002). Degeneracy and cognitive anatomy. *Trends Cogn. Sci.* 6, 416–421. doi: 10.1016/s1364-6613(02)01976-9

Price, J. L., and Drevets, W. C. (2010). Neurocircuitry of mood disorders. *Neuropsychopharmacology* 35, 192–216. doi: 10.1038/npp.2009.104

Qin, P., and Northoff, G. (2011). How is our self related to midline regions and the default-mode network? *Neuroimage* 57, 1221–1233. doi: 10.1016/j.neuroimage.2011.05.028

Raichle, M. E. (2001). Cognitive neuroscience. Bold insights. *Nature* 412, 128–130. doi: 10.1038/35084300

Raichle, M. E. (2003). Functional brain imaging and human brain function. *J. Neurosci.* 23, 3959–3962. doi: 10.1523/JNEUROSCI.23-10-03959.2003

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., and Shulman, G. L. (2001). A default mode of brain function. *Proc. Natl. Acad. Sci. U S A* 98, 676–682. doi: 10.1073/pnas.98.2.676

Rimes, K. A., and Watkins, E. (2005). The effects of self-focused rumination on global negative self-judgments in depression. *Behav. Res. Ther.* 43, 1673–1681. doi: 10.1016/j.brat.2004.12.002

Rubenstein, L. M., Freed, R. D., Shapero, B. G., Fauber, R. L., and Alloy, L. B. (2016). Cognitive attributions in depression: bridg-ing the gap between research and clinical practice. *J. Psychother. Integr.* 26, 103–115. doi: 10.1037/int0000030

Sajonz, B., Kahnt, T., Margulies, D. S., Park, S. Q., Wittmann, A., Stoy, M., et al. (2010). Delineating self-referential processing from episodic memory retrieval: common and dissociable networks. *Neuroimage* 50, 1606–1617. doi: 10.1016/j.neuroimage.2010.01.087

Sanacora, G. (2010). Cortical inhibition, γ-aminobutyric acid, and major depression: there is plenty of smoke but is there fire? *Biol. Psychiatry* 67, 397–398. doi: 10.1016/j.biopsych.2010.01.003

Schauenburg, H., and Clarkin, J. (2003). Relapse in depressive disorder—is there a need for maintenance psychotherapy? *Z. Psychosom. Med. Psychother.* 49, 377–390. doi: 10.13109/zptm.2003.49.4.377

Segal, H. (1957). Notes on symbol formation. *Int. J. Psychoanal.* 38, 391–397.

Sheline, Y. I., Barch, D. M., Price, J. L., Rundle, M. M., Vaishnavi, S. N., Snyder, A. Z., et al. (2009). The default mode network and self-referential processes in depression. *Proc. Natl. Acad. Sci. U S A* 106, 1942–1947. doi: 10.1073/pnas.0812686106

Sheppard, L. C., and Teasdale, J. D. (2004). How does dysfunctional thinking decrease during recovery from major depression? *J. Abnorm. Psychol.* 113, 64–71. doi: 10.1037/0021-843x.113.1.64

Smoski, M. J., Felder, J., Bizzell, J., Green, S. R., Ernst, M., Lynch, T. R., et al. (2009). fMRI of alterations in reward selection, anticipation and feedback in major depressive disorder. *J. Affect. Disord.* 118, 69–78. doi: 10.1016/j.jad.2009.01.034

Stern, H. (1983). "The early development of scheme of self, other, and 'self with other'," in *Reflections on Self Psychology*, eds J. D. Lichtenberg and S. Kaplan (Hillsdale, NY: Analytic Press), S49–S84.

Stern, D. N. (1985). *The Interpersonal World of the Infant. Basic Books, New York. Deutsch (1992). Die Lebenserfahrung des Säuglings.* Stuttgart: Klett-Cotta.

Stolorov, R. D. (1986). "On experiencing an object: a multi-dimensional perspective," in *Progress in Self-Psychology* (Vol. 2) ed. A. Goldberg (Hillsdale, NY: The Analytic Press), S273–S279.

Surguladze, S. A., Young, A. W., Senior, C., Brébion, G., Travis, M. J., and Phillips, M. L. (2004). Recognition accuracy and response bias to happy and sad facial expressions in patients with major depression. *Neuropsychology* 18, 212–218. doi: 10.1037/0894-4105.18.2.212

Tononi, G., and Edelman, G. M. (2000). Schizophrenia and the mechanisms of conscious integration. *Brain Res. Rev.* 31, 391–400. doi: 10.1016/s0165-0173(99)00056-9

Treynor, W., Gonzalez, R., and Nolen-Hoeksema, S. (2003). Rumination reconsidered: a psychometric analysis. *Cogn. Ther. Res.* 27, 247–259. doi: 10.1023/A:1023910315561

Walter, M., Henning, A., Grimm, S., Schulte, R. F., Beck, J., Dydak, U., et al. (2009). The relationship between aberrant neuronal activation in the pregenual anterior cingulate, altered glutamatergic metabolism and anhedonia in major depression. *Arch. Gen. Psychiatry* 66, 478–486. doi: 10.1001/archgenpsychiatry.2009.39

Wicker, B., Keysers, C., Plailly, J., Royet, J. P., Gallese, V., and Rizzolatti, G. (2003a). Both of us disgusted in My insula: the common neural basis of seeing and feeling disgust. *Neuron* 40, 655–664. doi: 10.1016/S0896-6273(03)00679-2

Wicker, B., Perrett, D. I., Baron-Cohen, S., and Decety, J. (2003b). Being the target of another's emotion: a PET study. *Neuropsychologia* 41, 139–146. doi: 10.1016/s0028-3932(02)00144-6

Wicker, B., Ruby, P., Royet, J. P., and Fonlupt, P. (2003c). A relation between rest and the self in the brain? *Brain Res. Rev.* 43, 224–230. doi: 10.1016/j.brainresrev.2003.08.003

Wiebking, C., Bauer, A., de Greck, M., Duncan, N. W., Tempelmann, C., and Northoff, G. (2010). Abnormal body perception and neural activity in the insula in depression: an fMRI study of the depressed "material me". *World J. Biol. Psychiatry* 11, 538–549. doi: 10.3109/15622970903563794

Zarate, C. A. Jr., Singh, J. B., Carlson, P. J., Brutsche, N. E., Ameli, R., Luckenbaugh, D. A., et al. (2006). A randomized trial of an *N*-methyl-D-aspartate antagonist in treatment-resistant major depression. *Arch. Gen. Psychiatry* 63, 856–864. doi: 10.1001/archpsyc.63.8.856

Zimmermann, J., Löeffler-Stastka, H., Huber, D., Klug, G., Alhabbo, S., Bock, A., et al. (2015). Is it all about the higher dose? why psychoanalytic therapy is an effective treatment for major depression. *Clin. Psychol. Psychother.* 22, 469–487. doi: 10.1002/cpp.1917

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer MB and handling Editor declared their shared affiliation.

frontiers in Human Neuroscience

REVIEW
published: 04 September 2018
doi: 10.3389/fnhum.2018.00359

The Experience of Pleasure: A Perspective Between Neuroscience and Psychoanalysis

Lorenzo Moccia[1†], *Marianna Mazza*[1,2*†], *Marco Di Nicola*[1] *and Luigi Janiri*[1,2]

[1] *Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Università Cattolica del Sacro Cuore, Rome, Italy,* [2] *Centro Psicoanalitico di Roma, Società Psicoanalitica Italiana, Rome, Italy*

Pleasure is more than a mere sensory event, but rather it can be conceptualized as a complex, multiform experience involving memory, motivation, homeostasis, and, sometimes, negative affects. According to Freud, affect is a perceptual modality that registers the internal drive state of the subject rather than the objective experience of the external world, and the quality of this perceptual modality is calibrated in degrees of pleasure and displeasure. Within this conceptual framework, the aim of drive is always pleasure, and objects become significant in so far as they provide a way of discharging drives pressure. Subsequent conceptual psychoanalytic developments have partially rejected such metapsychological theorizations, postulating that other intrinsic motivations that are independent from libido can be observed in humans. Intrinsic motivation broadly refers to a set of psychological concepts including the inherent propensity to pursue one's choices, to seek out novelty and challenges, to satisfy curiosity and competence, and to extend one's capacities and control over events. What these concepts have in common is an inner endorsement of one's action, which is the sense that action is self-generated and is one's own. The notions of pleasure, drives, and affects are all of utmost importance for a neuropsychoanalytic understanding of mental functioning, due to their capability to explain desire, thought, and behavior from the perspective of human subjective experience. The purpose of this paper is thus to discuss psychoanalytic conceptual developments that have addressed pleasure, drives, and affects, in the light of recent findings coming from neurosciences. In particular, we will explore for insights from Panksepp's theory of primary-process emotional feelings, including the notion of "wanting" and "liking" as dissociable components of reward. In the last part of the paper, we will indicate possible theoretical implications for a neuropsychoanalytic understanding of libido-independent intrinsic motivations and their relationship with the self, including neuroscientific observations on self-related processes, agency, body-ownerships, and attachment.

Keywords: pleasure, displeasure, pain, psychoanalysis, neuroscience, neuropsychoanalysis, affect, experience

OPEN ACCESS

Edited by:
Anatolia Salone,
Università degli Studi G. d'Annunzio Chieti e Pescara, Italy

Reviewed by:
Giuseppe Bruno,
Università degli Studi di Roma La Sapienza, Italy
Michele Ribolsi,
Università degli Studi di Roma Tor Vergata, Italy

***Correspondence:**
Marianna Mazza
mariannamazza@hotmail.com;
marianna.mazza@policlinicogemelli.it

[†] *These authors have contributed equally to this work*

Received: *30 April 2018*
Accepted: *20 August 2018*
Published: *04 September 2018*

Citation:
Moccia L, Mazza M, Di Nicola M and Janiri L (2018) The Experience of Pleasure: A Perspective Between Neuroscience and Psychoanalysis. Front. Hum. Neurosci. 12:359. doi: 10.3389/fnhum.2018.00359

PLEASURE AND AFFECTS: THE PERSPECTIVE OF NEUROSCIENCE

"The heart asks pleasure first,
And then, excuse from pain;
And then, those little anodynes
That deaden suffering. . ."
Emily Dickinson, *Complete Poems*, 1862

Far from being a mere sensorial representation, pleasure can on the contrary constitute a complex psychic experience entailing various processes such as memory, motivation, homoeostasis, and, in some occurrences, pain. Furthermore, the hedonic marking of affects is the quality that, at a basic level, distinguishes emotions from other psychological processes (Damasio, 2004).

The complexity of affects, as phenomena behind the mechanisms of the brain regulating the development of painful or gratifying experiences, explains why, from a biological point of view, these were understood only partially until recent years; since then significant progress has been made by neuroscience in this field.

Pleasure is the subjective hedonic quality linked to stimuli or objects defined in behavioral terms as incentivizing or rewarding. The concept of reward, however, entails various neuropsychological components: first, the hedonic qualities linked to consumption (i.e., liking); second, the motivational/appetizing properties that drive an individual to obtainment (i.e., wanting); finally, the mnestic representation and the subsequent associative learning that derive from the achievement of these gratifying experiences (i.e., learning). Each of these components plays a key role in predisposing the biological resources in the brain that are necessary for evolutionary survival, guaranteeing an essential contribution to the success of adaptive behavior (Kringelbach and Berridge, 2010).

Analogously, the concept of pain entails both the hedonic aspect (i.e., suffering) and the motivational one (i.e., avoidance) of a painful experience. Clearly, the search for pleasure and avoidance of pain are important with regard to survival, and these two motivational elements compete with each other in the various mechanisms that regulate the functioning of the brain. A determining factor is subjective utility or individual motivation, termed *meaning*, which has been shown to be conditioned by sensorial, homoeostatic, and cultural characteristics (Leknes and Tracey, 2008). For instance, the motivational value of a stimulus increases if its effectiveness in restoring bodily homoeostasis is greater (Cabanac, 1979). This effect, known as *alliesthesia*, is particularly evident if we think of the incentivizing/hedonic properties of food, which increase when it has the function of alleviating hunger.

Because also painful experiences are a deviation from homoeostatic equilibrium, the same principle can be applied to pain and, in particular, to the pleasure deriving from the alleviation of pain. Thus, when a threat to the internal equilibrium of an organism increases, unpleasant sensations grow stronger, and defense and avoidance mechanisms are immediately activated (Leknes and Tracey, 2008).

Therefore, the alternating of pleasure and pain guarantees a constant optimization of our homoeostatic equilibrium. The influence of homoeostatic imbalance generated by hunger or thirst can be assessed in physiological terms, for instance, measuring glucose levels or blood volume, or from a behavioral point of view by looking at the increase of food and fluids consumption. However, research on animals has shown that the quantitative and qualitative characteristics of objects (i.e., incentivizing properties) can influence behavioral reactions and learning to a much higher degree than homoeostatic modifications (Mook, 1989). Thus, the decrease of the homoeostatic drive alone is not always effective (Panksepp and Biven, 2012).

Pleasure, therefore, cannot be defined simply as a sensation. Even the simplest sensorial pleasure, such as the one associated with something sweet, requires the contemporary involvement of other neuronal circuits aimed at adding a positive hedonic impact to the stimulus. Without this emotional nuance, even a feeling associated to something with a sweet taste may result as being neutral or even unpleasant (Kringelbach et al., 2012). Furthermore, the characteristics of pleasure are not only subjective but also objective. Although the subjective and conscious dimension associated to pleasure is the most evident, this dimension is underlain by objective neural systems that are selected and maintained in time by the same evolutionary metamorphoses that interest all the main psychological functions.

Hedonic experience requires the contemporary activation of neuronal circuits situated in mesocorticolimbic areas (Damasio, 2010; Panksepp, 2011; LeDoux, 2012) which have undergone an extraordinary evolution in time, precisely because affective reactions guarantee a significant objective gain for the organism (Darwin, 1872).

Biological systems of pleasure connote different experiences linked to the survival of the species in a positive hedonic sense, such as experiences deriving from relationships of attachment or sexual relationships, and have, for this reason, an adaptive function (Schore, 1994; Panksepp and Biven, 2012).

However, some central issues relating to the nature of pleasure, and more in general the nature of affects, are still object of debate in the field of neuroscience today. Among the most pressing issues: is it possible to hypothesize the presence of unconscious affects? Or, in other terms: is the origin of an affective experience to be located in cortical or in the subcortical region?

As observed by some authors, the subjective/conscious dimension of pleasure cannot be separated from the ancestral objective/unconscious dimension, linked to more simple subcortical circuits. The translation of stereotypical behavioral reactions, normally associated to hedonic experience, into more complex subjective and conscious sensations, however, requires the activation in human beings of additional cortical circuits specialized in the cognitive-experiential evaluation of stimuli (Berridge and Kringelbach, 2013). According to this approach, there is a marked difference between unconscious visceral-motor and behavioral manifestations associated with emotions, mediated by subcortical regions, and conscious affective experience, which is regulated by prefrontal cortex (PFC) and other cortical areas activity. Affects are thus

constituted as a sort of cortical reading of physiological and automatic stimuli that are generated in subcortical region (LeDoux, 2002). On the contrary, other authors propose a radically different conceptual model, according to which the origin of affective perception can be located in subcortical brain regions, the activation of which supposedly influences a form of embryonic consciousness, defined *affective protoconsciousness* (Solms and Panksepp, 2012; Alcaro and Panksepp, 2014). This is described as being a form of consciousness centered around particular emotional states lacking an explicit objectual representation, a sort of "affective disposition" that is, however, necessary for the subsequent idiographic representation of experience (Northoff and Panksepp, 2008). Despite there being no differentiation between subject and object, this diffused state of affective consciousness is supposedly limited by an implicit sense of identity and differentiation that is established starting from the relationship between the perception of one's own body (i.e., interoception) and that of the external environment (i.e., exteroception). Perception and regulation of interoceptive states is accompanied by affective states of pleasure or unpleasure according to whether the body state is of instinctive relaxation or tension or, in other words, depending on the degree of internal homoeostasis (Damasio and Carvalho, 2013). Accordingly, primordial exteroceptive sensations have an intrinsic affective connotation (Alcaro et al., 2017), as in the case of innate pleasure generated by a sweet taste or by the unpleasure caused by a bitter taste, and are always linked to the activation of motor sequences of active exploration mediated by emotional operating systems (Panksepp, 2010).

Neurobiological Underpinnings of Pleasure: Brain Hedonic Systems

The sensation of pleasure linked to the consumption of tasty food differs from pleasure deriving from sexual intercourse or from pleasure deriving from substance abuse. Yet another different kind of pleasure is linked to experiences of socialization, or to the act of listening to music. Recent findings in the field of neuroscience have, however, demonstrated that a single functional circuit, incorporated inside the broader dopaminergic mesocorticolimbic system, seems to be involved in the various experiences of pleasure (Veldhuizen et al., 2010; Salimpoor et al., 2011; Georgiadis et al., 2012). Moreover, studies on animal models have recently identified a network for enhancing "liking" hedonic reactions, embedded as a set of small hedonic hot spots distributed among several limbic structures throughout the brain, ranging from the cortex to the brainstem (Berridge and Kringelbach, 2015). However, these hedonic hotspots are only partially overlapping with the so-called *brain reward system* (Berridge and Kringelbach, 2013), which was once thought to be at the origin of every sensation of pleasure, and that today some authors believe may mediate the enthusiastic drive to search and explore the environment in mammals (SEEKING System; Panksepp, 2010), while according to others its function is to mediate the expectation of gratification or, in a broader sense, to mediate desire (Berridge and Robinson, 1998).

Neuroimaging studies indicate that a distinct group of cortical [e.g., orbitofrontal cortex, anterior cingulate cortex (ACC), insular cortex] and subcortical regions (e.g., nucleus accumbens, amygdala, ventral pallidum) are activated by diverse hedonic stimuli in humans. Cortical hedonic representations (i.e., *encoding*) seem to be regulated by the activity of orbitofrontal cortex, particularly within medial and anterior regions (Murray et al., 2007). These structures seem to be particularly active in the subjective attribution of pleasure in reaction to a hedonic stimulus which may be of differing nature; also, they seem to mediate variations in the subjectively perceived hedonic intensity. Similarly, additional medial PFC areas, along with regions of the anterior insular cortex, seem to be connected to monitoring and anticipating pleasant objects reward value, as well as to the integration of perceptual stimuli with associated interoceptive states (Craig, 2009). However, it seems possible to trace the origin (*i.e., causation*) of affective experience, including hedonic experience, in subcortical regions more than in cortical ones, at least in humans. Cortical affective representation would thus imply elements that are inherent in cognitive contextualization of hedonic experience and second, the capacity of affective regulation and of decision-making. This aspect is demonstrated by the fact that relatively normal affective reactions continue to occur in human beings also when PFC and other cortical areas have been severely damaged (Damasio et al., 2013). The neural circuits believed to be responsible for the actual origin of hedonic experiences, at least of sensorial ones relating to the pleasure associated with sweet food, have been identified in brain stimulation experiments carried out on animals. In fact, the ability to experience pleasure in relation to sweet food is innate, just as expressive-facial manifestations associated with responses to these stimuli, which are, it must be noted, extremely evident in mammals (also in human new-borns; Berridge and Kringelbach, 2013). Thus, the hedonic impact of specific food can be measured objectively in rats by carefully observing their facial expressions, in particular the movements of their tongue (Steiner et al., 2001). From a neurochemical point of view, the neural systems implicated in the development of sensorial pleasure are much more limited than what was previously believed. For instance, it has been found that dopamine released in mesocorticolimbic region, in no way mediates any hedonic manifestation linked to consumption (i.e., *liking*), but rather it mediates aspects linked to motivation or, in a broader sense, to desire (i.e., *wanting*; Berridge, 2012). However, as some authors stress (Di Chiara, 2005; Panksepp, 2010), the release of dopamine within mesocorticolimbic regions may actually promote a behavioral state of appetite, intrinsically connected to positive affective states, even to hedonic ones (i.e., *state hedonia*; Di Chiara, 2005). Similarly, the neural centers responsible for the development of sensory pleasure are, from an anatomical point of view, much smaller than what was previously hypothesized, and that only the selective stimulation of μ opioid and endocannabinoid receptors located inside these centers can effectively amplify sensations of pleasure (Mahler et al., 2007; Smith et al., 2011). Specifically, opioid and endocannabinoid stimulation is able to amplify pleasure derived from consumption only in some specific sub-regions of the nucleus accumbens and of the ventral pallidum,

while in other limbic structures, it only promotes an increase of appetitive motivation. From a functional point of view, NAc and ventral pallidum are deeply interconnected, so that the activity and integrity of both structures seems to be indispensable for maintaining normal hedonic reactions (Peciña and Berridge, 2005; Smith and Berridge, 2005).

Interactions Between Pleasure and Pain

A large quantity of neuroscientific evidence indicates that there is a high degree of superimposition, in anatomical and functional terms, between areas of the brain and the neurotransmitter systems responsible for the regulation of physical pain and those responsible for the regulation of affective states. For instance, endogenous opioids and dopamine seem to be involved in a series of processes that take place in central and peripheral regions, among which the regulation of the motivational and hedonic aspects of reward, nociception, and modulation of physical pain and, in a broader sense, affective regulation (Leknes and Tracey, 2008). An increase of the activity of the μ and δ opioid receptors in the amygdala and in the ACC, other than being associated with deep analgesic states, seems also to be associated with a decrease of subjective unpleasantness experienced in response to nociceptive stimuli (Zubieta et al., 2001). On the contrary, a reduction of the activity of the μ receptors in the ACC region, of the amygdala and of the ventral pallidum, has been recorded during a prolonged recollection of painful memories, whereas an increase in the activity of the κ opioid receptor is generally associated with states of fatigue, confusion, dysphoria, and, at higher levels, with states of depersonalization (Zubieta et al., 2003a). In the region of the striate, the dopaminergic system seems to carry out various functions depending on the level of activation: states of tonic dopaminergic stimulation have been associated with an increase of an algesic response in relation to nociceptive stimuli, while phasic stimulation seems to have antinociceptive properties, perhaps involving the activation of μ opioid receptors (King et al., 2001; Zubieta et al., 2003b). The fine neurobiological interactions between dopaminergic neurotransmitter systems and opioids may finally explain some behaviors, such as self-harming behaviors, which are apparently conflicting with the principle which, according to some, guides human beings toward maximization of pleasure and avoidance of pain. As research on animals and humans has shown, self-harming components could be associated to a substantial release of endogenous opioids such as β-endorphines and enkephalins. Similarly, it has been demonstrated that algesic stimuli can reduce, through opioid receptor stimulation, the subjectively perceived intensity of emotional states connoted by a negative affective value. Finally, numerous studies have highlighted a reduction of basal levels of endogenous opioids in individuals who perform self-harming behavior or who are prone to suicide (Bresin and Gordon, 2013). From this point of view, according to some authors, self-harming behavior can be understood as the only way to regulate particularly painful, if nor traumatic, negative affective states, which cannot be otherwise symbolized (Fonagy et al., 2004; Stanley et al., 2010). Others believe that, because of the decreased basal levels of endogenous opioids, the release of β-endorphines, associated with the insurgence of self-harming acts, could have an effect of reward in these individuals (Bandelow et al., 2010). However, as is stressed by most authors, cumulative trauma can have an etiopathogenetic meaning in the genesis of self-harming behavior. Indeed, it seems that the repetition of traumatic episodes in early childhood can have, among its effects, a negative impact on the development of the young opioid and dopaminergic transmission systems (Schore, 1996).

PLEASURE AND AFFECTS: PSYCHOANALYTIC AND NEUROPSYCHOANALYTIC DEVELOPMENTS

Pleasure, Unpleasure, and Affect in Freud's Theory

The issue of pleasure and, more in general, of motivation and affects, has a fundamental importance in the psychoanalytical theory because it is able to explain aspirations, thoughts, and behaviors of human beings from the point of view of subjective experience. Their role in psychoanalysis has been the object of debate for a century, a debate started with Freud's formulation of the concept of drive, which is itself already a theory of motivation and affect (Yovell, 2008). Freud originally claimed that the guiding principle behind the functioning of human beings is the pleasure principle: that is the search for pleasure and avoidance of pain. The pleasure principle, as set out in the texts dating to 1900, is based on the idea that the psychic apparatus is constituted at the level of a reflex arc, the discharge of which is motility: the quantitative accumulation of excitement is indicated as unpleasure, its decrease as pleasure, while the fluctuation from one state to the other is desire, the only able to set the apparatus in motion, because the course of excitement is regulated automatically by the perception of the quantum of pleasure and unpleasure (Le Guen, 2008). Later, at the time of his writings on metapsychology, Freud fully elaborated what has been defined as the "drive model of the mind" (Greenberg and Mitchell, 1983). According to this model, man has, from birth, a motivational system, "pushes" that are on the border between the psychic and the somatic, an inner source of stimuli that influences and even guides the dynamics of the mind. The concept of drive is central in this model, "a request of work put forward to the mind," a paraphysiological quantity of energy able to determine, from inside the psychic apparatus, the disturbance of a homoeostatic condition (Ammaniti and Dazzi, 1991).

Similarly, the aim of all drives is their satisfaction, achieved only through the suppression of the state of excitement that is present at the source. An affect, in this more complex explanation, is constituted again as the primary manifestation of a drive, equally elementary, and also grounded in biology, a qualitative and subjective expression of the quantity of drive energy. According to Freud: "an affect includes in the first place particular motor innervations or discharges and secondly certain feelings; the latter are of two kinds – perceptions of the motor

actions that have occurred and the direct feelings of pleasure and unpleasure which, as we say, give the affect its keynote" (Freud, 1917, p. 395). Also: "we have decided to relate pleasure and unpleasure to the quantity of excitement that is present in the mind but is not in any way 'bound'; and to relate them in a such a manner that unpleasure corresponds to an *increase* in the quantity of excitement and pleasure to a *diminution*." (Freud, 1920, p.8)

Probably, Freud's most original idea came from the fact that he intended affects as conscious perceptive modalities, experienced subjectively in the qualities of pleasure and unpleasure, and so relating to the Ego, whereas the unconscious affect is only a potentiality, blocked by the mechanism of repression. Previously, in his *Project for a Scientific Psychology* (1895), Freud had started to describe in theoretical terms the way experiences of pleasure and pain could interact with the issue of affects. In the chapter titled *The Experience of Satisfaction*, Freud puts forward his hypothesis on the economy of the mind: the endogenous psychic excitement cannot be arrested if not by a specific action brought on by an external object, an action a child, initially, is not capable of. And again: "in this way this path of discharge acquires a secondary function of the highest importance, that of communication, and the initial helplessness of human beings is the primal source of all moral motive" (Freud, 1895, p.318). From now on, pleasure will be associated with the image of the object that provided it and with the motor image of the movement of the reflex that allowed the discharge. Thus, according to Freud, affects are linked on the one hand to the function of communication, and so of language, and on the other to corporeal experience, by means of the motor image of discharge (Green, 1973).

Neuropsychoanalytic Contributions to the Concept of Drive

The area of the brain in which the requests of the body are supposedly metalized could be located, according to some authors, in the hypothalamic region, and, more specifically, in the regions of the neural groupings specialized in the detection of homoeostatic physiological parameters and in the control of the activity of both the autonomic and the neuroendocrine nervous systems (Solms and Turnbull, 2002; Panksepp, 2010). The activity of these neural groups, both from an electrophysiological and neurochemical point of view, is able to evoke intense somatic, visceral sensations in human beings, at a subjective level, such as the ones linked to hunger, thirst, and sexual arousal. The Freudian concept of drive is deeply connected to energetic aspects, not only in terms of discharge, but also in terms of energy necessary to set the psychic apparatus in motion. As some authors have observed (Pfaff, 1999), such a mechanism predisposed to the generalized arousal of the whole activity of the brain can be found in all vertebrates, including human beings. This neural system, called BBURB (Bilateral, Bipolar, Universal Response Potentiating System), is thought to originate at the level of the brainstem's medial and ventral reticular formations, which have projections to both superior and inferior anatomical areas. The ascending projections of the BBURB system are believed to enhance the sensorimotor response and the affective one in relation to stimuli that act with diverse modalities, while the descending ones enhance the autonomic response of the organism. The activity of the BBURB system thus guarantees the necessary quantity of energy for the promotion of all intrinsically motivated behaviors, from affective processes to cognitive ones, and, finally, also of the aspects linked to the emergence of individual consciousness. One of the branches of the BBURB system is thought to coincide with the ascending portions of the abovementioned mesocorticolimbic dopaminergic system (Panksepp, 1998). Thus, the latter constitutes the neuroanatomical substratum of what Panksepp (1998) has defined as the emotional SEEKING/desire system (SEEKING system). As some authors have observed in the field of neuropsychoanalysis (Solms and Turnbull, 2002; Yovell, 2008; Pfaff et al., 2014), the SEEKING emotional system displays a series of analogies with the Freudian concept of *libido*. The activity of the SEEKING system, in fact, promotes an appetitive predisposition in individuals, a euphoric mental state that is itself gratifying, which is thought to allow individuals to enter into relation with the surroundings in positive affective terms. This predisposition activates specific behavioral patterns (increased motor energy, exploration, and approach energy), and also affects the cognitive level, leading to associative reinforcement between gratifying experiences and the stimulus behind experience itself, through the creation of episodic memories. The activity of the SEEKING system thus predisposes the immediate organization of specific behavioral assets, which are thought to confer a direction to the action also when the object is not represented as the final goal (i.e., *intention-in-action*; Panksepp and Biven, 2012). This aspect characterizes the basic, unconditioned nature of the SEEKING system, in that the latter is able to unconditionally activate behavioral patterns (for instance, of search, approach, removal, attack), the aim of which becomes increasingly clear with the interaction taking place between the processes initiated by the basic affective systems (so at the level of subcortical regions) and neocortical areas. Thanks to these feedbacks between subcortical and neocortical areas, it is possible to construct patterns of relationship with the external object, with its potential ability to offer gratification and with our capacity to experience it by acting (Panksepp and Biven, 2012). The affective pre-representational (lacking an object) disposition, mediated by the activity of the SEEKING system, seems thus to project the organism toward external space, pushing it to act in a specific way. Only through interaction with the surroundings this affective disposition is, however, able to achieve full realization.

This characteristic inherent in the functioning of the SEEKING system can be seen in relation not only to the concept of *libido*, but also to some conceptual formulations by Bion and, in particular, to the notion of *pre-conception* (Bion, 1962). This is described by Bion as a sort of a priori knowledge, in psychoanalysis the equivalent of the Kantian concept of "empty thought," its main quality being that it can be "thought" but not "become known." In the mind of a newborn there is a preconception of the breast, an innate presentiment of it, which is, so to speak, "preformed." What in fact characterizes preconceptions is essentially a sentiment of expectation that has the capacity to orient the newborn toward certain realization. Bion claims that when an expectation meets its corresponding realization, the psychological result is conception. In other words,

when a newborn is breastfeeding, its preconception (or "idea") of the breast is connected with its corresponding realization. Thus, conceptions (or "notions") must be connected to an experience of satisfaction: not only at a physical level, but also at a cognitive one (Neri, 1987). Similarly, in the field of ethology, the theory of instinct says that the phenomenon of imprinting in a young animal is the encounter of a temporized predisposition and of an object present in its surrounding that realizes it, although imprinting seems to not entail forms of rewarding (Lorenz, 1988). Other than playing a fundamental role in the whole of the appetitive behaviors, the SEEKING system seems to be able to promote and energize dream activity (Solms and Turnbull, 2002). Also, the malfunctioning of this system seems to be behind some conditions such as mood disorders and pathological addictions (Zellner et al., 2011).

Pleasure Beyond the Pleasure Principle: Motivations That Are Independent of Libido, Psychoanalytic, and Neuroscientific Contributions

A dilemma that Fred was not able to solve was the full understanding of what produces pleasure in human beings. Freud himself found that the hypothesis that pleasure is solely linked to the decrease of the drive tension was not completely satisfactory: it will suffice to think of the intensification of tension that is sought in sexuality (even though it later leads to an optimal decrease of tension). Similarly, the idea that all motivated behavior observable in human beings can be explained by the original libidic drive is not confirmed by evidence available today. Already in *Beyond the Pleasure Principle* (1920) Freud hypothesized that other drives coexist in the Ego beyond the libidic one and the self-preservation one, and that among these, a compulsion to repeat which is "more primitive, more elementary, more instinctual that the pleasure principle which it over-rides." (Freud, 1920, p. 23) With regard to the genesis of this compulsion, according to Hartmann and the entire field of Ego psychology, Freud's observations, relating to the existence of a primary motivation in human beings aimed at actively reproducing distressing events originally experienced passively, are significant: it is the case of separations, unexpected events, or traumatic experiences that are viewed as "having no explanation." Hartmann (1939) writes: "the pleasure possibilities of the apparatuses of the conflict-free ego sphere seem, in any case, to play an important role in the adaptation to the external world, since the opening of such new sources of pleasure furthers ego development" (Hartmann, 1939, p.46). Here what Hartmann describes is pleasure for an activity, gratification in exerting a function that allows the Ego to "dominate reality," as opposed to pleasure that originates from the mere satisfaction of a drive. It is from this principle that some later psychoanalytic concepts derive, such as competence (White, 1963), as well as the considerations by Rapaport (1953) relating to forms of human behavior, such as curiosity and the search for novelty, that are found to be direct expression of this principle. Motivation researchers in the field of psychology distinguish extrinsic motivation, based on the effect of attractive external rewards, from intrinsic motivation, which drives individuals into action regardless the incentive properties of environmental rewards, or internal homeostatic drives (Deci, 1971). Intrinsic motivation broadly refers to a set of psychological processes which includes the inherent propensity to pursue one's choices, to seek out novelty and challenges, to satisfy curiosity and competence, and to extend one's capacities and control over events. What these concepts have in common is an inner endorsement of one's action, which is the sense that action is self-generated and is one's own (Ryan et al., 1983).

Within this conceptual framework, the major distinction between intrinsic and extrinsic motivation has been postulated to be based on the degree of self-determination or, in a broader sense, on the degree of personal agency (Deci and Ryan, 1985). Agency refers to the experience of being in control of one's own actions, and through them, to actively manage events in the external world. The neural basis of agency has generally been examined by comparing the neural activations of self-generated behavior to those of other-generated behavior (Lee and Reeve, 2013). Neuroimaging findings demonstrated that neural activities of the PFC, insular cortex, cerebellum and motor-related regions (e.g., supplementary motor area, pre-supplementary motor area, precentral gyrus, and postcentral gyrus) are related to the execution, observation, or imagination of self-generated behavior (Gallagher, 2000; Haggard, 2008; Nachev et al., 2008). Besides, the degree of agency is closely related to the degree of insular cortex activity, which provides a conscious representation of bodily self-related information (i.e., homestatic needs; Lee and Reeve, 2013). Research on the bodily self focuses on the development, maintenance, or disturbance of the link between a body and the experience of this body as "mine," a process that is also known as body-ownership (Gallese and Sinigaglia, 2010). Body-ownership involves a complex neural network comprising the right temporo-parietal junction (which tests the incorporeability of the external object), the secondary somatosensory cortex (which maintains an on-line representation of the body), the posterior parietal and ventral premotor cortices (which code for the recalibration of the hand-centered coordinate systems), and the right posterior insula (which underpins the subjective experience of body-ownership; Tsakiris, 2010). Several approaches have attempted to explain the sense of agency and the sense of body-ownership: these two senses jointly constitute the sense of self and seem to derive from an interaction between current multisensory input and internal models of the body (Tsakiris, 2010). Regardless differences in the definition of the self, it is possible to identify "self-related processes" involving stimuli that are experienced as strongly related to one's own person. The process of relating stimuli to the self should not be considered as an isolated phenomenon, but rather as embedded in a larger process depending on the environmental context (Salone et al., 2016). It has been suggested that 18-months-old infants who were coded as non-recognizers at the mirror-test task spent more time looking at the picture of their own face compared to the other-face, suggesting that before the onset of mirror self-recognition, featural information about the self might are more relevant in the process of recognizing one's face, compared to multisensory cues (Filippetti and Tsakiris, 2018).

Subortical-cortical midline structures (SCMS) are brain areas that enable self-related processing (SRP; Northoff and Panksepp, 2008). However, specific features of the self are also related to other cerebral regions (i.e., self-agency to right posterior insula, right inferior parietal cortex and motor-related areas, self-ownership to right parietal, ventromedial prefrontal, and insular cortices). The self therefore results from the integration of different brain regions, necessarily involving neural connectivity (Salone et al., 2016). A broader definition of SRP includes the coordination of various basic emotional processes and bodily interoceptive stimuli (e.g., emotional, motivational, homeostatic, bodily need states) with exteroceptive stimuli (e.g., sensory stimuli) in relation to the organism's goal-directed activities (Northoff and Panksepp, 2008). Interestingly, a recent study demonstrated that SRP also induces neural activity in the same regions that are recruited by various rewards. This underlines that both reward processes and self-relatedness might share a similar evaluative process (de Greck et al., 2008). SCMS and their networks (e.g., right posterior insula, right inferior parietal cortex, ventromedial PFC) may represent neural correlates of the "core self," defined as the continuous interaction between intero- and exteroceptive stimuli allowing the self to feel as a unit (Northoff, 2012). Within this conceptual framework, "core self" is thus to be considered as the subjective experience that oneself is the agent of perception, action, cognition, and emotion.

Some authors in the fields of psychoanalysis and biology have claimed that other proactive motivations that are independent of libido can be observed in human beings and in animals. One of these is no doubt attachment, today considered a primary motivation, biologically innate, which makes any attempt to explain it as a secondary element, with respect to the gratification of drives, awkward (Pine, 2005). To this regard, it must be noted that Freud elaborated two different theories of pleasure: a *quantitative* one, founded on the model of discharge-reduction of the drive tension, and a *qualitative* one, its model a type of sensual pleasure linked to child sexuality which is not easy to conceptualize in the terms set out by the principle of constancy (Eagle, 2013). According to Freud (1938): "the baby's obstinate persistence in sucking gives evidence at an early stage of a need for satisfaction which, although it originates from and is stimulated by the taking of nourishment, nevertheless seeks to obtain pleasure independently of nourishment and for that reason may and should be described as *sexual*" (Freud, 1938, p. 154). Authors such as Fairbairn (1952) have claimed, in an even clearer way, that "libido is primarily object-seeking," implying that object relations have an innate grounding, and implicitly refusing the centrality of drives in this context.

Later, the pioneering observation by Bowlby (1969) and, in a second moment, the review of literature on infancy by Stern (1985), made it clear once and for all that objectual attachment is present in human beings, in such an evident and precocious manner that it is possible to consider it in all respects as a primary and autonomous motivation.

Again, according to Stern (1990), the pleasure in children that can be observed during transitions characterized by secure attachment seems to be associated with moderate stimulation (and therefore excitement), rather than by a decrease or disappearance of excitement.

The work carried out by some authors in the field of neuroscience has allowed to identify with a higher degree of clarity the neural systems involved in attachment relationships in human beings and animals. One of the core motivational and emotional systems identified by Jaak Panksepp is CARE (Panksepp and Biven, 2012), which, other than being responsible for the promotion of attachment relationships, is also responsible for the creation of social bonds in a broader sense. Phylogenetically, this system could have evolved starting from other regions responsible for sexual desire and would thus share a certain neuroregulation with the latter.

From a neurochemical point of view, in fact, the high levels of oxytocin and endogenous opioids that can be observed in mothers caring for their offspring, could explain why the experience of caring for newborns is so gratifying for many mothers (Panksepp and Biven, 2012). Other authors have instead suggested that during periods that are critical for attachment the presence of stimuli associated with the mother's face or tactile/auditory stimulation (Panksepp and Bishop, 1981; Schore, 1994) can induce gratifying affective states in the child, associated with the release of β-endorphins. Accordingly, endogenous opioid activity seems to play a role not only at the level of the tegmental dopaminergic mesolimbic system, promoting appetitive and approach behaviors toward the maternal object, but it also seems to play a role in the physiological development of the orbitofrontal system, a region characterized by a high density of endogenous opioids that is responsible for maintaining attachment patterns, beyond being responsible for the subsequent ability in affect regulation. Psychobiological attunement, interactive resonance, and the mutual synchronization and entrainment of physiological rhythms are fundamental processes that mediate attachment bond formation. Over the course of the first year after birth, limbic circuitries emerge in a sequential progression, from amygdala to anterior cingulate, to insula and, finally, to orbitofrontal cortex. As a result of attachment experiences, orbitofrontal cortex enters a critical period of maturation in the last quarter of the first year, the same time that working models of attachment are first measured (Schore, 2001). The orbital cortex matures in the middle of the second year, gradually allowing for an internal sense of security and self-regulation, which ultimately lead to the ability to regulate flexibly emotional states through interactions with other humans (Schore, 2001). The emergence of these flexible predictive capacities are dependent on extended parental investment and caring, through which the child becomes less rigidly controlled by the environment and more in tune with possibilities for action and gratification. It has been suggested that individual differences in the security of attachment and their sequelae can be viewed as reflecting, in part, variations in perceptions of personal agency among infants and toddlers (Ford and Thompson, 1985). Besides, various forms of attachment pathologies specifically represent inefficient patterns of organization of the right brain, especially the right orbitofrontal areas (Schore, 1994, 2001).

TO CONCLUDE: INTERACTIONS OF INTEGRATIONS?

What has been discussed concerns, on the one hand, the complexity and, conversely, the risk of reductionism that connote the concept of pleasure, and on the other, the neurobiological substratum that supports the view of such complexity. Pleasure is not the mere absence of tension, a return to the central fluctuating state prescribed by homoeostasis: on the contrary, the use of substances and consequent addiction suggest that an allostatic model is better at predicting relapses and that the desire of a reward accompanies behaviors of sensation or novelty seeking (Pettorruso et al., 2014). Pleasure is inextricably linked to its "negative," that is pain: the psychopathological and dynamic issue of masochism addressed by Freud (1924) in economic terms, reveals the drive interconnection of hedonic and anti-hedonic or destructive forces, which have potentially extreme consequences. Pleasure can become independent of libido and can include objects apparently unrelated to sexuality or instinctual satisfaction: perception of self-efficiency, cultural signification, and the propensity to communicate and form interpersonal relationships are telling examples of a type of "pleasure beyond the pleasure principle." The concept of pleasure is closely connected to other bordering concepts, such as affect, desire, motivation, drive, which are not always unequivocally definable and differentiable and belong to different epistemological domains, such as experimental and cognitive psychology and psychoanalysis. What we have attempted to do, by necessarily restricting the field of research, is to describe the neural structures and neurochemical systems involved in the functioning of pleasure, without giving into the paradigm of simple localizationism. The advancement of neuroscientific knowledge actually allows to explain plurisemantic and sometimes paradoxical phenomena linked to pleasure and to the search of pleasure. The development of "bordering" or "bridging" disciplines, such as neuropsychoanalysis, that study conceptual methodologies of modeling of experimental data that can be understood with a theory of the functioning of the mind and that have possible clinical applications, seems to confirm the need for integrated knowledge (Moore et al., 2010; Leotti and Delgado, 2014; Leotti et al., 2015; Murayama et al., 2015). However, it is appropriate to ask whether the level of knowledge so far achieved is enough to speak of interaction, mutual influence, however, promising it may be, correspondences, or even of proper integrations. Writing about the border between psychoanalysis and neurosciences, already Modell (1996) remarked that "unification of ideas derived from neurobiology and psychoanalysis can help to illuminate a very broad and diverse range of problems extending from traumatic memories to the repetition compulsion, the psychoanalytic theory of instinct and the concept of the self." Because both psychoanalysis and neurosciences have distinct and separate objects, methods, and types of knowledge, the objective of integration is complex and difficult to pursue in a clear way, that is, without running the risk of hyper-simplification or vagueness. Indeed, integration presupposes that two subjects, which are irreducible one to the other at a structural level, share or render compatible parts or functions of themselves. What parts or functions can psychoanalysis and neuroscience share? The issue forms the backdrop, as it were, or a challenge, for the emerging dialog.

The experience of pleasure, also beyond its limits and in the complexity of its interrelations, represents a useful and interesting testing site to attempt to integrate neuroscience and psychoanalysis. The change in psychobiological functioning that it entails, also in the long term, by means of the processes of learning and memory, evidently occurs as an only phenomenon that the insufficient instruments our knowledge depends on translates into two different and parallel orders of events, one that can be ascribed to the body (or the brain), the other to the mind. To leave the Cartesian dualism behind is the fundamental and ideal objective of this work in progress.

AUTHOR CONTRIBUTIONS

LJ contributed to article writing and personally revised and approved the final version of the manuscript. All authors revised and approved the final version of the manuscript.

ACKNOWLEDGMENTS

The authors would like to thank Prof. Filippo Maria Ferro for his precious theoretical suggestions in the preparation of the manuscript.

REFERENCES

Alcaro, A., Carta, S., and Panksepp, J. (2017). The affective core of the self: a neuro-archetypical perspective on the foundations of human (and Animal) subjectivity. *Front. Psychol.* 8:1424. doi: 10.3389/fpsyg.2017.01424

Alcaro, A., and Panksepp, J. (2014). "Le radici affettive e immaginative del Sé. Un'indagine neuroetologica sulle origini della soggettività," in *La Plasticità del Sé. Una Prospettiva Neuropsicodinamica*, eds G. Northoff, M. Farinelli, R. Chattat, and F. Baldoni (Bologna: Il Mulino), 65–89.

Ammaniti, M., and Dazzi, N. (1991). *Affetti. Natura e Sviluppo delle Relazioni Interpersonali*. Roma: Laterza.

Bandelow, B., Schmahl, C., Falkai, P., and Wedekind, D. (2010). Borderline personality disorder: a dysregulation of the endogenous opioid system? *Psychol. Rev.* 117, 623–636. doi: 10.1037/a0018095

Berridge, K. C. (2012). From prediction error to incentive salience: mesolimbic computation of reward motivation. *Eur. J. Neurosci.* 35, 1124–1143. doi: 10.1111/j.1460-9568.2012.07990.x

Berridge, K. C., and Kringelbach, M. L. (2013). Neuroscience of affect: brain mechanisms of pleasure and displeasure. *Curr. Opin. Neurobiol.* 23, 294–303. doi: 10.1016/j.conb.2013.01.017

Berridge, K. C., and Kringelbach, M. L. (2015). Pleasure systems in the brain. *Neuron* 86, 646–664. doi: 10.1016/j.neuron.2015.02.018

Berridge, K. C., and Robinson, T. E. (1998). What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? *Brain Res. Brain Res. Rev.* 28, 309–369. doi: 10.1016/S0165-0173(98)00019-8

Bion, W. R. (1962). *Learning from Experience*. London: Tavistock.

Bowlby, J. (1969). *Attachment and Loss: Attachment*, Vol. 1. London: The Hogarth Press and the Institute of Psycho-Analysis.

Bresin, K., and Gordon, K. H. (2013). Endogenous opioids and nonsuicidal self-injury: a mechanism of affect regulation. *Neurosci. Biobehav. Rev.* 37, 374–383. doi: 10.1016/j.neubiorev.2013.01.020

Cabanac, M. (1979). Sensory pleasure. *Q. Rev. Biol.* 54, 1–29. doi: 10.1086/410981

Craig, A. D. (2009). How do you feel now? The anterior insula and human awareness. *Nat. Rev. Neurosci.* 10, 59–70. doi: 10.1038/nrn2555

Damasio, A., and Carvalho, G. B. (2013). The nature of feelings: evolutionary and neurobiological origins. *Nat. Rev. Neurosci.* 14, 143–152. doi: 10.1038/nrn3403

Damasio, A., Damasio, H., and Tranel, D. (2013). Persistence of feelings and sentience after bilateral damage of the insula. *Cereb. Cortex* 23, 833–846. doi: 10.1093/cercor/bhs077

Damasio, A. R. (2004). "Emotions and feelings: a neurobiological perspective," in *Feelings and Emotions: The Amsterdam Symposium*, eds A. S. R. Manstead, N. Frijda, and A. Fischer (Cambridge: Cambridge University Press). doi: 10.1017/CBO9780511806582.004

Damasio, A. R. (2010). *Self Comes to Mind: Constructing the Conscious Brain*. New York, NY: Pantheon Books.

Darwin, C. (1872). *The Expression of the Emotions in Man and Animals (1998 edition: Revised and with Commentary by P. Ekman)*. Oxford: Oxford University Press. doi: 10.1037/10001-000

de Greck, M., Rotte, M., Paus, R., Moritz, D., Thiemann, R., Proesch, U., et al. (2008). Is our self based on reward? Self-relatedness recruits neural activity in the reward system. *Neuroimage* 39, 2066–2075. doi: 10.1016/j.neuroimage.2007.11.006

Deci, E. L. (1971). Effects of externally mediated rewards on intrinsic motivation. *J. Pers. Soc. Psychol* 18, 105–115. doi: 10.1037/h0030644

Deci, E. L., and Ryan, R. M. (1985). *Intrinsic Motivation and Self-determination in Human Behavior*. New York, NY: Plenum. doi: 10.1007/978-1-4899-2271-7

Di Chiara, G. (2005). *Dopamine, Motivation and Reward*. New York, NY: Elsevier.

Eagle, M. N. (2013). *Attachment and Psychoanalysis. Theory, Research, and Clinical Implications*. New York, NY: Guilford Press.

Fairbairn, R. D. (1952). *Psychoanalytic Studies of the Personality*. Hove: Psychology Press.

Filippetti, M. L., and Tsakiris, M. (2018). Just before i recognize myself: the role of featural and multisensory cues leading up to explicit mirror self-recognition. *Infancy* 23, 577–590. doi: 10.1111/infa.12236

Fonagy, P., Gergely, G., Jurist, E., and Target, M. (2004). *Affect Regulation, Mentalization and the Development of the Self*. London: Karnac.

Ford, M. E., and Thompson, R. A. (1985). Perceptions of personal agency and infant attachment: toward a life-span perspective on competence development. *Int. J. Behav. Dev.* 8, 377–406. doi: 10.1177/016502548500800402

Freud, S. (1895). *Project for a Scientific Psychology. The Standard Edition of the Complete Psychological Works of Sigmund Freud*, Vol. 1. London: Hogarth Press.

Freud, S. (1917). *Introductory Lectures on Psycho-Analysis. The Standard Edition of the Complete Psychological Works of Sigmund Freud*, Vol. 16. London: Hogarth Press.

Freud, S. (1920). *Beyond the Pleasure Principle, Group Psychology and Other Works. The Standard Edition of the Complete Psychological Works of Sigmund Freud*, Vol. 18. London: Vintage.

Freud, S. (1924). *The Economic Problem of Masochism. The Standard Edition of the Complete Psychological Works of Sigmund Freud, (*1923-1925): The Ego and the Id and Other Works, Vol. 19. London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1938). *An Outline of Psycho-Analysis. The Standard Edition of the Complete Psychological Works of Sigmund Freud, (*1937-1939): Moses and Monotheism, An Outline of Psycho-Analysis and Other Works, Vol. 23. London: The Hogarth Press.

Gallagher, I. I. (2000). Philosophical conceptions of the self: implications forcognitive science. *Trends Cogn. Sci.* 4, 14–21. doi: 10.1016/S1364-6613(99)01417-5

Gallese, V., and Sinigaglia, C. (2010). The bodily self as power for action. *Neuropsychologia* 48, 746–755. doi: 10.1016/j.neuropsychologia.2009.09.038

Georgiadis, J. R., Kringelbach, M. L., and Pfaus, J. G. (2012). Sex for fun: a synthesis of human and animal neurobiology. *Nat Rev Urol.* 9, 486–498. doi: 10.1038/nrurol.2012.151

Green, A. (1973). *Le Discours vivant*. Paris: Presses Universitaires de France.

Greenberg, J. A., and Mitchell, S. A. (1983). *Object Relations in Psychoanalytic Theory*. London: Harvard University Press.

Haggard, P. (2008). Human volition: towards a neuroscience of will. *Nat. Rev. Neurosci.* 9, 934–946. doi: 10.1038/nrn2497

Hartmann, H. (1939). *Ego Psychology and the Problem of Adaptation*. New York, NY: International Universities Press, Inc.

King, M. A., Bradshaw, S., Chang, A. H., Pintar, J. E., and Pasternak, G. W. (2001). Potentiation of opioid analgesia in dopamine2 receptor knock-out mice: evidence for a tonically active anti-opioid system. *J. Neurosci.* 21, 7788–7792. doi: 10.1523/JNEUROSCI.21-19-07788.2001

Kringelbach, M. L., and Berridge, K. C. (2010). *Pleasures of the Brain*. Oxford: Oxford University Press.

Kringelbach, M. L., Stein, A., and van Hartevelt, T. J. (2012). The functional human neuroanatomy of food pleasure cycles. *Physiol. Behav.* 106, 307–316. doi: 10.1016/j.physbeh.2012.03.023

Le Guen, C. (2008). *Dictionnaire Freudien*. Paris: Presses Universitaires de France.

LeDoux, J. (2002). *Synaptic Self: How Our Brains Become Who We Are*. London: Macmillan.

LeDoux, J. (2012). Rethinking the emotional brain. *Neuron* 73, 653–676. doi: 10.1016/j.neuron.2012.02.004

Lee, W., and Reeve, J. (2013). Self-determined, but not non-self-determined, motivation predicts activations in the anterior insular cortex: an fMRI study of personal agency. *Soc. Cogn. Affect. Neurosci.* 8, 538–545. doi: 10.1093/scan/nss029

Leknes, S., and Tracey, I. (2008). A common neurobiology for pain and pleasure. *Nat. Rev. Neurosci.* 9, 314–320. doi: 10.1038/nrn2333

Leotti, L. A., Cho, C., and Delgado, M. R. (2015). "The Neural Basis Underlying the Experience of Control in the Human Brain," in *The Sense of Agency*, eds M. Haggard and B. Eitam (Oxford: Oxford University Press).

Leotti, L. A., and Delgado, M. R. (2014). The value of exercising control over monetary gains and losses. *Psychol. Sci.* 25, 596–604. doi: 10.1177/0956797613514589

Lorenz, K. (1988). *Hier bin ich - wo bist du? Ethologie der Graugans*. Munich: Serie Piper.

Mahler, S. V., Smith, K. S., and Berridge, K. C. (2007). Endocannabinoid hedonic hotspot for sensory pleasure: anandamide in nucleus accumbens shell enhances 'liking' of a sweet reward. *Neuropsychopharmacology* 32, 2267–2278. doi: 10.1038/sj.npp.1301376

Modell, A. H. (1996). "The interface of psychoanalysis and neurobiology," in *Paper Presentation - The Poles of Health: Biological and Social approaches to Disordered Minds. Boston Colloquium for Philosophy of Science*, Boston, MA.

Mook, D. G. (1989). Oral factors in appetite and satiety. *Oral factors in appetite and satiety. Ann N Y Acad Sci.* 575, 265–278. doi: 10.1111/j.1749-6632.1989.tb53249.x

Moore, J. W., Ruge, D., Wenke, D., Rothwell, J., and Haggard, P. (2010). Disrupting the experience of control in the human brain: pre-supplementary motor area contributes to the sense of agency. *Proc. Biol. Sci.* 277, 2503–2509. doi: 10.1098/rspb.2010.0404

Murayama, K., Matsumoto, M., Izuma, K., Sugiura, A., Ryan, R. M., Deci, E. L., et al. (2015). How self-determined choice facilitates performance: a key role of the ventromedial prefrontal cortex. *Cereb. Cortex* 25, 1241–1251. doi: 10.1093/cercor/bht317

Murray, E. A., O'Doherty, J. P., and Schoenbaum, G. (2007). What we know and do not know about the functions of the orbitofrontal cortex after 20 years of cross-species studies. *J. Neurosci.* 27, 8166–8169. doi: 10.1523/JNEUROSCI.1556-07.2007

Nachev, P., Kennard, C., and Husain, M. (2008). Functional role of the supplementary and pre-supplementary motor areas. *Nat. Rev. Neurosci.* 9, 856–869. doi: 10.1038/nrn2478

Neri, C. (1987). *Letture Bioniane*. Roma: Borla.

Northoff, G. (2012). Psychoanalysis and the brain-why did Freud abandon neuroscience? *Front. Psychol.* 3:71. doi: 10.3389/fpsyg.2012.00071

Northoff, G., and Panksepp, J. (2008). The trans-species concept of self and the subcortical-cortical midline system. *Trends Cogn. Sci.* 12, 259–264. doi: 10.1016/j.tics.2008.04.007

Panksepp, J. (1998). *Affective Neuroscience: The Foundations of Human and Animal Emotions*. New York, NY: Oxford University Press.

Panksepp, J. (2010). Affective neuroscience of the emotional BrainMind: evolutionary perspectives and implications for understanding depression. *Dialog. Clin. Neurosci.* 12, 533–545.

Panksepp, J. (2011). The basic emotional circuits of mammalian brains: do animals have affective lives? *Neurosci. Biobehav. Rev.* 35, 1791–1804. doi: 10.1016/j.neubiorev.2011.08.003

Panksepp, J., and Bishop, P. (1981). An autoradiographic map of (3H) diprenorphine binding in rat brain: effects of social interaction. *Brain Res. Bull.* 7, 405–410. doi: 10.1016/0361-9230(81)90038-1

Panksepp, J., and Biven, L. (2012). *The Archaeology of Mind: Neuroevolutionary Origins of Human Emotion*. New York, NY: W. W. Norton & Company.

Peciña, S., and Berridge, K. C. (2005). Hedonic hot spot in nucleus accumbens shell: where do mu-opioids cause increased hedonic impact of sweetness? *J. Neurosci.* 25, 11777–11786. doi: 10.1523/JNEUROSCI.2329-05.2005

Pettorruso, M., De Risio, L., Di Nicola, M., Martinotti, G., Conte, G., and Janiri, L. (2014). Allostasis as a conceptual framework linking bipolar disorder and addiction. *Front. Psychiatry.* 5:173. doi: 10.3389/fpsyt.2014.00173

Pfaff, D., Martin, E. M., and Kow, L. M. (2014). Generalized Brain Arousal Mechanisms Contributing to Libido. *Neuropsychoanalysis* 9, 173–181. doi: 10.1080/15294145.2007.10773556

Pfaff, D. W. (1999). *Drive: Neurobiological and Molecular Mechanisms of Sexual Motivation*. Cambridge, MA: MIT Press.

Pine, F. (2005). "Theories of motivation in psychoanalysis," in *Textbook of Psychoanalysis*, eds E. S. Person, A. M. Cooper, and G. O. Gabbard (Washington, DC: American Psychiatric Publishing, Inc.), 3–19.

Rapaport, D. (1953). On the Psycho-Analytic Theory of Affects. *Int. J. Psycho Anal.* 34, 177–198.

Ryan, R. M., Mims, V., and Koestner, R. (1983). Relation of reward contingency and interpersonal context to intrinsic motivation: a review and test using cognitive evaluation theory. *J. Pers. Soc. Psychol.* 45, 736–750. doi: 10.1037/0022-3514.45.4.736

Salimpoor, V. N., Benovoy, M., Larcher, K., Dagher, A., and Zatorre, R. J. (2011). Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nat. Neurosci.* 14, 257–262. doi: 10.1038/nn.2726

Salone, A., Di Giacinto, A., Lai, C., De Berardis, D., Iasevoli, F., Fornaro, M., et al. (2016). The inteface between neuroscience and neuro-psychoanalysis: focus on brain connectivity. *Front. Hum. Neurosci.* 10:20. doi: 10.3389/fnhum.2016.00020

Schore, A. N. (1994). *Affect Regulation and the Origin of the Self: The Neurobiology of Emotional Development*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Schore, A. N. (1996). The experience-dependent maturation of a regulatory system in the orbital prefrontal cortex and the origin of developmental psychopathology. *Dev. Psychopathol.* 8, 59–87. doi: 10.1017/S0954579400006970

Schore, A. N. (2001). Minds in the making: attachment, the self-irganizing brain, and developmentally-oriented psychoanalitical psychotherapy. *Br. J. Psychother.* 17, 299–328. doi: 10.1111/j.1752-0118.2001.tb00593.x

Smith, K. S., and Berridge, K. C. (2005). The ventral pallidum and hedonic reward: neurochemical maps of sucrose "liking" and food intake. *J. Neurosci.* 25, 8637–8649. doi: 10.1523/JNEUROSCI.1902-05.2005

Smith, K. S., Berridge, K. C., and Aldridge, J. W. (2011). Disentangling pleasure from incentive salience and learning signals in brain reward circuitry. *Proc. Natl. Acad. Sci. U.S.A.* 108, E255–E264. doi: 10.1073/pnas.1101920108

Solms, M., and Panksepp, J. (2012). The "id" knows more than the "ego" admits: neuropsychoanalytic and primal consciousness perspectives on the interface between affective and cognitive neuroscience. *Brain Sci.* 2, 147–175. doi: 10.3390/brainsci2020147

Solms, M., and Turnbull, O. (2002). *The Brain and the Inner World: An Introduction to the Neuroscience of Subjective Experience*. London: Karnac.

Stanley, B., Sher, L., Wilson, S., Ekman, R., Huang, Y. Y., and Mann, J. J. (2010). Non-suicidal self-injurious behavior, endogenous opioids and monoamine neurotransmitters. *J. Affect. Disord.* 124, 134–140. doi: 10.1016/j.jad.2009.10.028

Steiner, J. E., Glaser, D., Hawilo, M. E., and Berridge, K. C. (2001). Comparative expression of hedonic impact: affective reactions to taste by human infants and other primates. *Neurosci. Biobehav. Rev.* 25, 53–74. doi: 10.1016/S0149-7634(00)00051-8

Stern, D. N. (1985). *The interpersonal world of the infant*. New York: Basic Books.

Stern, D. N. (1990). "Joy and satisfaction in infancy," in *Pleasure Beyond the Pleasure Principle*, eds R. A. Glick and S. Bone (New Haven: Yale University Press), 13–25.

Tsakiris, M. (2010). My body in the brain: a neurocognitive model of body-ownership. *Neuropsychologia* 48, 703–712. doi: 10.1016/j.neuropsychologia.2009.09.034

Veldhuizen, M. G., Rudenga, K. J., and Small, D. M. (2010). "The pleasure of taste flavor and food," in *Pleasures of the Brain*, eds M. L. Kringelbach and K. C. Berridge (Oxford: Oxford University Press).

White, R. W. (1963). *Ego and Reality in Psychoanalytic Theory*. New York: International Universities Press.

Yovell, Y. (2008). Is there a drive to love? *Neuropsychoanalysis* 10, 117–144. doi: 10.1080/15294145.2008.10773578

Zellner, M. R., Watt, D. F., Solms, M., and Panksepp, J. (2011). Affective neuroscientific and neuropsychoanalytic approaches to two intractable psychiatric problems: why depression feels so bad and what addicts really want. *Neurosci. Biobehav. Rev.* 35, 2000–2008. doi: 10.1016/j.neubiorev.2011.01.003

Zubieta, J. K., Heitzeg, M. M., Smith, Y. R., Bueller, J. A., Xu, K., Xu, Y., et al. (2003a). COMT val158met genotype affects mu-opioid neurotransmitter responses to a pain stressor. *Science* 299, 1240–1243.

Zubieta, J. K., Ketter, T. A., Bueller, J. A., Xu, Y., Kilbourn, M. R., Young, E. A., et al. (2003b). Regulation of human affective responses by anterior cingulate and limbic mu-opioid neurotransmission. *Arch. Gen. Psychiatry* 60, 1145–1153.

Zubieta, J. K., Smith, Y. R., Bueller, J. A., Xu, Y., Kilbourn, M. R., Jewett, D. M., et al. (2001). Regional mu opioid receptor regulation of sensory and affective dimensions of pain. *Science* 293, 311–315. doi: 10.1126/science.1060952

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Human Neuroscience

ORIGINAL RESEARCH
published: 24 September 2018
doi: 10.3389/fnhum.2018.00387

A Novel Insight of Effects of a 3-Hz Binaural Beat on Sleep Stages During Sleep

Nantawachara Jirakittayakorn and Yodchanan Wongsawat**

Brain Computer Interface Laboratory, Department of Biomedical Engineering, Faculty of Engineering, Mahidol University, Salaya, Thailand

The dichotic presentation of two almost equivalent pure tones with slightly different frequencies leads to virtual beat perception by the brain. In this phenomenon, the so-called binaural beat has a frequency equaling the difference of the frequencies of the two pure tones. The binaural beat can entrain neural activities to synchronize with the beat frequency and induce behavioral states related to the neural activities. This study aimed to investigate the effect of a 3-Hz binaural beat on sleep stages, which is considered a behavioral state. Twenty-four participants were allocated to experimental and control groups. The experimental period was three consecutive nights consisting of an adaptation night, a baseline night, and an experimental night. Participants in both groups underwent the same procedures, but only the experimental group was exposed to the 3-Hz binaural beat on the experimental night. The stimulus was initiated when the first epoch of the N2 sleep stage was detected and stopped when the first epoch of the N3 sleep stage detected. For the control group, a silent sham stimulus was used. However, the participants were blinded to their stimulus group. The results showed that the N3 duration of the experimental group was longer than that of the control group, and the N2 duration of the experimental group was shorter than that of the control group. Moreover, the N3 latency of the experimental group was shorter.

Keywords: binaural beat, sleep modulation, delta activity, sleep stage, slow wave sleep

OPEN ACCESS

Edited by:
Massimo Di Giannantonio, Università degli Studi G. d'Annunzio Chieti e Pescara, Italy

Reviewed by:
Gary N. Garcia-Molina, Philips, United States
Vasil Kolev, Institute of Neurobiology (BAS), Bulgaria
Mauro Pettorruso, Catholic University of Rome, Italy

****Correspondence:***
Nantawachara Jirakittayakorn
Nantawachara.jir@student.mahidol.ac.th
Yodchanan Wongsawat
Yodchanan.won@mahidol.ac.th

Received: *15 March 2018*
Accepted: *06 September 2018*
Published: *24 September 2018*

Citation:
Jirakittayakorn N and Wongsawat Y (2018) A Novel Insight of Effects of a 3-Hz Binaural Beat on Sleep Stages During Sleep. Front. Hum. Neurosci. 12:387. doi: 10.3389/fnhum.2018.00387

INTRODUCTION

Beat is a phenomenon that occurs by interference of two almost equivalent sinusoidal tones but with slightly different frequencies and presents as fluctuation of a single tone. The fluctuation single tone is perceived as amplitude modulation with the frequency equaling the difference of the frequencies of the two interfering tones. A binaural beat, which occurs when the two mentioned tones are simultaneously presented to different ears, a virtual fluctuation of a single tone is generated in the brain by the ascending auditory pathway. For example, when a sinusoidal 250-Hz pure tone is presented to the left ear, and a 253-Hz tone is simultaneously presented to the right ear, a fluctuation of amplitude with a frequency rate of 3 Hz is perceived by the brain (**Figure 1**). The binaural beat cannot be measured by measurement tools but can be perceived by humans because the origination of the beat is in the brain; however, the difference of the two presented frequencies is greater than 35 Hz or two separate tones would not be perceived (Oster, 1973). Moreover, one study measured perception of the beat on different frequency carrier tones – the tone that is generated at each ear – and suggested that an intermediate frequency carrier tone of 440 Hz facilitated a

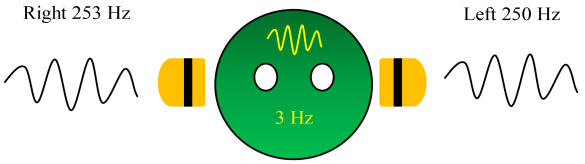


FIGURE 1 | A 3-Hz binaural beat on a 250-Hz carrier tone generated in the brain.

wider range of beat perception than lower or higher frequency carrier tones (Licklider et al., 1950). The auditory signal from each ear is conducted ipsilaterally along the ascending auditory pathway to the auditory cortex. However, at the brainstem, auditory signals from both sides are passed to the superior olivary complex (Kuwada et al., 1979; Schwarz and Taylor, 2005), the first nucleus in the ascending auditory pathway receiving bilateral auditory signals. The so-called binaural beat is spontaneously generated with a frequency equaling the difference of the frequencies of the two tones. The binaural beat is then conducted to the auditory cortex in phase-locked fashion described by the response of the inferior colliculus – a part of the ascending auditory pathway – as a binaural beat (Kuwada et al., 1979; McAlpine et al., 1996; Spitzer and Semple, 1998; Schwarz and Taylor, 2005; Karino et al., 2006).

After the primary auditory cortex receives the binaural beat signal, the signal is consequently sent to associated auditory areas and other associated areas inducing the brain to oscillate at the rate of binaural beat frequency, which can be measured by EEG rhythms. This phenomenon is called entrainment of neural oscillation (Wahbeh et al., 2007). EEG is a non-invasive technique for monitoring and recording electrical activity of the brain. Normally, spectral elements of EEG signals can be divided into five frequency bands: delta (0.5–4 Hz), theta (4–7 Hz), alpha (7–13 Hz), beta (13–30 Hz), and gamma (30–50 Hz) bands. These neural activities are entrained due to the frequency of the binaural beat, which is known as a frequency-following response (Worden and Marsh, 1968; Moushegian et al., 1973; Grose and Mamo, 2012). However, several studies have reported that binaural beats have effects on both EEG rhythms and psychophysiological aspects (Schwarz and Taylor, 2005; Pratt et al., 2009; Pratt et al., 2010; Lavallee et al., 2011; Chakalov et al., 2014).

The frequency-following response, which is one effect of a binaural beat, is described by the fact that binaural beat can entrain neurons to oscillate at the frequency rate related to the binaural beat frequency. Several studies have shown an entrainment effect in almost all frequency bands, including theta, beta, and gamma bands, after participants are exposed to a binaural beat within the ranges of those frequencies (Schwarz and Taylor, 2005; Draganova et al., 2008; Pratt et al., 2009; Magezi and Krumbholz, 2010; Ross et al., 2014). However, the cortical positions responding to the binaural beat remain a topic of discussion because different brain processes occur for different frequency activities (Ross et al., 2014), i.e., the cerebral cortex can be synchronized with a binaural beat, but previous studies have utilized different binaural stimuli in terms of carrier tone and beat frequency. Hence, with a phase-locked response of the ascending auditory pathway, different responses at the cortical level may appear. However, based on this discussion, other researchers have conducted experiments on the psychophysiological effects of binaural beats and shown interesting supporting evidence (Lane et al., 1998; Padmanabhan et al., 2005; Lavallee et al., 2011; Reedijk et al., 2013).

Normally, each EEG rhythm is associated with a particular activity, cognition, or behavior. For example, gamma oscillations are associated with the maintenance of arousal of the brain during the awake stage (Gray and Singer, 1989; Llinas and Pare, 1991; Gray, 1999; Vanderwolf, 2000), while theta oscillations are found during meditation (Takahashi et al., 2005; Lagopoulos et al., 2009) and associated with alertness, attention, orientation, and working memory, including the enhancement of cognitive and perceptual performances (Aftanas and Golocheikine, 2001; Stern et al., 2001). One study stated that listening to a 6-Hz binaural beat can induce EEG rhythms to reflect a meditative state and reduce negative emotions (Jirakittayakorn and Wongsawat, 2017a). Moreover, a binaural beat in the theta range also showed an effect on reducing stress and anxiety in pre-operative procedures (Padmanabhan et al., 2005), and a binaural beat in the beta range enhanced vigilance performance (Lane et al., 1998). A theta binaural beat could potentially be used to induce novice meditators into a deep meditative stage, while a beta binaural beat strongly inhibits meditators to maintain the same level of meditation (Lavallee et al., 2011). Recent studies have also shown that a binaural beat in the beta range improves word recall and affects long-term memory (Garcia-Argibay et al., 2017), and a binaural beat in the gamma range enhances short-term memory (Jirakittayakorn and Wongsawat, 2017b). These studies support an entrainment of neural oscillations in the brain because these activities, cognitions, and behaviors are related to specific neural oscillations that are specifically induced and entrained in EEG rhythms.

From literature, binaural beats have been shown to entrain neural oscillations, even though obviously cortical areas responding to the binaural beat remain under discussion. Moreover, activities, cognitions, and behaviors can be manipulated via those entrainments following the perception of a binaural beat and presented depending on the related EEG rhythm. This evidence suggests that binaural beats affect neural activities, as shown in EEG recordings, and thus, binaural beats could be utilized to modulate behavioral states. However, observation of responses of binaural beat in range of delta activity is lacking because delta activity is typically found during sleep in normal adults.

Sleep is a physiological activity and is considered as one of the natural states of the body, occurring in every species. It is a behavioral state that can be described by reduced motility and sensory responses to external stimuli (Carskadon and Dement, 2005). In short, all sensory thresholds during sleep are higher than during the awake stage. Sleep and wakefulness are regulated by the ascending arousal system, which originates in the brainstem, sending projection fibers throughout the thalamus,

hypothalamus, basal forebrain, and cerebral cortex. Several nuclei population groups are included in this system (Schwartz and Roth, 2008). Among those nuclei groups, some are categorized as part of the sleep-promoting system (Sherin et al., 1996; Szymusiak et al., 1998; Gallopin et al., 2000; Chamberlin et al., 2003), and some are firing as wake promoting system (Moruzzi and Magoun, 1949; Panula et al., 1984; Takahashi et al., 2006). These two groups of nuclei play regulatory roles as a flip-flop switch (Saper et al., 2001, 2005, 2010; Lu et al., 2006), with reciprocal interactions to each other. The reciprocal flip-flop switch is essential to prevent a prolonged transitional stage between sleep and awake stages (Saper et al., 2010). In other words, nuclei in the wake-promoting system fire to inhibit nuclei in the sleep-promoting system to maintain the waking state, and vice versa; nuclei in the sleep-promoting system also inhibit nuclei in the wake-promoting system during sleep, leading to different neural oscillations that can be observed by changes in EEG signals during sleep.

The different EEG patterns during sleep are indicated as sleep stages. Sleep stages have been classified into two types by eye movement which are non-rapid eye movement and rapid eye movement sleep. For non-rapid eye movement (NREM), three different EEG patterns are indicated by the American Academy of Sleep Medicine (AASM), which are N1, N2, and N3 stages (Iber et al., 2007; Berry et al., 2015). The patterns of EEG signals are as follows: N1 shows low voltage with a mixed frequency of EEGs; N2 shows sleep spindle activity with an average frequency of 14 Hz and the K-complex, a brief negative high-voltage peak followed by a slower positive complex; N3 shows many slow waves or delta waves in EEGs. Rapid eye movement (REM) shows similar EEG pattern with the N1 stage during which random and rapid movement of the eyes also occurs. These patterns of EEG repeatedly occur during the sleep period in a cyclical fashion. Sensory thresholds are higher during sleep than during the awake stage, and responses to external stimuli are decreased; however, only one sensation that is active throughout the sleep period is auditory sensation. The auditory system is the only system being active during sleep, with a lower threshold than other sensory systems, and plays a role as a guardian to prevent against danger by screening all audible sounds in the surrounding environment (Velluti, 1997). The threshold of auditory stimuli is approximately 60 dB SPL (Williams et al., 1964), and sound intensity over 65 dB SPL induces an arousal response (Velluti, 1997). Each sleep stage responds differently to the same auditory stimulus intensity. The N2 stage shows an obvious response and less variation, while the response is not observed during the N3 stage (Velluti, 1997). Therefore, binaural beats could be used to modulate sleep stages, as they can be used to modulate behavioral states followed by an entrainment effect. Moreover, as there is a lack of investigations of the effects of binaural beats during sleep, we present important, novel observations of their effects during sleep.

One another interesting point of sleep is memory. Once information is received in the first time during learning period, that memory is labile and fragile, after a period of time, that memory is consolidated and becomes long-lasting memory during sleep, especially during N3 stage. However, due to modern lifestyle in nowadays, slow wave sleep or N3 stage seems to be disturbed by distress (Buckley and Schatzberg, 2005). The sleep is changed by reduction of slow wave sleep, REM sleep, delta power (Rolls et al., 2010), and sleep efficiency including increase in awakening (Kim and Dimsdale, 2007). With these reasons, memory consolidation during sleep is impaired due to N3 sleep stage reduction (Prince and Abel, 2013; Havekes et al., 2016). Increase in N3 sleep stage or slow wave sleep can be implied to improve strengthening memory in a person who lack of N3 sleep stage due to memory consolidation process, if N3 sleep stage can be modulated by the stimulus.

This study aimed to investigate the effect of a 3-Hz binaural beat stimulus on a 250-Hz carrier tone of 60 dB SPL on sleep stages, especially on stages N2 and N3. According to sleep characteristics, the N3 stage presents delta activity on EEGs and, thus, should be entrained by a 3-Hz binaural beat, which is in the range of delta activity, if the binaural beat is able to induce EEG rhythms to synchronize with its frequency. Therefore, the N3 stage should exhibit extended duration and shortened latency. Moreover, N3 stage play an important role in memory consolidation so increase in N3 sleep stage may lead to improve memory.

MATERIALS AND METHODS

This study aimed to investigate the effect of 3-Hz binaural beat on 250-Hz carrier tone on sleep stages by delivering binaural beat stimulus to participants in experimental group during the third night, experimental night. Electroencephalograms (EEGs), electro-oculograms (EOGs), and electromyograms (EMGs) were utilized to score sleep stages as recommended by the American Academy of Sleep Medicine (AASM) (Iber et al., 2007; Berry et al., 2015). Effect of the stimulus to sleep stage was focusly observed within subjects in experimental group; however, experimental and control groups were included in this study to confirm stimulus effect not habituation to environment. All experimental procedures were approved by the Institutional Review Board of Mahidol University with certificate of approval (COA) number 2016/119.1209. Prior to including the participants in the study, all procedures were described to the participants and written informed consent were given by all participants. The participants can freely withdraw their participations from the study by any reasons.

Experimental Room

The experimental room was a sound-attenuated room and completely dark after turning off the lights with the temperature controlled to 25°C. The color of the room's walls was ivory to promote neutral perceptions of emotion and mood according to white color (Sroykham et al., 2014) but without refulgent light reflection to arouse awakening. The bed was set under an air-conditioner to prevent air directly flowing onto the participant's face and inducting congestion or allergies but allowing temperature to be controlled. A monitoring unit was located outside the experimental room for privacy, but video

monitoring was available for monitoring the inside of the experimental room.

Binaural Beat Stimulus

The stimulus used in this study was a 3-Hz binaural beat on a 250-Hz carrier tone, which was specifically generated for the experiment. A 250-Hz carrier tone was presented to the left ear and a 253-Hz tone was presented to the right ear. This binaural beat file was set to 60 dB SPL as the threshold of auditory stimulation during sleep (Williams et al., 1964).

Participants

Twenty-four healthy participants with an average age of 24.12 years and a standard deviation of 2.54 years were included in this study (13 males and 11 females). The participants were randomly divided into two groups, experimental and control groups. The purpose of this study and the experimental procedures were explained to all participants before participation, but participants were blinded to the details of the stimulus and group allocation. The experimental group was composed of 16 participants, eight males and eight females, with an average age of 24.75 years and a standard deviation of 1.92 years, while the control group was composed of eight participants, five males and three females, with an average age of 22.88 years and a standard deviation of 3.27 years. However, one participant of the experimental group could not complete the experimental protocol on the third night because of a personal issue unrelated to the experimental procedures, and therefore, he was excluded from the study. Finally, 15 participants of the experimental group were included in the statistical analysis.

Sleep Parameter Recording

Electroencephalogram, EOG, and EMG were utilized to score sleep stages in this study, as recommended by the AASM. These bio-signals were used without full polysomnography (PSG) in this study because they are sufficient for scoring sleep stages and ensuring comfort to the participants. Four EEG electrodes were attached to positions of F4, C4, O2, and Cz due to the international 10/20 system for EEG electrode placement. These positions were practically recommended for sleep stage scoring by the AASM standard (Iber et al., 2007; Berry et al., 2015). A reference EEG electrode was placed at the left mastoid process (M1 position), while a ground electrode was placed at the right mastoid process (M2 position). For EOG, an electrode was attached to the left and right sides, 1 cm below the left eyelid and 1 cm above the right eyelid. A reference EOG electrode was placed on the forehead. Two electrodes for chin EMG were placed as mental electrode and submental electrode. The mental electrode was placed at the midline 1 cm above the inferior edge of the mandible, and the submental electrode was placed at the midline 2 cm below the inferior edge. A ground electrode used for both EOG and EMG was placed at the same position as EEG on the right mastoid process (M2 position). Both EOG and EMG were used to determine REM stage.

All EEG, EOG, and EMG were recorded using a Guger Technologies (g.tec) G.USBamp 3.0 16 channels Bio-signal amplifier brain computer interface BCI2000 as amplifier for data acquisition with a sampling rate of 516 samples per second, which is higher than the recommendation of the AASM of 500 samples per second. All signals were sampled at the same rate, but different band-pass filters were used as follows: 0.3 to 35 Hz for all EEG and EOG channels, and 10 to 100 Hz for chin EMG.

After wiring all electrodes, the system was connected to a monitoring PC via a networking system which displayed 30 s per one epoch to monitor the real-time sleep stage with video monitoring outside the experimental room.

Experimental Procedures

The experiment was composed of three consecutive nights, corresponding to adaptation, baseline, and experimental nights. All participants were required to attend all consecutive nights for inclusion in the statistical analysis. Both experimental and control groups underwent recordings during these three consecutive nights, and all procedures were the same. The last night, the experimental night, differed between the experimental and control groups. On this night, the 3-Hz binaural beat stimulus was delivered to the experimental group, while a sham stimulus was presented to the control group. The sham stimulus used in this study was silence for comparing sleep stages between a binaural beat and a non-binaural beat.

For each night of the experiment period, the participant arrived at the experimental room at 9 p.m. to prepare themselves for participation in the study. The procedures were described to the participants on the first night, the adaptation night, at which time the participants completed the informed consent form. Participants can withdraw their participations for any reasons. Emotion and mood were then evaluated by the Brunel Mood Scale (BRUMS) questionnaire.

The BRUMS is a self-report emotional state questionnaire composed of 24 items. These items correspond to a 6-factor model including "Anger," "Confusion," "Depression," "Fatigue," "Tension," and "Vigor." Each item is responded to using a 5-point Likert scale, which ranges from 0 to 4 representing "not at all" to "extremely" depending of the participant's feelings. However, only fatigue and vigor factors were focus in this study to indicate sleep disturbance in the last night.

After completing the emotional questionnaire, the participant put on a pair of Beats^{x} wireless in-ear headphones. The 3-Hz binaural beat stimulus was delivered to each participant for 3 s to test the sound, and then, a sound was separately delivered to each ear for another 3 s each. The headphones were then removed. The participant's head was measured for electrode positions according to the international 10/20 system. F4, C4, O2, and Cz positions were marked. Genuine Grass® 10 mm gold cup electrodes were utilized for bio-signal acquisition with Ten20® EEG conductive paste. Prior to attaching each electrode at their positions, the skin was gently scrubbed to remove dead cells and the sebum layer for close attachment between the electrode and skin. All eleven electrodes were attached as described in the sleep parameter recording section and connected to the g.tec amplifier and monitoring PC. The headphones were put back on and gently attached to the participant's ears by tape to prevent the headphones from falling out of the ears during the night. The participant subsequently went to bed

and the lights were turned off at 11 p.m. At 7 a.m. of the following morning, the participant was awakened by turning on the lights, and all electrodes were removed. During the sleep period, EEG, EOG, and EMG signals were continuously monitored. The BRUMS was completed again by the participant to evaluate their emotional state. The appointment for the next night was scheduled at the same time of the previous night.

These procedures were conducted for each participant both in the experimental and control groups for all study nights. For the last night of the experimental group (the experimental night), a 3-Hz binaural beat was initiated for delivery to the participants each time that the first epoch of N2 stage appeared and was stopped when the first epoch of N3 stage appeared. The auditory stimulation was continually delivered to the participants although N1, and REM sleep stages appeared. The reason of delivery stimulus during N2 was that the N2 stage shows an obvious response and less variation, while the response is not observed during the N3 stage (Velluti, 1997). Moreover, one study presented audible sound with intensity around 68 dB SPL to participants who slept in N2 sleep stage, and that sound let the participants waking up (Bonnet, 1986). More recent studies on auditory stimulation during sleep have delivered auditory stimulus to the participants during N2 sleep stage or deeper appeared by fixing time (Ngo et al., 2013), or at slow oscillation was detected during N2 sleep stage or deeper (Besedovsky et al., 2017). However, stable N2 sleep stage is utilized as an important stimulus trigger criterion. Furthermore, the primary focus sleep stage in this study was N3 sleep stage, and transition from N2 sleep stage to N3 sleep stage typically showed more possibility compared to transition from other sleep stages to N3 sleep stage by releasing slow oscillation stimulus to sleepers during sleep (Saebipour et al., 2015). Therefore, providing the stimulus during N2 stage can investigate less variation of response, and is consistent with several studies. These procedures were continued through the 5th hour of sleep, after which the stimulus was terminated. As mentioned, human sleep stages are cyclical, and therefore, the 3-Hz binaural beat stimulus was stopped if a waking stage appeared for three consecutive epochs after releasing. The experimental procedures are shown in **Figure 2**.

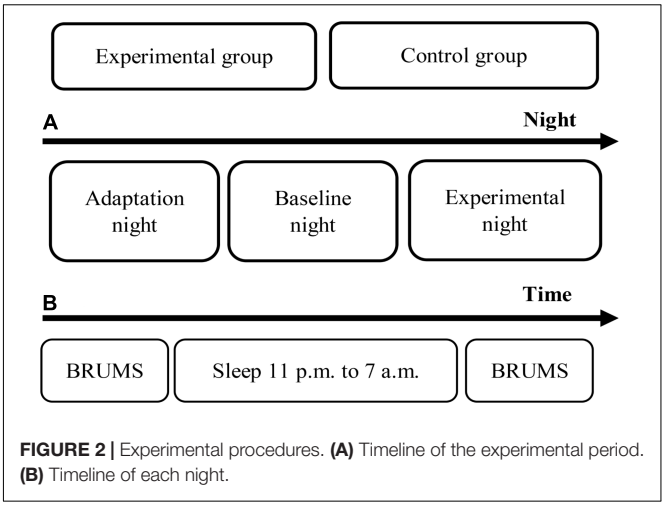


FIGURE 2 | Experimental procedures. **(A)** Timeline of the experimental period. **(B)** Timeline of each night.

Sleep Stage Scoring

Sleep stages of the recorded data were scored for every epoch following the AASM standards for sleep stage scoring as W, N1, N2, N3, and REM stages, depending on the characteristics of EEG, EOG, and EMG signals (Iber et al., 2007; Berry et al., 2015). The sleep parameters focused on in this study were total sleep time (TST), sleep latency (SL), REM latency, arousal index, wake after sleep onset (WASO), percent of sleep efficiency, time in each stage, percent of TST in each stage, N3 latency, N3 duration, and N2 duration. Three scorers were included in scoring process, each scorer scored all participants data in one of three consecutive nights, but the night was blinded. Arousal in this study is scored due to AASM scoring manual and includes movement arousal. Arousal index is then calculated from total arousal divided by TST.

EEG Data Analysis

Electroencephalogram signals recorded along the baseline and the experimental nights, night 2 and night 3, were processed to analyze in frequency domain by fast Fourier transform (FFT). Waking stage and arousal including movement arousal were removed from the analysis process because waking stage was not associated with increase in delta activity during sleep induced by 3-Hz binaural beat, while movement arousal signal was transformed into low frequency data in frequency domain, especially in delta activity. Other noise signals were also excluded from the analysis such as electrode displacement signal. Absolute power of each frequency was summed to represent absolute power of each frequency band including delta (0.5–4 Hz), theta (4–7 Hz), alpha (7–13 Hz), beta (13–30 Hz), and gamma (30–50 Hz) bands. This process was conducted on every electrode positions which were F4, C4, O2, and Cz. Consequently, average of four electrode positions was conducted in each frequency band to represent that frequency band of each participant during night 2 and night 3 for statistical analysis.

Another FFT was performed on EEG signals in which the epoch was considered as N2 sleep stage in both experimental and control groups of night 2 and night 3 to reveal characteristics of delta activity in each condition. Absolute power of delta activity of N2 sleep stage was summed and used as delta power during N2 sleep stage of each group and night. Changes in delta power during N2 sleep stage in night 3 with respect to night 2 of each group were operated for correlation analysis.

Statistical Analysis

Comparisons were performed for each mentioned parameter both within groups to investigate effect of 3-Hz binaural beat on sleep stage and between groups to confirm that occurred effect was the stimulus effect not habituation to environment. Paired *t*-tests were conducted to evaluate the effect of the 3-Hz binaural beat stimulus on the experimental night (night 3) and the baseline night (night 2) of both groups. The adaptation night (night 1) was compared with night 2 by paired *t*-tests to

evaluate the effect of sleep deprivation due to the environmental changes. Independent *t*-tests were conducted to ensure that the observed effects were only due to the 3-Hz binaural beat stimulus and not to habituation to the changed environment. In other words, differences in parameters between night 3 and night 2 ($\bar{d}$ of night 3 and that of night 2 by paired *t*-tests) were consequently compared. *P*-values less than 0.05 were considered significant in all statistical analyses.

Similar comparisons were performed on FFT absolute power to compare each frequency band which were delta, theta, alpha, beta, and gamma bands both within groups and between groups. The analysis of frequency bands was conducted to investigate effect of 3-Hz binaural beat on neural activity during sleep and to evaluate association between N3 sleep stage and delta activity.

Correlation analysis via Fisher transformation was conducted to change in delta activity during N2 sleep stage of night 3 with respect to night 2 in the group, that had expressed significant difference in delta activity within the whole night by paired *t*-test, and N3 duration and N3 latency to evaluate the relationship between change in delta activity during auditory stimulation and the two primary variable investigated in this study, N3 duration and N3 latency. In other words, the correlation analysis was performed on delta activity during N2 sleep stage and N3 duration and N3 latency only in experimental group. *P*-value of less than 0.05 was considered significant.

Survival analysis with log-rank test was conducted on transition period from N2 sleep stage to N3 sleep stage to assess sleep fragmentation described somewhere (Swihart et al., 2015) between experimental and control groups only in night 3 due to 3-Hz binaural beat stimulation.

Paired *t*-tests were conducted on BRUMS score in both groups comparing between before sleep and after waking for night 3, only the focusing emotion which were fatigue and vigor factors to evaluate whether the stimulus disturbed the sleep period and which emotional states were significantly changed, either increased or decreased, in each group.

RESULTS

The stimulus was presented to participants in each group during the experimental night (night 3) of three consecutive nights. A 3-Hz binaural beat, which is in the delta range, was delivered to participants of the experimental group when the first epoch of the N2 stage appeared and was terminated when the first epoch of the N3 stage appeared; no sounds were delivered to the control group throughout the night. All participants were blinded to the experimental and control groups and underwent in the same procedures every night. Sleep stages and emotions were investigated following the stimulation.

Sleep Parameters

All sleep parameters of both the experimental group and the control group are shown in **Table 1**. The TST was approximately 450 min each night, with the maximum duration in the N2 stage of approximately 250 min, which was 50% of the TST. The percent of time in each stage is displayed in **Figure 3**.

Experimental Group

The results show that in experimental period, participants almost slept in the N2 stage every night. The significant findings of the experimental group are shown in **Table 2**. Comparing the experimental night with the baseline night (night 3 compared with night 2), after the stimulus was released to the participants during sleep, the N3 sleep stage showed significant increases in terms of both minutes and percent (*p*-value <0.0001.) The N3 latency was significant shorter. The N2 sleep stage also showed significant decreases in terms of both minutes and

TABLE 1 | Averages of the sleep parameters of the experimental and control groups during the experimental period (mean ± SD).

Parameter	Experimental group			Control group		
	Night 1	Night 2	Night 3	Night 1	Night 2	Night 3
Total sleep time (min)	434.8 ± 41.3	457.4 ± 16.2	455.9 ± 19.1	446.7 ± 40.7	463.0 ± 8.0	456.7 ± 12.6
Sleep latency (min)	12.2 ± 10.8	8.8 ± 7.1	8.9 ± 9.4	6.2 ± 3.7	6.8 ± 2.8	9.1 ± 4.6
REM latency (min)	146.1 ± 86.9	95.1 ± 31.8	88.8 ± 30.5	103.8 ± 45.7	96.1 ± 41.3	87.8 ± 13.0
N3 latency (min)	21.0 ± 9.5	22.9 ± 19.6	13.5 ± 4.9	17.7 ± 5.8	17.6 ± 4.8	18.4 ± 5.6
Arousal index	3 ± 1.3	2 ± 1.1	2 ± 0.9	2 ± 0.7	2 ± 0.5	2 ± 0.8
Wake after sleep onset (min)	33.4 ± 38.7	14.3 ± 13.8	15.7 ± 13.9	27.6 ± 40.5	10.7 ± 6.6	14.8 ± 8.8
Sleep efficiency (%)	90.6 ± 8.6	95.3 ± 3.4	95.0 ± 4.0	93.1 ± 8.5	96.5 ± 1.7	95.1 ± 2.6
Time in N1 (min)	23.7 ± 12.0	23.7 ± 9.6	23.1 ± 11.3	30.6 ± 8.0	27.5 ± 7.8	29.6 ± 5.8
Time in N2 (min)	234.1 ± 29.2	251.0 ± 16.8	209.8 ± 42.8	222.8 ± 26.5	239.9 ± 24.6	226.9 ± 27.0
Time in N3 (min)	94.8 ± 27.7	90.6 ± 16.3	125.9 ± 30.8	207.3 ± 32.9	101.4 ± 28.3	103.1 ± 19.8
Time in REM (min)	82.3 ± 15.6	90.3 ± 21.4	97.0 ± 17.7	74.8 ± 23.6	94.2 ± 16.5	97.1 ± 18.2
Percent of N1 (%)	5.7 ± 3.3	5.2 ± 2.1	5.1 ± 2.6	7.0 ± 102	5.9 ± 1.7	6.5 ± 1.2
Percent of N2 (%)	53.9 ± 5.0	54.9 ± 3.7	45.9 ± 8.9	49.9 ± 4.2	51.9 ± 5.7	49.7 ± 5.8
Percent of N3 (%)	21.6 ± 5.1	19.8 ± 3.5	27.7 ± 6.9	25.4 ± 6.6	21.9 ± 6.1	22.6 ± 4.6
Percent of REM (%)	18.9 ± 3.1	19.7 ± 4.4	21.3 ± 3.7	16.6 ± 4.6	20.3 ± 3.3	21.2 ± 3.7

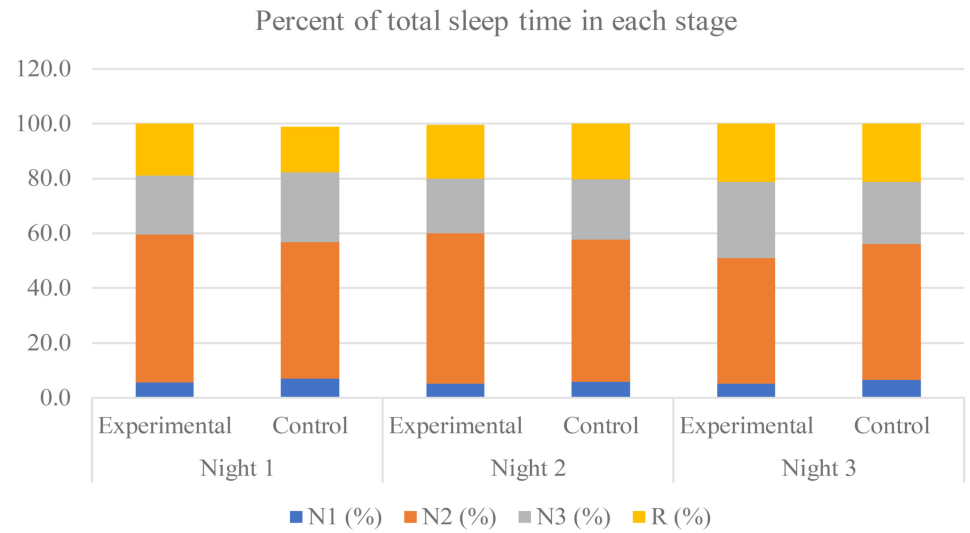


FIGURE 3 | Percent of total sleep time in each stage during the experimental period of both groups. The non-rapid eye-movement stage 1, stage 2, stage 3, and the rapid-eye movement (REM) are labeled as "N1," "N2," "N3," and "R," respectively.

percent (p-value <0.0001). Other sleep parameters did not show any significant differences. Average stimulation duration with standard deviation of experimental group in night 3 was 193.21 ± 35.27 min.

The significant differences between the baseline night and the adaptation night (night 2 compared with night 1) are expressed in **Table 3**. TST and percent of sleep efficiency were significantly increased (p-value = 0.0249). REM latency was significant shorter, while N3 latency did not change. The remaining parameters were not significantly different.

Control Group

The results show that in each night, participants slept almost entirely in the N2 sleep stage. Significant differences found in the control group are shown in **Table 2**. Comparing the experimental night with the baseline night (night 3 compared with night 2), after the control stimulus (silence) was delivered to the participants during sleep, no significant differences were observed.

Significant differences between the baseline night and the adaptation night (night 2 compared with night 1) are shown in **Table 3**. REM sleep stage significantly increased in terms of both minutes (p-value = 0.0035) and percent (p-value = 0.0048), while the N3 sleep stage significantly decreased in terms of percent (p-value = 0.0060). The remaining parameters did not significantly change.

Comparisons Between Groups

The mean differences in these sleep parameters were investigated by independent t-tests. The mentioned parameters were compared for differences between nights 2 and 3 of within each group ($\bar{d}$ between night 2 and night 3 of each group). Significant differences are displayed in **Table 2**. The change in N3 latency between night 3 and night 2 of the experimental group was significantly smaller than that of the control group (p-value = 0.0226). The increases in N3 duration between night 3 and night 2 in terms of both minutes (p-value = 0.0011) and percent (p-value = 0.0017) of the experimental group were significantly greater than those of the control group, while the decreases in N2 duration between night 3 and night 2 in terms of both minutes (p-value = 0.0254) and percent (0.0115) of the experimental group were significantly smaller than those of the control group.

Similar comparisons of the mean differences were conducted for night 1 and night 2 between the experimental group and the control group. Significant differences are shown in **Table 3**. Only the mean difference in REM latency between night 1 and night 2 of the experimental group was found to be significantly decreased compared to that of the control group with a p-value of 0.0496, which is close to the critical p-value of 0.05. The remaining parameters were not significantly different.

Neural Activity in Each Frequency Band

All frequency bands of neural activity are exhibited in **Figure 4**. FFT absolute power of night 2 and night 3 of both experimental and control groups were calculated to evaluate effect of 3-Hz binaural beat on neural activity.

Comparisons Within Groups

The results show that only delta activity of experimental group was significantly increase between night 2 and night 3 (p-value = 0.0293). Other frequency bands of both experimental and control groups were not significant. Power spectral analysis of delta activity during N2 sleep stage of both groups and both nights displayed peaks of activities in range of 0.5–4 Hz of experimental group in night 3 in which the 3-Hz binaural beat was released compared to other nights and control groups (**Figure 5**).

TABLE 2 | Paired *t*-tests of sleep parameters between night 2 and night 3 of both the experimental and control groups; and independent *t*-tests of the mean difference between the experimental and control groups (comparison of $\bar{d}$ of night 2 and night 3 between groups; an up arrow indicates an increase or longer duration, and a down arrow indicates a decrease or shorter duration; *indicates a two-tailed test).

Parameter	Paired *t*-test						Independent *t*-test	
	Experimental group			Control group			*P*-value	Sig.
	$\bar{d} \pm$ SD	*P*-value	Sig.	$\bar{d} \pm$ SD	*P*-value	Sig.		
Total sleep time (min)	−1.5 ± 24.2	0.8135	n.s.*	−6.3 ± 10.3	0.1258	n.s.*	0.5123	n.s.*
Sleep latency (min)	0.1 ± 11.3	0.9820	n.s.*	2.3 ± 3.9	0.1500	n.s.*	0.5058	n.s.*
REM latency (min)	−6.3 ± 26.4	0.1842	n.s.	−8.4 ± 39.0	0.2816	n.s.	0.8825	n.s.*
N3 latency (min)	−9.4 ± 17.5	0.0285	↓	0.9 ± 3.8	0.7314	n.s.	0.0226	↓
Arousal index	0 ± 0.5	1.0000	n.s.*	0.1 ± 0.4	0.3506	n.s.*	0.5090	n.s.*
Wake after sleep onset (min)	1.4 ± 18.6	0.7694	n.s.*	4.1 ± 6.7	0.1313	n.s.*	0.6286	n.s.*
Percent of sleep efficiency (%)	−0.3 ± 5.0	0.8135	n.s.*	−1.3 ± 2.1	0.1258	n.s.*	0.5123	n.s.*
Time in N1 (min)	−0.6 ± 8.1	0.7912	n.s.*	2.1 ± 5.9	0.3562	n.s.*	0.4300	n.s.*
Time in N2 (min)	−41.2 ± 35.2	0.0002	↓↓	−13.0 ± 20.4	0.0574	n.s.	0.0254	↓
Time in N3 (min)	35.3 ± 24.8	<0.0001	↑↑	1.8 ± 15.2	0.3768	n.s.	0.0011	↑↑
Time in REM (min)	6.7 ± 20.1	0.2156	n.s.*	2.9 ± 17.1	0.6494	n.s.*	0.6504	n.s.*
Percent of N1 (%)	−0.1 ± 1.8	0.8667	n.s.*	0.5 ± 1.3	0.3049	n.s.*	0.4210	n.s.*
Percent of N2 (%)	−9.0 ± 7.1	0.0001	↓↓	−2.2 ± 4.3	0.0987	n.s.	0.0115	↓
Percent of N3 (%)	7.9 ± 5.6	< 0.0001	↑↑	0.8 ± 3.2	0.2628	n.s.	0.0017	↑↑
Percent of REM (%)	1.6 ± 4.0	0.1475	n.s.*	0.9 ± 3.6	0.5095	n.s.*	0.6853	n.s.*

TABLE 3 | Paired *t*-tests of sleep parameters between night 1 and night 2 of both the experimental and control groups; and independent *t*-tests of the mean difference between the experimental and control groups (comparison of $\bar{d}$ of night 1 and night 2 between groups; an up arrow indicates an increase or longer duration, and a down arrow indicates a decrease or shorter duration; *indicates a two-tailed test).

Parameter	Paired *t*-test						Independent *t*-test	
	Experimental group			Control group			*P*-value	Sig.
	$\bar{d} \pm$ SD	*P*-value	Sig.	$\bar{d} \pm$ SD	*P*-value	Sig.		
Total sleep time (min)	22.6 ± 40.7	0.0249	↑	16.3 ± 38.1	0.2652	n.s.*	0.7237	n.s.*
Sleep latency (min)	−3.4 ± 13.0	0.3225	n.s.*	0.6 ± 3.0	0.5753	n.s.*	0.2640	n.s.*
REM latency (min)	−5.1 ± 93.7	0.0264	↓	−7.6 ± 15.0	0.0973	n.s.	0.0496	↓
N3 latency (min)	2.0 ± 20.2	0.6442	n.s.	−0.1 ± 3.0	0.4542	n.s.	0.6996	n.s.*
Arousal index	−0.1 ± 1.3	0.6976	n.s.*	−0.4 ± 0.9	0.2849	n.s.*	0.6101	n.s.*
Wake after sleep onset (min)	−19.1 ± 38.9	0.0772	n.s.*	−16.9 ± 38.7	0.2558	n.s.*	0.8984	n.s.*
Percent of sleep efficiency (%)	4.7 ± 8.5	0.0249	↑	3.4 ± 7.9	0.2652	n.s.*	0.7237	n.s.*
Time in N1 (min)	0.0 ± 14.5	0.9930	n.s.*	−3.1 ± 10.5	0.4383	n.s.*	0.6013	n.s.*
Time in N2 (min)	16.9 ± 32.0	0.0298	↑	17.2 ± 31.2	0.1628	n.s.*	0.9856	n.s.*
Time in N3 (min)	−4.2 ± 26.7	0.5488	n.s.*	−12.1 ± 18.6	0.1071	n.s.*	0.4661	n.s.*
Time in REM (min)	8.0 ± 24.4	0.2233	n.s.*	19.4 ± 14.5	0.0035	↑	0.2444	n.s.*
Percent of N1 (%)	−0.5 ± 3.8	0.6485	n.s.*	−1.0 ± 2.8	0.3294	n.s.*	0.7126	n.s.*
Percent of N2 (%)	1.0 ± 5.8	0.4994	n.s.*	2.0 ± 4.5	0.2546	n.s.*	0.7028	n.s.*
Percent of N3 (%)	−1.8 ± 5.1	0.2009	n.s.*	−3.5 ± 2.9	0.0060	↓	0.3933	n.s.*
Percent of REM (%)	0.8 ± 4.7	0.5263	n.s.*	3.7 ± 3.0	0.0048	↑	0.1305	n.s.*

As the significances of absolute power of delta activity and extended N3 duration and shorten N3 latency were exhibited only in experimental group, correlations between these factors were performed to evaluate the relationship showing in **Figure 6**. Increase in N3 duration was not significant correlated to increase in delta activity during N2 (r = 0.2688, p-value = 0.3607), while N3 decrease in N3 latency was negatively significant correlated to increase in delta activity during N2 (r = −0.5859, p-value = 0.0260).

Comparisons Between Groups

The mean differences of these five frequency bands were compared by independent *t*-test and greater significance was found only delta activity between experimental and control

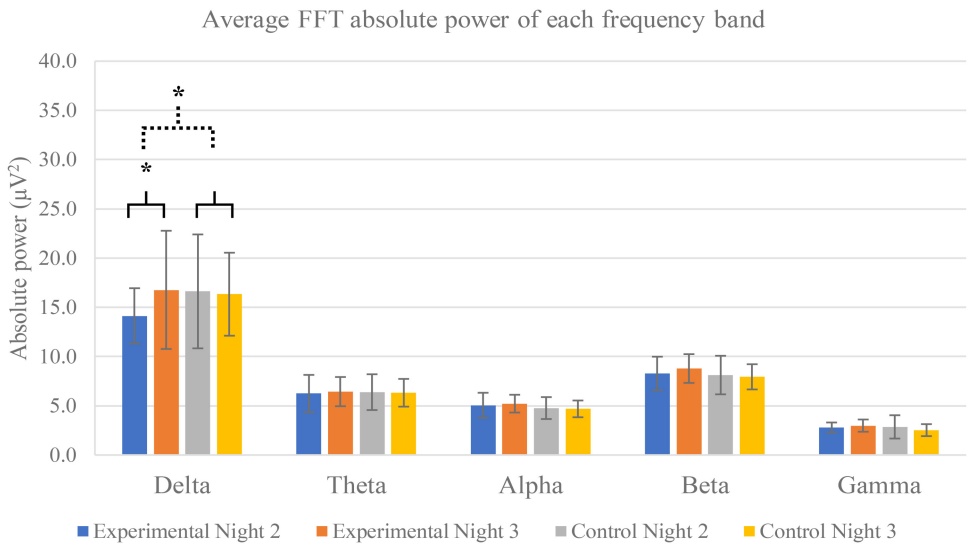


FIGURE 4 | Average FFT absolute power of each frequency band separated by groups and nights. Five frequency bands are exhibited: delta, theta, alpha, beta, and gamma frequency bands. The averages are calculated from all electrode positions including F4, C4, O2, and Cz. Error bars show standard deviations. Solid line brace displays paired *t*-test, and dash line brace displays independent *t*-test. *Indicates significance.

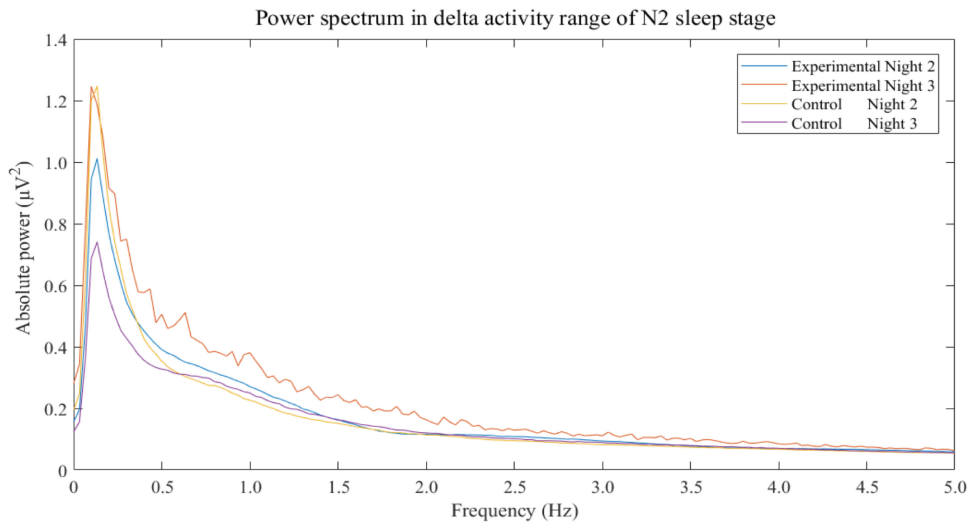


FIGURE 5 | Power spectrum in delta activity range of N2 sleep stage separated by groups and nights. The non-rapid eye-movement stage 2 is labeled as "N2." Frequencies of more than 5 Hz do not display.

groups (p-value = 0.0261). Other frequency bands were not found any significance.

N3 Sleep Stage Fragmentation

Figure 7 displays survival curve of sleep stage transition from N2 sleep stage to N3 sleep stage of both experimental and control groups to assess sleep fragmentation of experimental group during receiving of 3-Hz binaural beat. Transition time from N2 sleep stage to N3 sleep stage of every transitions from N2 sleep stage was observed in both group. The result shows that no significant difference between experimental group and control group occurred (p-value = 0.9782). Therefore, fragmentation of transition from N2 sleep stage to N3 sleep stage in experimental group during 3-Hz binaural beat stimulation was not different from normal sleep of control group.

Emotional Factors

The emotions of the participants were evaluated by the BRUMS questionnaire each night during the experimental period (three consecutive nights) before going to sleep and after awakening the following morning. Statistical analysis was conducted only fatigue and vigor factors of the experimental night to evaluate sleep disturbance effect of 3-Hz binaural beat.

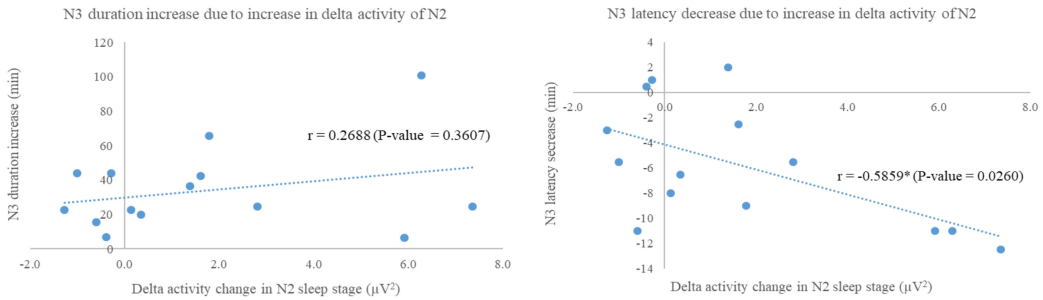


FIGURE 6 | Scatter plots show correlations between delta activity change in N2 sleep stage of night 3 with respect to night 2 of experimental group and N3 duration increase **(Left)**; and N3 latency decrease **(Right)**. Correlation analyses via Fisher transformation were performed only on experimental group due to change in delta activity. The non-rapid eye-movement stages 2 and 3 were labeled as "N2" and "N3," respectively. *Indicated significant difference.

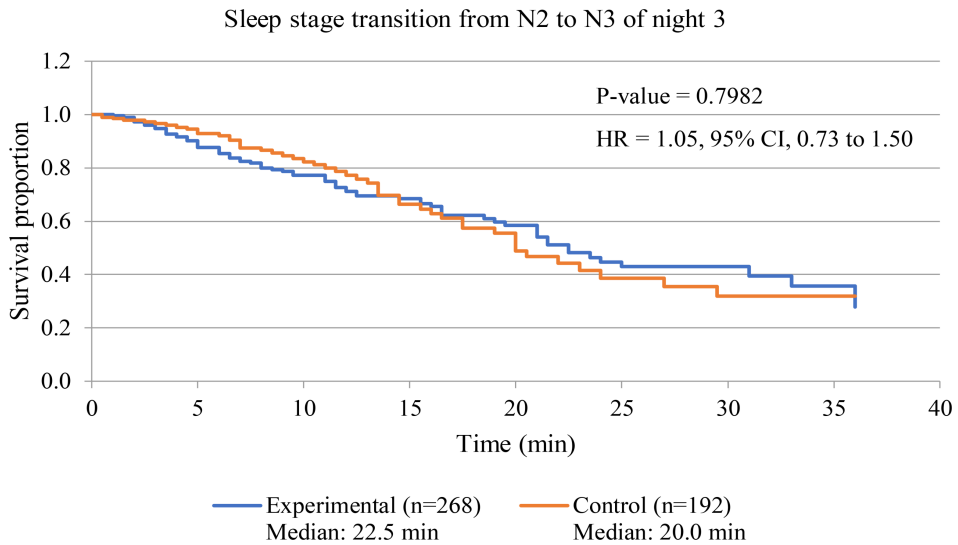


FIGURE 7 | Survival curve of sleep stage transition from N2 sleep stage to N3 sleep stage of night 3 of both experimental and control groups. *P*-value of Log-rank test is displayed. Hazard ratio is labeled as "HR," and calculated from hazard function of experimental group with respect to that of control group.

Comparisons Within Groups

The results showed that almost items of fatigue factors decreased after waking up in both experimental and control group, and two items of vigor factor increased after waking up in experimental group (**Table 4**).

Comparison Between Groups

Only significant differences in experimental group were greater analysis. From **Table 4**, the significant difference of the mean difference between before sleep and after waking up between both group revealed that only active was found to significantly increase. The remaining emotions did not show any significant changes. Therefore, the increase in active feelings of the experimental group was greater than that of the control group.

DISCUSSION

Three-Hz binaural beat on 250-Hz carrier tone cloud modulate neural activity by inducing delta activity during sleep and exhibited effects on sleep stages by increase in N3 sleep stage with decrease in N2 sleep stage, shorten N3 latency, and did not disturb sleep continuity indicated by arousal index and WASO without sleep fragmentation induction.

The 3-Hz binaural beat on a 250-Hz carrier tone seemed to directly affect the N3 and N2 sleep stages. Time in N3 sleep was extended during the experimental night of the experimental group compared with the baseline night of the same group. This increased N3 duration was induced by the 3-Hz binaural beat, as was clearly observed by the comparison of the change in the control group at the same time-point, night 3 compared with night 2. This comparison was conducted to confirm that this effect was indeed the effect of the stimulus, not the effect of habituation to the surrounding environment. The duration of N3 sleep was increased by the 3-Hz binaural beat not only in terms of time but also normalized time, as the percent of TST in the N3 stage. Because of different sleep onsets, the percent of TST in each stage should be used to normalize the sleep time in each stage for comparisons. The results suggest that the

TABLE 4 | Paired *t*-test of the BRUMS scores only fatigue and vigor factors between before sleep and after waking for night 3 of both the experimental and control groups; and independent *t*-tests of the mean difference between the experimental and control groups, which were only performed for significant differences shown by the paired *t*-test (comparison of $\bar{d}$ for night 3 between the groups; up arrow indicates an increase, down arrow indicates a decrease).

Factor	Emotion	Paired *t*-test						Independent *t*-test	
		Experimental group			Control group			*P*-value	Sig.
		$\bar{d} \pm$ SD	*P*-value	Sig.	$\bar{d} \pm$ SD	*P*-value	Sig.		
Fatigue	Worn out	-0.40 ± 0.91	0.0554	n.s.	-0.38 ± 0.52	0.0398	↓		
	Exhausted	-0.47 ± 0.99	0.0447	↓	-0.63 ± 0.52	0.0056	↓	0.2827	n.s.
	Sleepy	-0.67 ± 1.05	0.0136	↓	0.13 ± 0.99	0.3659	n.s.	0.0512	n.s.
	Tired	-0.67 ± 1.29	0.0326	↓	-1.00 ± 0.53	0.0006	↓↓	0.2312	n.s.
Vigor	Lively	-0.13 ± 1.30	0.3488	n.s.	-0.75 ± 1.16	0.0557	n.s.		
	Energetic	0.53 ± 1.41	0.0822	n.s.	0.25 ± 0.89	0.2256	n.s.		
	Active	0.73 ± 0.70	0.0006	↑	-0.38 ± 0.92	0.1425	n.s.	0.0064	↑
	Alert	0.53 ± 0.92	0.0203	↑	0.25 ± 0.89	0.2256	n.s.	0.2197	n.s.

increase in the duration and percent of N3 sleep stage of the experimental group on the experimental night compared with other nights and groups was an effect of the 3-Hz binaural beat. With these procedures of comparison, N3 latency was shorten and N2 duration was decreased by the effects of 3-Hz binaural beat without sleep discontinuity revealed by WASO.

In other words, N3 duration was extended with shortening N2 duration, and N3 latency was shorten potentially resulting from 3-Hz binaural beat stimulation during sleep in which comparisons were performed within the experimental group, and the results were confirmed indeed effect of the stimulus, not the habituation to the surrounding environment, by comparisons of the changes of the control group.

The changes in N3 sleep stage during the experimental night was in accordance with the increase in delta activity during that night. Delta activity contains frequency of 3 Hz so 3-Hz binaural beat is in range of delta activity. According to binaural beat effects which can entrain neural synchronization, several studies have reported this entrainment effect on other frequency bands as mentioned (Gray and Singer, 1989; Llinas and Pare, 1991; Gray, 1999; Vanderwolf, 2000; Takahashi et al., 2005; Lagopoulos et al., 2009; Jirakittayakorn and Wongsawat, 2017a,b) but investigation of the enhancement effect of delta activity during sleep have been lacked. However, this study was shown that power of delta activity seemed to be induced by 3-Hz binaural beat and the increase in delta activity was related to the increase in N3 sleep stage. Moreover, spectral components of delta activity which are in range of 0.5 Hz to 4 Hz of experimental group in experimental night, night 3, were clearly over compared to baseline of the same group and those of control group (**Figure 5**). The power spectrum of delta activity during N2 sleep stage was closely reflect the effect of the stimulus on EEG signal due to criteria of stimulation. The results showed higher values and peaks in every delta component which potentially indicated that the 3-Hz binaural beat affected delta activity EEG signal during sleep.

In order to reveal how does the 3-Hz binaural beat affect to N3 sleep stage, correlation analyses between increase in delta power during N2 sleep stage and either increase in N3 duration or decrease in N3 latency were performed pairwise. The significance was found only relationship between increase in delta power during N2 and decrease in N3 latency with a strong negative correlation which reflected that the more delta power during N2 increase, the shorter N3 latency. However, increase in N3 duration showed slight positive trend related to increase in delta power during N2 sleep stage. With these, the 3-Hz binaural beat seemed to increase N3 sleep stage by shorten N3 latency after that N3 duration trended to increase, spontaneously. Some explanations were given in recent study that a unidirectional increase in firing rate related to the stimulus of cortical neurons during UP-states without decreasing the firing rate during DOWN-states (Reato et al., 2013; Saebipour et al., 2015), and lasting of after-effect of the transcranial alternating current stimulation on EEG endogenous power, especially on low frequency power (Neuling et al., 2013). These explanations seemed to be used to explain our findings as the 3-Hz binaural beat could be used to induce delta activity during N2 sleep stage leading to shorten N3 latency. After N3 sleep stage occurred, the neurons firing during N3 sleep stage continuously fired in delta activity due to homeostasis without decrease in firing rate of delta activity until transition out to the other sleep stages.

The interesting role of slow wave sleep or N3 sleep stage is memory consolidation (Walker, 2009a). The consolidation process is important for memory stabilization after receiving of information into the brain which occurs during learning phase. Sleep is also associated with all processes including memory reconsolidation, memory enhancement, preventing memory destabilization, and deterioration (Walker and Stickgold, 2006). Non-emotional, fact-based memories or episodic memories is associated with presence and integrity of slow wave sleep (Backhaus et al., 2006). An experiment reported that primary insomnia of which slow wave sleep decreased showing less memory consolidation than normal (Backhaus et al., 2006), and normal healthy people with the age of over 30 years old whose polysomnography exhibited decrease in slow wave sleep during the night were found decrease in memory consolidation (Backhaus et al., 2007).

The process of memory formation and consolidation occurs by which co-ordination between neocortex and hippocampus of

the brain (Wiltgen et al., 2004; Frankland and Bontempi, 2005). Fragments of memory are formed at several regions and binding together of these fragments is generated within this network. This stage is so-called learning phase. Gamma oscillation plays an important role to combine them together (Jirakittayakorn and Wongsawat, 2017b). During consequent period, sleep period in slow wave sleep stage or N3 sleep stage, the memory receiving in learning phase is reactivated again (Walker, 2009b), and consolidation process occurs. The neural oscillation of slow wave sleep has origination at neocortex (Buzsaki, 1996).

The relationship of memory formation and consolidation and slow wave sleep potentially indicates that our study can be widely implied, nowadays. Because of modern lifestyle, slow wave sleep seems to be disturbed. Stress in modern lifestyle has interacted with sleep architecture and other factors (Buckley and Schatzberg, 2005) leading to impairment of quality of life (Hirotsu et al., 2015) by reduction of slow wave sleep, REM sleep, delta power (Rolls et al., 2010), and sleep efficiency including increase in awakening (Kim and Dimsdale, 2007). In addition, chronic work overload is also the cause of slow wave sleep and REM sleep decreases (Gonnissen et al., 2013). Because stress in daily life perturb healthy sleep (Mason, 1968) by decrease in slow wave sleep. Slow wave sleep play an important role in memory formation and consolidation so our finding can be utilized to improve sleep quality and memory by inducing of slow wave sleep.

Besides memory consolidation, memory reconsolidation is another process related to slow wave sleep. Memory reconsolidation process is explained that once storage memory is retrieved from a trace after storage, it becomes labile or unstable memory once again. That unstable memory which is sensitive to disruption is reconsolidated to the storage after reactivation (Alberini and LeDoux, 2013). The function of memory reconsolidation is still unclear (Walker and Stickgold, 2006) but it has been hypothesized into to two separate thoughts. The first one is considered to be memory updating of incremental learning following re-exposure to an experience similar to the first learning. The second one is considered to be memory strengthening and weakening depending on an experience that retrieve the learned experience (Alberini and LeDoux, 2013; Bisaz et al., 2014). However, due to the fragile state in a limited time of that memory, some disruptions can lead to change in some part of that memory before reconsolidation process. After reconsolidation process, the changed memory is re-stored to the storage. With this phenomenon, our finding seems to be one potential tool of several tools for memory reconsolidation in memory reconsolidation study. By increase in N3 sleep stage or slow wave sleep leading to improve the memory reconsolidation process. During unstable memory or labile state, if that memory is interfered by some stimulus, it trends to be adjusted or modulated by that stimulus. After memory reconsolidation process is completed due to quality sleep, the changed memory is stored instead of the old one. Potentially, these procedures can become session training either for strengthening or weakening the targeted memory. One study, which has been in line with our postulation, showed that fear memory can be abolished by a stimulus which was similar to the stimulus that induced fear memory (James et al., 2015) during reconsolidation process. Further studies are required for this postulation but improve quality of sleep due to increase in slow wave sleep is like to be modulated by the 3-Hz binaural beat.

Some studies have attempted to modulate sleep stage by inducing of slow wave sleep and indicated that recognition memories have been increased due to increase of slow wave sleep which were related to this study. One study reported that memory can be greater recalled in napping participant with slow wave sleep than without slow wave sleep (Takashima et al., 2006). Odor stimulus was used in one study (Rasch et al., 2007) stating that memory to card pair increased after odor stimulation was performed to participants during slow wave sleep compared with odorless group. Moreover, the researchers found that odor stimulation during REM sleep and wakefulness did not affect memory. However, the studies of inducing of slow wave sleep have exhibited the results consisting to our results in which slow wave sleep can be induced. Transcranial magnetic stimulation (TMS) (Huber et al., 2007; Massimini et al., 2007) and transcranial direct current stimulation (tDCS) (Marshall et al., 2004, 2006) have been used to induce slow wave sleep. The TMS of 5 Hz pulse was delivered to participants during wakefulness finding that slow wave activity rose up during sleep (Huber et al., 2007), while the TMS of <1 Hz pulse delivered during sleep was also raised slow wave activity up (Massimini et al., 2007). The uses of tDCS expressed enhancement of memory (Marshall et al., 2004) and slow wave sleep (Marshall et al., 2006). The tDCS was delivered to participants during slow wave sleep finding that memory was improved (Marshall et al., 2004), while the tDCS of 0.75 Hz delivered in N2 sleep stage can induce slow wave sleep and improve the memory recall (Marshall et al., 2006). These studies were firmly corresponding to our finding. However, our finding provided a novel investigation of 3-Hz binaural beat on sleep architecture during sleep.

To clarify that these effects, extended N3 duration and percent, shortened N3 latency, and shortened N2 duration and percent, were the effects of the stimulus and not other factors, all baseline nights should be the same. The results indicated that participants in both the experimental group and the control group were not deprived of sleep during the adaptation night (the first night) and that the adaptation night only allowed the participants to adapt to the new environment. TST, percent of sleep efficiency, WASO, and time in each stage including the percent of each sleep stage did not differ. N3 latency and REM latency were also not different, which also offers potential supporting evidence, because sleep in every night is affected by the sleep history of the previous night. If sleep deprivation occurs, slow wave sleep or N3 sleep stage and REM sleep stage are observed less (Hediger, 1980; Carskadon and Dement, 2005). Thus, the baseline nights of the experimental and control groups did not differ.

Sleep stages and other sleep parameters indicated that the 3-Hz binaural beat on a 250-Hz carrier tone can be potentially used to modulate sleep stage. Shortened N2 duration, extended N3 duration, and shortened N3 latency were presented after receiving the 3-Hz binaural beat on a 250-Hz carrier tone during sleep. Furthermore, the results also suggested that an auditory stimulus can be utilized to modulate sleep stage without

disturbing sleep, which is in agreement with some studies on auditory pathways and sleep (Drucker-Colin et al., 1983; Arankowsky-Sandoval et al., 1986; Vazquez et al., 1998; Amici et al., 2000) and with some studies on stimulation during sleep discussed above (Huber et al., 2007; Massimini et al., 2007; Marshall et al., 2004, 2006). Sleep disturbance can be observed by increases in N2 duration and the awake stage (Terzano et al., 1990), contrary to the results. Moreover, arousal index did not differ between experimental and control groups, so the 3-Hz binaural beat did not induce arousal during sleep. However, emotions were evaluated to subjectively identify any sleep disturbances due to receiving the 3-Hz binaural beat. Fatigue factor of BRUMS reveals exhaustion of the participants after waking up, the results indicated that all participants of did not feel any fatigue after waking up. While vigor factor reveals powerfulness, the results indicated that participants in experimental group were active and alert than control group. Therefore, the stimulus did not disturb the sleep of all participants.

In addition to sleep disturbance which had to be concerned during sleep stimulation, sleep fragmentation should be evaluated to clarify continuity of sleep stage. As the stimulation released to participants in this study, transition stage from N2 sleep stage to N3 sleep stage was kept an eye on due to auditory stimulation at N2 sleep stage. Three-Hz binaural beat can induce N3 sleep stage from N2 sleep stage but after auditory stimulation was over, sleep stage may become N2 sleep stage, so sleep fragmentation was a concerned factor. The results showed that during experimental night of experimental group and that of control group, transition stage from N2 sleep stage to N3 sleep stage did not differ. This result from survival analysis indicated that 3-Hz binaural beat did not cause sleep fragmentation.

These findings suggested that the 3-Hz binaural beat on a 250-Hz carrier tone can be used to modulate sleep stage by decreasing the latency to the N3 stage, extending the N3 duration, and reducing the N2 duration without sleep disturbance and sleep fragmentation, while increasing the quality of sleep in this study is also associated slow wave sleep in which is related to memory consolidation and other regulation of the body; and the 3-Hz binaural beat can enhance power of delta activity during sleep. Other effects should be further study, but with this novel insight, it seems to imply to several applications using the binaural beat as stimulus to modulate the brain during sleep. Surprisingly, after the experimental period had finished, some participants in the experimental group asked the researchers about the training session for sleep quality improvement, because they reported that they felt excellent after waking up; however, they had remained blinded to the fact that they were part of the experimental group.

Limitations

This study evaluated the acute effect of a binaural beat stimulus in a single night. Long-term exposure and habituation should be further investigated. The carrier tone utilized in this study was only 250 Hz, and other carrier tones should be further investigated because different brain processes are affected by different carrier tones. Another beat frequency should be used to compare effect on sleep with 3-Hz, binaural beat. Moreover, event-related potential (ERP) should be further analyzed at the time of stimulation occurs to evaluate the brain response to auditory sudden change, transition from environmental sound intensity to stimulus intensity, but the methodology should be time-fixed. Cross-over design of the experiment should be conducted to more clarify effects of the stimulus does not depend on groups of participants.

Suggested Application

One interesting application of using 3-Hz binaural beat besides induction of N3 sleep stage was investigations of long-term memory function due to exposure of 3-Hz binaural beat as training session for improvement of sleep quality. With this investigation, long-term exposure to the 3-Hz binaural beat can be observed and effect of habituation can be clarified.

CONCLUSION

A 3-Hz binaural beat on a 250-Hz carrier tone can be used to modulate neural activity by enhancement of power of delta activity; and to modulate sleep stage by decreasing N2 duration, inducing the N3 stage, and increasing N3 duration without sleep disturbance and sleep fragmentation.

AUTHOR CONTRIBUTIONS

NJ generated the protocol and conducted the experiments. YW proved and edited the protocol.

REFERENCES

Aftanas, L. I., and Golocheikine, S. A. (2001). Human anterior and frontal midline theta and lower alpha reflect emotionally positive state and internalized attention: high-resolution EEG investigation of meditation. *Neurosci. Lett.* 310, 57–60. doi: 10.1016/S0304-3940(01)02094-8

Alberini, C. M., and LeDoux, J. E. (2013). Memory reconsolidation. *Curr. Biol.* 23, R746–R750. doi: 10.1016/j.cub.2013.06.046

Amici, R., Domeniconi, R., Jones, C. A., Morales-Cobas, G., Perez, E., Tavernese, L., et al. (2000). Changes in REM sleep occurrence due to rhythmical auditory stimulation in the rat. *Brain Res.* 868, 241–250. doi: 10.1016/S0006-8993(00)02337-4

Arankowsky-Sandoval, G., Prospero-Garcia, O., Aquilar-Roblero, R., and Drucker-Colin, R. (1986). Cholinergic reduction of REM sleep duration is reverted by auditory stimulation. *Brain Res.* 375, 377–380. doi: 10.1016/0006-8993(86)90762-6

Backhaus, J., Born, J., Hoeckesfeld, R., Fokuhl, S., Hohagen, F., and Junghanns, K. (2007). Midlife decline in declarative memory consolidation is correlated with a decline in slow wave sleep. *Learn. Mem.* 14, 336–341. doi: 10.1101/lm.470507

Backhaus, J., Junghanns, K., Born, J., Hohaus, K., Faasch, F., and Hohagen, F. (2006). Impaired declarative memory consolidation during sleep in patients with primary insomnia: influence of sleep architecture and nocturnal cortisol release. *Biol. Psychiatry* 60, 1324–1330. doi: 10.1016/j.biopsych.2006.03.051

Berry, R. B., Gamaldo, C. E., Harding, S. M., Brooks, R., Lloyd, R. M., Vaughn, B. V., et al. (2015). AASM scoring manual version 2.2 updates: new chapters for scoring infant sleep staging and home sleep apnea testing. *J. Clin. Sleep Med.* 11, 1253–1254. doi: 10.5664/jcsm.5176

Besedovsky, L., Ngo, H. V., Dimitrov, S., Gassenmaier, C., Lehmann, R., and Born, J. (2017). Auditory closed-loop stimulation of EEG slow oscillations strengthens sleep and signs of its immune-supportive function. *Nat. Commun.* 8:1984. doi: 10.1038/s41467-017-02170-3

Bisaz, R., Travaglia, A., and Alberini, C. M. (2014). The neurobiological bases of memory formation: from physiological conditions to psychopathology. *Psychopathology* 47, 347–356. doi: 10.1159/000363702

Bonnet, M. H. (1986). Auditory thresholds during continuing sleep. *Biol. Psychol.* 22, 3–10. doi: 10.1016/0301-0511(86)90016-5

Buckley, T. M., and Schatzberg, A. F. (2005). On the interactions of the hypothalamic-pituitary-adrenal (HPA) axis and sleep: normal HPA axis activity and circadian rhythm, exemplary sleep disorders. *J. Clin. Endocrinol. Metab.* 90, 3106–3114. doi: 10.1210/jc.2004-1056

Buzsaki, G. (1996). The hippocampo-neocortical dialogue. *Cereb. Cortex* 6, 81–92. doi: 10.1093/cercor/6.2.81

Carskadon, M. A., and Dement, W. C. (2005). "Normal humna sleep: an overview," in *Principles and Practice of Sleep Medicine*, 4th Edn, eds M. H. Keyger, T. Roth, and W. C. Dement (Philadelphia, PA: Elsevier Saunders).

Chakalov, I., Paraskevopoulos, E., Wollbrink, A., and Pantev, C. (2014). Mismatch negativity to acoustical illusion of beat: how and where the change detection takes place? *Neuroimage* 100, 337–346. doi: 10.1016/j.neuroimage.2014.06.026

Chamberlin, N. L., Arrigoni, E., Chou, T. C., Scammell, T. E., Greene, R. W., and Saper, C. B. (2003). Effects of adenosine on gabaergic synaptic inputs to identified ventrolateral preoptic neurons. *Neuroscience* 119, 913–918. doi: 10.1016/S0306-4522(03)00246-X

Draganova, R., Ross, B., Wollbrink, A., and Pantev, C. (2008). Cortical steady-state responses to central and peripheral auditory beats. *Cereb. Cortex* 18, 1193–1200. doi: 10.1093/cercor/bhm153

Drucker-Colin, R., Bernal-Pedraza, J., Fernandez-Cancino, F., and Morrison, A. R. (1983). Increasing PGO spike density by auditory stimulation increases the duration and decreases the latency of rapid eye movement (REM) sleep. *Brain Res.* 278, 308–312. doi: 10.1016/0006-8993(83)90261-5

Frankland, P. W., and Bontempi, B. (2005). The organization of recent and remote memories. *Nat. Rev. Neurosci.* 6, 119–130. doi: 10.1038/nrn1607

Gallopin, T., Fort, P., Eggermann, E., Cauli, B., Luppi, P. H., Rossier, J., et al. (2000). Identification of sleep-promoting neurons in vitro. *Nature* 404, 992–995. doi: 10.1038/35010109

Garcia-Argibay, M., Santed, M. A., and Reales, J. M. (2017). Binaural auditory beats affect long-term memory. *Psychol. Res.* doi: 10.1007/s00426-017-0959-2 [Epub ahead of print].

Gonnissen, H. K., Hulshof, T., and Westerterp-Plantenga, M. S. (2013). Chronobiology, endocrinology, and energy- and food-reward homeostasis. *Obes. Rev.* 14, 405–416. doi: 10.1111/obr.12019

Gray, C. M. (1999). The temporal correlation hypothesis of visual feature integration: still alive and well. *Neuron* 24, 31–47. doi: 10.1016/S0896-6273(00)80820-X

Gray, C. M., and Singer, W. (1989). Stimulus-specific neuronal oscillations in orientation columns of cat visual cortex. *Proc. Natl. Acad. Sci. U.S.A.* 86, 1698–1702. doi: 10.1073/pnas.86.5.1698

Grose, J. H., and Mamo, S. K. (2012). Electrophysiological measurement of binaural beats: effects of primary tone frequency and observer age. *Ear Hear.* 33, 187–194. doi: 10.1097/AUD.0b013e318230bbbd

Havekes, R., Park, A. J., Tudor, J. C., Luczak, V. G., Hansen, R. T., Ferri, S. L., et al. (2016). Sleep deprivation causes memory deficits by negatively impacting neuronal connectivity in hippocampal area CA1. *eLife* 5:e13424. doi: 10.7554/eLife.13424

Hediger, H. (1980). The biology of natural sleep in animals. *Experientia* 36, 13–16. doi: 10.1007/BF02003943

Hirotsu, C., Tufik, S., and Andersen, M. L. (2015). Interactions between sleep, stress, and metabolism: from physiological to pathological conditions. *Sleep Sci.* 8, 143–152. doi: 10.1016/j.slsci.2015.09.002

Huber, R., Esser, S. K., Ferrarelli, F., Massimini, M., Peterson, M. J., and Tononi, G. (2007). TMS-induced cortical potentiation during wakefulness locally increases slow wave activity during sleep. *PLoS One* 2:e276. doi: 10.1371/journal.pone.0000276

Iber, C., Ancoli-Israel, S., Andrew, L., Chesson, J. R., and Stuart, F. (2007). *The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications*. Westchester, IL: American Academy of Sleep Medicine.

James, E. L., Bonsall, M. B., Hoppitt, L., Tunbridge, E. M., Geddes, J. R., Milton, A. L., et al. (2015). Computer game play reduces intrusive memories of experimental trauma via reconsolidation-update mechanisms. *Psychol. Sci.* 26, 1201–1215. doi: 10.1177/0956797615583071

Jirakittayakorn, N., and Wongsawat, Y. (2017a). Brain responses to a 6-Hz binaural beat: effects on general theta rhythm and frontal midline theta activity. *Front. Neurosci.* 11:365. doi: 10.3389/fnins.2017.00365

Jirakittayakorn, N., and Wongsawat, Y. (2017b). Brain responses to 40-Hz binaural beat and effects on emotion and memory. *Int. J. Psychophysiol.* 120, 96–107. doi: 10.1016/j.ijpsycho.2017.07.010

Karino, S., Yunoto, M., Itoh, K., Uno, A., Yamakawa, K., Sekimoto, S., et al. (2006). Neuromagnetic responses to binaural beat in human cerebral cortex. *J. Neurophysiol.* 96, 1927–1938. doi: 10.1152/jn.00859.2005

Kim, E. J., and Dimsdale, J. E. (2007). The effect of psychosocial stress on sleep: a review of polysomnographic evidence. *Behav. Sleep Med.* 5, 256–278. doi: 10.1080/15402000701557383

Kuwada, S., Yin, T. C., and Wickesberg, R. E. (1979). Response of cat inferior colliculus neurons to binaural beat stimuli: possible mechanisms for sound localization. *Science* 206, 586–588. doi: 10.1126/science.493964

Lagopoulos, J., Xu, J., Rasmussen, I., Vik, A., Malhi, G. S., Eliassen, C. F., et al. (2009). Increased theta and alpha EEG activity during nondirective meditation. *J. Altern. Complement. Med.* 15, 1187–1192. doi: 10.1089/acm.2009.0113

Lane, J. D., Kasian, S. J., Owens, J. E., and Marsh, G. R. (1998). Binaural auditory beats affect vigilance performance and mood. *Physiol. Behav.* 63, 249–252. doi: 10.1016/S0031-9384(97)00436-8

Lavallee, C. F., Koren, S. A., and Persinger, M. A. (2011). A quantitative electroencephalographic study of meditation and binaural beat entrainment. *J. Altern. Complement. Med.* 17, 351–355. doi: 10.1089/acm.2009.0691

Licklider, J. C. R., Webster, J. C., and Hediun, J. M. (1950). On the frequency limits of binaural beats. *J. Acoust. Soc. Am.* 22, 468–473. doi: 10.1121/1.1906629

Llinas, R. R., and Pare, D. (1991). Of dreaming and wakefulness. *Neuroscience* 44, 521–535. doi: 10.1016/0306-4522(91)90075-Y

Lu, J., Sherman, D., Devor, M., and Saper, C. B. (2006). A putative flip-flop switch for control of REM sleep. *Nature* 441, 589–594. doi: 10.1038/nature04767

Magezi, D. A., and Krumbholz, K. (2010). Evidence for opponent-channel coding of interaural time differences in human auditory cortex. *J. Neurophysiol.* 104, 1997–2007. doi: 10.1152/jn.00424.2009

Marshall, L., Helgaddottir, H., Molle, M., and Born, J. (2006). Boosting slow oscillations during sleep potentiates memory. *Nature* 444, 610–613. doi: 10.1038/nature05278

Marshall, L., Molle, M., Hallschmid, M., and Born, J. (2004). Transcranial direct current stimulation during sleep improves declarative memory. *J. Neurosci.* 24, 9985–9992. doi: 10.1523/JNEUROSCI.2725-04.2004

Mason, J. W. (1968). A review of psychoendocrine research on the pituitary-adrenal cortical system. *Psychosom. Med.* 30(Suppl.), 576–607. doi: 10.1097/00006842-196809000-00020

Massimini, M., Ferrarelli, F., Esser, S. K., Riedner, B. A., Huber, R., Murphy, M., et al. (2007). Triggering sleep slow waves by transcranial magnetic stimulation. *Proc. Natl. Acad. Sci. U.S.A.* 104, 8496–8501. doi: 10.1073/pnas.0702495104

McAlpine, D., Jiang, D., and Palmer, A. R. (1996). Interaural delay sensitivity and the classification of low best-frequency binaural responses in the inferior colliculus of the guinea pig. *Hear. Res.* 97, 136–152. doi: 10.1016/S0378-5955(96)80015-3

Moruzzi, G., and Magoun, H. W. (1949). Brain stem reticular formation and activation of the EEG. *Electroencephalogr. Clin. Neurophysiol.* 1, 455–473. doi: 10.1016/0013-4694(49)90219-9

Moushegian, G., Rupert, A. L., and Stillman, R. D. (1973). Laboratory note. Scalp-recorded early responses in man to frequencies in the speech range. *Electroencephalogr. Clin. Neurophysiol.* 35, 665–667. doi: 10.1016/0013-4694(73)90223-X

Neuling, T., Rach, S., and Herrmann, C. S. (2013). Orchestrating neuronal networks: sustained after-effects of transcranial alternating current stimulation depend upon brain states. *Front. Hum. Neurosci.* 7:161. doi: 10.3389/fnhum.2013.00161

Ngo, H. V., Martinetz, T., Born, J., and Molle, M. (2013). Auditory closed-loop stimulation of the sleep slow oscillation enhances memory. *Neuron* 78, 545–553. doi: 10.1016/j.neuron.2013.03.006

Oster, G. (1973). Auditory beats in the brain. *Sci. Am.* 229, 94–102. doi: 10.1038/scientificamerican1073-94

Padmanabhan, R., Hildreth, A. J., and Laws, D. (2005). A prospective, randomised, controlled study examining binaural beat audio and pre-operative anxiety in patients undergoing general anaesthesia for day case surgery. *Anaesthesia* 60, 874–877. doi: 10.1111/j.1365-2044.2005.04287.x

Panula, P., Yang, H. Y., and Costa, E. (1984). Histamine-containing neurons in the rat hypothalamus. *Proc. Natl. Acad. Sci. U.S.A.* 81, 2572–2576. doi: 10.1073/pnas.81.8.2572

Pratt, H., Starr, A., Michalewski, H. J., Dimitrijevic, A., Bleich, N., and Mittelman, N. (2009). Cortical evoked potentials to an auditory illusion: binaural beats. *Clin. Neurophysiol.* 120, 1514–1524. doi: 10.1016/j.clinph.2009.06.014

Pratt, H., Starr, A., Michalewski, H. J., Dimitrijevic, A., Bleich, N., and Mittelman, N. (2010). A comparison of auditory evoked potentials to acoustic beats and to binaural beats. *Hear. Res.* 262, 34–44. doi: 10.1016/j.heares.2010.01.013

Prince, T. M., and Abel, T. (2013). The impact of sleep loss on hippocampal function. *Learn. Mem.* 20, 558–569. doi: 10.1101/lm.031674.113

Rasch, B., Buchel, C., Gais, S., and Born, J. (2007). Odor cues during slow-wave sleep prompt declarative memory consolidation. *Science* 315, 1426–1429. doi: 10.1126/science.1138581

Reato, D., Gasca, F., Datta, A., Bikson, M., Marshall, L., and Parra, L. C. (2013). Transcranial electrical stimulation accelerates human sleep homeostasis. *PLoS Comput. Biol.* 9:e1002898. doi: 10.1371/journal.pcbi.1002898

Reedijk, S. A., Bolders, A., and Hommel, B. (2013). The impact of binaural beats on creativity. *Front. Hum. Neurosci.* 7:786. doi: 10.3389/fnhum.2013.00786

Rolls, A., Schaich Borg, J., and de Lecea, L. (2010). Sleep and metabolism: role of hypothalamic neuronal circuitry. *Best Pract. Res. Clin. Endocrinol. Metab.* 24, 817–828. doi: 10.1016/j.beem.2010.08.002

Ross, B., Miyazaki, T., Thompson, J., Jamali, S., and Fujioika, T. (2014). Human cortical responses to slow and fast binaural beats reveal multiple mechanisms of binaural hearing. *J. Neurophysiol.* 112, 1871–1884. doi: 10.1152/jn.00224.2014

Saebipour, M. R., Joghataei, M. T., Yoonessi, A., Sadeghniiat-Haghighi, K., Khalighinejad, N., and Khademi, S. (2015). Slow oscillating transcranial direct current stimulation during sleep has a sleep-stabilizing effect in chronic insomnia: a pilot study. *J. Sleep Res.* 24, 518–525. doi: 10.1111/jsr.12301

Saper, C. B., Chou, T. C., and Scammell, T. E. (2001). The sleep switch: hypothalamic control of sleep and wakefulness. *Trends Neurosci.* 24, 726–731. doi: 10.1016/S0166-2236(00)02002-6

Saper, C. B., Fuller, P. M., Pedersen, N. P., Lu, J., and Scammell, T. E. (2010). Sleep state switching. *Neuron* 68, 1023–1042. doi: 10.1016/j.neuron.2010.11.032

Saper, C. B., Scammell, T. E., and Lu, J. (2005). Hypothalamic regulation of sleep and circadian rhythms. *Nature* 437, 1257–1263. doi: 10.1038/nature04284

Schwartz, J. R. L., and Roth, T. (2008). Neurophysiology of sleep and wakefulness: basic science and clinical implications. *Curr. Neuropharmacol.* 6, 367–378. doi: 10.2174/157015908787386050

Schwarz, D. W., and Taylor, P. (2005). Human auditory steady state responses to binaural and monaural beats. *Clin. Neurophysiol.* 116, 658–668. doi: 10.1016/j.clinph.2004.09.014

Sherin, J. E., Shironmani, P. J., McCarley, R. W., and Saper, C. B. (1996). Activation of ventrolateral preoptic neurons during sleep. *Science* 271, 216–219. doi: 10.1126/science.271.5246.216

Spitzer, M. W., and Semple, M. N. (1998). Transformation of binaural response properties in the ascending auditory pathway: influence of time-varying interaural phase disparity. *J. Neurophysiol.* 80, 3062–3076. doi: 10.1152/jn.1998.80.6.3062

Sroykham, W., Wongsathikun, J., and Wongsawat, Y. (2014). The effects of perceiving color in living environment on QEEG, oxygen saturation, pulse rate, and emotion regulation in humans. *Conf. Proc. IEEE Eng. Med. Biol. Soc.* 2014, 6226–6229. doi: 10.1109/EMBC.2014.6945051

Stern, R. M., Ray, W. J., and Quigley, K. S. (2001). *Psychophysiological Recording*, 2nd Edn. New York, NY: Oxford University Press.

Swihart, B. J., Punjabi, N. M., and Crainiceanu, C. M. (2015). Modeling sleep fragmentation in sleep hypnograms: an instance of fast, scalable discrete-state, discrete-time analyses. *Comput. Stat. Data Anal.* 89, 1–11. doi: 10.1016/j.csda.2015.03.001

Szymusiak, R., Alam, N., Steininger, T. L., and McGinty, D. (1998). Sleep-waking discharge patterns of ventrolateral preoptic/anterior hypothalamic neurons in rats. *Brain Res.* 803, 178–188. doi: 10.1016/S0006-8993(98)00631-3

Takahashi, K., Lin, J. S., and Sakai, K. (2006). Neuronal activity of histaminergic tuberomammillary neurons during wake-sleep states in the mouse. *J. Neurosci.* 26, 10292–10298. doi: 10.1523/JNEUROSCI.2341-06.2006

Takahashi, T., Murata, T., Hamada, T., Omori, M., Kosaka, H., Kikuchi, M., et al. (2005). Changes in EEG and autonomic nervous activity during meditation and their association with personality traits. *Int. J. Psychophysiol.* 55, 199–207. doi: 10.1016/j.ijpsycho.2004.07.004

Takashima, A., Petersson, K. M., Rutters, F., Tendolkar, I., Jensen, O., Zwarts, M. J., et al. (2006). Declarative memory consolidation in humans: a prospective functional magnetic resonance imaging study. *Proc. Natl. Acad. Sci. U.S.A.* 103, 756–761. doi: 10.1073/pnas.0507774103

Terzano, M. G., Parrino, L., Floriti, G., Orofiamma, B., and Depoortere, H. (1990). Modifications of sleep structure induced by increasing levels of acoustic perturbation in normal subjects. *Electroencephalogr. Clin. Neurophysiol.* 76, 29–38. doi: 10.1016/0013-4694(90)90055-O

Vanderwolf, C. H. (2000). Are neocortical gamma waves related to consciousness? *Brain Res.* 855, 217–224.

Vazquez, J., Merchant-Nancy, H., Garcia, F., and Drucker-Colin, R. (1998). The effects of sensory stimulation on REM sleep duration. *Sleep* 21, 138–142. doi: 10.1093/sleep/21.2.138

Velluti, R. A. (1997). Interactions between sleep and sensory physiology. *J. Sleep Res.* 6, 61–77. doi: 10.1046/j.1365-2869.1997.00031.x

Wahbeh, H., Calabrese, C., Zwickey, H., and Zajdel, D. (2007). Binaural beat technology in humans: a pilot study to assess neuropsychologic, physiologic, and electroencephalographic effects. *J. Altern. Complement. Med.* 13, 199–206. doi: 10.1089/acm.2006.6201

Walker, M. P. (2009a). The role of slow wave sleep in memory processing. *J. Clin. Sleep Med.* 5(Suppl. 2), S20–S26.

Walker, M. P. (2009b). The role of sleep in cognition and emotion. *Ann. N. Y. Acad. Sci.* 1156, 168–197. doi: 10.1111/j.1749-6632.2009.04416.x

Walker, M. P., and Stickgold, R. (2006). Sleep, memory, and plasticity. *Annu. Rev. Psychol.* 57, 139–166. doi: 10.1146/annurev.psych.56.091103.070307

Williams, H. L., Hammack, J. T., Daly, R. L., Dement, W. C., and Lubin, A. (1964). Responses to auditory stimulation, sleep loss and the EEG stages of sleep. *Electroencephalogr. Clin. Neurophysiol.* 16, 269–279. doi: 10.1016/0013-4694(64)90109-9

Wiltgen, B. J., Brown, R. A., Talton, L. E., and Silva, A. J. (2004). New circuits for old memories: the role of the neocortex in consolidation. *Neuron* 44, 101–108. doi: 10.1016/j.neuron.2004.09.015

Worden, F. G., and Marsh, J. T. (1968). Frequency-following (microphonic-like) neural responses evoked by sound. *Electroencephalogr. Clin. Neurophysiol.* 25, 42–52. doi: 10.1016/0013-4694(68)90085-0

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Human Neuroscience

PERSPECTIVE
published: 04 October 2018
doi: 10.3389/fnhum.2018.00346

Is Our Self Related to Personality? A Neuropsychodynamic Model

Andrea Scalabrini[1]*, *Clara Mucci*[1] and *Georg Northoff*[2,3,4,5,6]

[1]Department of Psychological, Health and Territorial Sciences (DiSPuTer), G. d'Annunzio University of Chieti-Pescara, Chieti, Italy, [2]University of Ottawa Institute of Mental Health Research and University of Ottawa Brain and Mind Research Institute, Ottawa, ON, Canada, [3]Mental Health Centre, Zhejiang University School of Medicine, Hangzhou, China, [4]Centre for Cognition and Brain Disorders, Hangzhou Normal University, Hangzhou, China, [5]TMU Research Centre for Brain and Consciousness, Shuang Ho Hospital, Taipei Medical University, Taipei, Taiwan, [6]Graduate Institute of Humanities in Medicine, Taipei Medical University, Taipei, Taiwan

The concept and the assessment of personality have been extensively discussed in psychoanalysis and in clinical psychology over the years. Nowadays there is large consensus in considering the constructs of the self and relatedness as central criterions to assess the personality and its disturbances. However, the relation between the psychological organization of personality, the construct of the self, and its neuronal correlates remain unclear. Based on the recent empirical data on the neural correlates of the self (and others), on the importance of early relational and attachment experiences, and on the relation with the brain's spontaneous/resting state activity (rest–self overlap/containment), we propose here a multilayered model of the self with: (i) relational alignment; (ii) self-constitution; (iii) self-manifestation; and (iv) self-expansion. Importantly, these different layers of the self can be characterized by different neuronal correlates—this results in different neuronally grounded configurations or organizations of personality. These layers correspond to different levels of personality organization, such as psychotic (as related to the layer of self-constitution), borderline (as related to the layer of self-manifestation) and neurotic (as related to the layer of self-expansion). Taken together, we provide here for the first time a neurobiologically and clinically grounded model of personality organization, which carries major psychodynamic and neuroscientific implications. The study of the spontaneous activity of the brain, intrinsically related to the self (rest–self overlap/containment) and the interaction with stimuli (rest–stimulus interaction) may represent a further advance in understanding how our *default* state plays a crucial role in navigating through the internal world and the external reality.

Keywords: neuroscience, psychoanalysis, self-relatedness, resting state fMRI, personality organization, rest-self overlap/containment

OPEN ACCESS

Edited by:
Felix Blankenburg,
Freie Universität Berlin, Germany

Reviewed by:
Irene Messina,
Università degli Studi di Padova, Italy
Adriano Schimmenti,
Kore University of Enna, Italy

***Correspondence:**
Andrea Scalabrini
andrea.scalabrini@unich.it

Received: *24 April 2018*
Accepted: *13 August 2018*
Published: *04 October 2018*

Citation:
Scalabrini A, Mucci C and Northoff G (2018) Is Our Self Related to Personality? A Neuropsychodynamic Model. Front. Hum. Neurosci. 12:346. doi: 10.3389/fnhum.2018.00346

INTRODUCTION: SELF-OTHER ORGANIZATION OF PERSONALITY

Personality can be considered as a dimension or a continuum from healthy features, characterized by a coherent sense of the self and identity, engagements in satisfying relationships, relatively flexible functioning when stressed by external events or internal conflicts, appropriate expression of impulses and emotions, internalized moral values and maladaptive features. These are characterized by identity diffusion and incoherent sense of the self, problems in self-other

differentiation and relatedness, lack or transient loss in reality testing, problems in affect and impulse regulation, mentalization and attention and inflexibility and rigidity in several domains (Kernberg and Caligor, 2005; Bateman and Fonagy, 2010; Kernberg, 2016; Lingiardi and McWilliams, 2017).

Historically several authors tried to classify patients who did not reach the criteria to be placed either in neurotic or in psychotic diagnosis (e.g., Knight, 1953). However, it was only in 1967 that Kernberg (1967) proposed a broader concept of Borderline personality organization (BPO), which included the evaluation of the identity (see also Erikson, 1968), of defense mechanisms and reality testing, as closely associated with the continuity and coherence of the sense of self and significant others. Kohut (1971) conceptualized how a failure in the development of a cohesive sense of the self, depending from the interaction with the environment, leads to a fragmentation of the body, self, mind and the self-object. Recently, several authors, departing from the background of the attachment theory (Schore, 2000, 2001, 2012; Lyons-Ruth, 2003, 2008; Fonagy et al., 2007; Mucci, 2013, 2017; Beebe and Lachmann, 2014), proposed that the parent-infant dyad can be considered as the first intersubjective encounter that predisposes the development of the self and emphasized how the dual caregiver–infant exchange continuously modulates the formation of the growing subject, organizing the mind-body-brain interoceptive and exteroceptive connections in relation to the other.

Nowadays there are empirical evidences postulating that the degree of impairments in levels of self-definition and interpersonal relations are core features in defining the personality disorders (see Bender et al., 2011; Morey et al., 2011; DSM-5, American Psychiatric Association, 2013). The intrapsychic structure of the self–other personality organization is based on a neurobiological one (Kernberg, 2015).

NEUROSCIENTIFIC CORRELATES OF THE SELF AND ITS RELATION WITH THE BRAIN'S SPONTANEOUS/RESTING STATE ACTIVITY

The self has been investigated extensively in neuroscience and has been related to a cerebral network also recruited during the resting state, the other's mind-reading, autobiographical memory, enhanced perception and embodied simulation (Metzinger and Gallese, 2003; Wicker et al., 2003; Gillihan and Farah, 2005; Northoff et al., 2006; Legrand and Ruby, 2009; Sui and Humphreys, 2015).

Among others, authors such as Northoff (Northoff and Bermpohl, 2004; Northoff et al., 2006; Northoff and Panksepp, 2008; Damasio, 2010, 2012; Panksepp and Biven, 2012) emphasized the existence of a complex, distributed and functionally based system of the self. The core self (Panksepp, 1998a,b) is considered as a trans-species functional entity based on subcortical midline structures (SCMS), in a mutually regulating process with the higher CMS, a more complex, reflective and conscious self-distributed sytem. This system allows the linking of the external events to the internal (motivational and emotional) impulses of the organism (Panksepp and Biven, 2012).

In addition to CMS and SCMS, a right lateralized frontoparietal network, including lateral somatosensory cortices overlapping with the distribution of mirror neuron areas, is also involved in self-recognition, self-awareness, social understanding and embodied simulation, i.e., in the re-enactment of sensory and motor experiences, empathy, mentalizing and symbolic activity (Gallese, 2007; Rizzolatti and Sinigaglia, 2008; Iacoboni, 2009; Keysers et al., 2010; Panksepp and Biven, 2012; Cozolino, 2014; Siegel, 2015).

Self-processing has been operationalized in many experimental studies in terms of self-relatedness (SR, Northoff, 2016a) and has been associated with the basic functions such as perception (Sui et al., 2012, 2013), action (Frings and Wentura, 2014), reward (de Greck et al., 2008) and emotions (Phan et al., 2004; Northoff et al., 2009).

Intriguingly, CMS, a core part of the Default Mode Network (DMN; Raichle et al., 2001; Buckner et al., 2008), has been associated with SR not only during the stimulus-induced states but also during the resting state characterized by spontaneous thought (Gusnard and Raichle, 2001; Zhu, 2004; D'Argembeau et al., 2005; Moran et al., 2006; Schneider et al., 2008; Enzi et al., 2009; Northoff et al., 2010; Whitfield-Gabrieli et al., 2011; Hu et al., 2016).

Therefore, the "rest-self overlap" concept (Bai et al., 2016; Northoff, 2016a) has been introduced to describe the convergence in anterior and posterior CMS (Qin and Northoff, 2011; Murray et al., 2015; Davey et al., 2016) between the self and the brain's spontaneous (or resting state) activity.

Based on these findings one may hypothesize that the spontaneous activity of the brain may contain some specific information related to the self, serving to process and assign contents to the subsequent internal or external stimuli. Therefore, one may conceptualize a "rest-self overlap/containment" (Huang et al., 2016, 2017; Northoff, 2016a), where the self-specific information, not only overlap with the resting state, but are contained in the spontaneous activity and may provide the basis for the assignment of contents as processed in affective, cognitive, social and sensorimotor functions.

EARLY RELATIONAL EXPERIENCES, ATTACHMENT AND THE DEVELOPMENT OF THE SELF FROM THE OTHER

Early relational experiences and attachment play a fundamental role in shaping the sense of self, the sense of relatedness, and the capacities to regulate emotions and to mentalize, leading to what Bowlby (1969) has defined as internal working models (IWM). The relational internalization of benign or adverse interpersonal experiences is enabled by the human capacity for intersubjectivity, attunement and empathy, which are present from birth (Stern, 1985; Meltzoff and Brooks, 2001; Trevarthen, 2001; Meltzoff and Decety, 2003; Tronick, 2007).

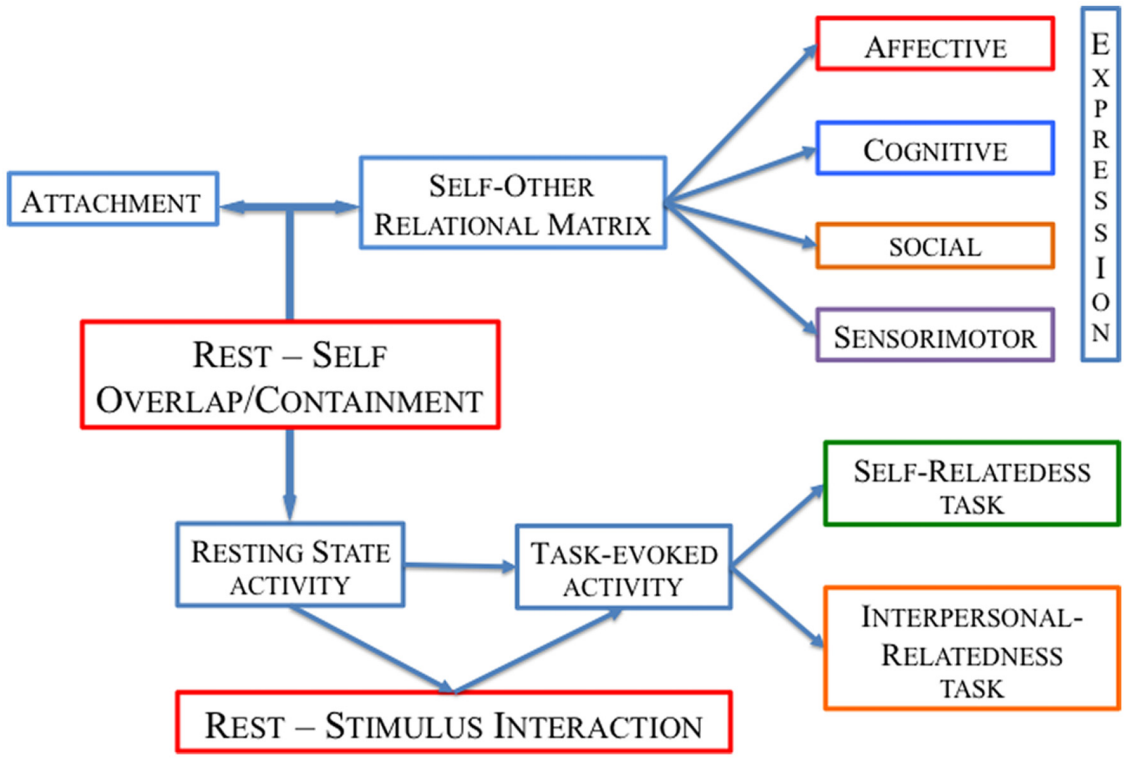


FIGURE 1 | Schematic illustration for the study of the "Brain, Self and Personality": the *Rest-Self overlap/containment* and *Rest-Stimulus interaction* model.

Traumatic experiences, particularly attachment trauma and early relational adverse experiences, not only foster dissociation and psychopathology (Schimmenti, 2017) creating a vertical disconnection in the mind-brain-body system but also elicit the impulsivity, lack of effortful control, emotional dysregulation and use of immature defenses that are characteristics of self-other pathologies (see alternative model of personality disorders, DSM-5, 2013), such as BPO or maladaptive personality pathologies in general (Mucci, 2016, 2018; Granieri et al., 2017, 2018).

The enduring effect of early traumatization does not allow the connection between the limbic areas and superior orbito-frontal areas (Schore, 2000, 2001, 2003, 2012) creating the dysfunctions typical of personality pathologies, characterized by long-term abuse and dysfunctional families (Felitti et al., 1998; Mucci, 2013; Schimmenti and Caretti, 2016; Liotti, 2017; Scalabrini et al., 2017a).

Decety and Sommerville (2003) proposed how the distinct cognitive representations of self and others are related to self–other processing in the brain and how the right hemisphere plays a predominant role in the way that the self is connected to the other. In this regard, Schore has suggested that early relational trauma between mother and child alters the development of the right brain (Schore, 2001).

The early growth and maturation of brain regions involved in self and social development (Pfeifer and Peake, 2012) is experience-dependent and requires nurturing self-other interactions in the context of attachment for developing the capacity to regulate cognitive and emotional states (Messina et al., 2016b). For instance, a recent study (Brauer et al., 2016) indicated how 5-year old children exposed to higher maternal touch experiences show additional regional connectivity within the right dorso-medial prefrontal cortex and may benefit in terms of "social brain development." In contrast, when an individual is denied these positive experiences, serious failures of self-development occur (Schore, 2005; Messina et al., 2016a; Mucci, 2016, 2018).

Recently, several studies investigated the neurobiology of attachment in animals (Insel and Young, 2001) and humans using functional magnetic resonance imaging (fMRI; Lorberbaum et al., 2002; Bartels and Zeki, 2004; Swain et al., 2007; Strathearn et al., 2008; Laurita et al., 2017, 2018). These studies showed how the regions prevalently located in the CMS and limbic areas are fundamentally involved in the context of attachment and have an impact on self-other related functions. Other studies investigated the neural correlates of attachment trauma, as in the case of borderline personality disorder (e.g., Buchheim et al., 2008).

Departing from this background, if attachment influences the development of the self, the constitution, and the differentiation of the self and others and is considered closely linked to SR processing (Brockman, 2002; Northoff, 2011), we may expect an impact on the spontaneous/resting state activity of the brain, as suggested by a study showing a relation between increased measures of individual negative childhood experiences and a more entropic neuronal activity

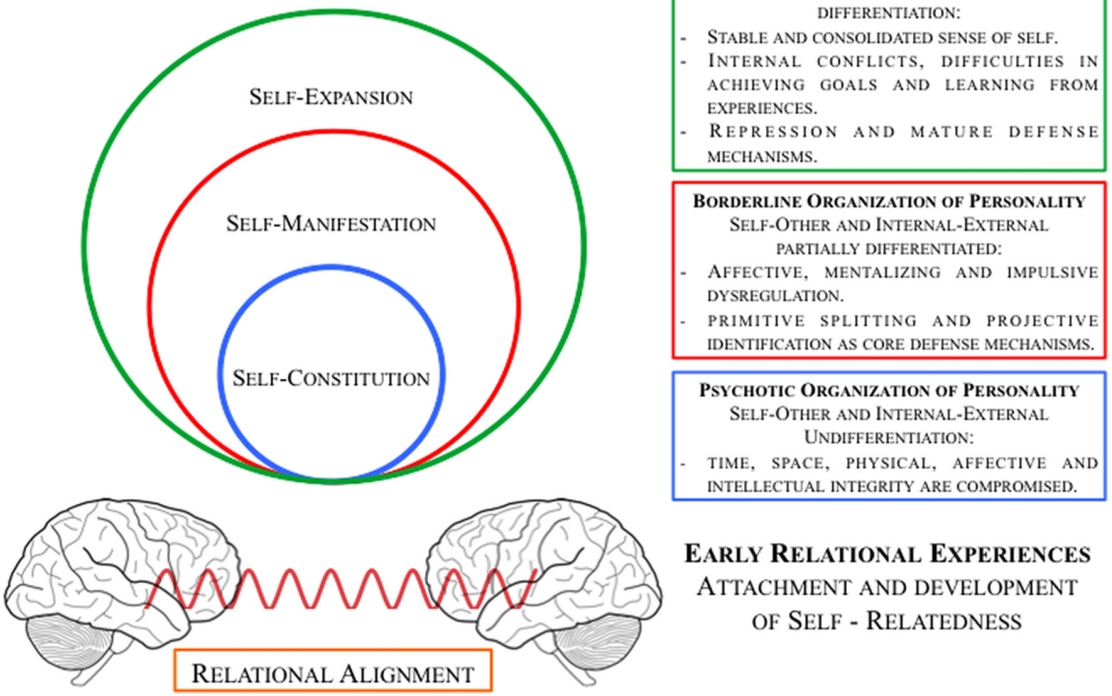


FIGURE 2 | Schematic illustration of intrinsic neuronal and intrapsychic organization of self and personality: association of different *Rest-Self states* and *levels of personality organizations*.

in medial prefrontal cortex during rest (Duncan et al., 2015; see **Figure 1**). Moreover, research on the resting state fMRI showed that emotional processing of attachment-related content induces carryover effects and alters the brain network configurations at rest (Krause et al., 2016, 2018; Borchardt et al., 2018).

NEUROPSYCHODYNAMIC MODEL OF SELF AND PERSONALITY ORGANIZATION

Given the role of the experience-dependent (or attachment-dependent) rest-self overlap/containment, we hypothesize that self-specific information of individuals, and their personality features, may be present in the resting state activity and may shape task-evoked activity.

In summary, the study of personality needs to consider the so-called rest-stimulus interaction (Northoff et al., 2010) as a way to conceive how the brain's intrinsic activity encodes self-specific information of the past and (possible) future input-output relationship (Northoff, 2016a).

In this context, we propose a novel conceptualization that aims to link the rest-self states and personality organization (see **Figure 2**).

In our view, different and interconnected states of the self are embedded in the intrinsic activity of the brain that predisposes the construction of subjectivity and consciousness (Northoff, 2017).

First, we propose that *Relational Alignment* is a prerequisite that gives the framework for the construction of the *Self*, a sort of neuro-ecological continuum between the brain and the external world. It is given by the first relational encounter with a caregiver and his/her capacity to attune with the mind-brain of the infant. The infant's brain, if facilitated by a secure environment, starts becoming a part of the world's time and space by the relational alignment with the temporo-spatial structure of the animate and inanimate reality (Schore, 2000, 2001; Trevarthen and Aitken, 2001; Pfeifer and Peake, 2012; Northoff, 2017). This predisposes the constitution and the development of the *Self*.

Self-Constitution represents the building blocks of the consciousness processing—it includes the construction (rather than perception) of both time and space. It is linked with the ownership of one's own body, location of self in space, authorship and control of one's own actions, and difference between fantasy and reality. It is linked with the capacity to distinguish the self from the non-self and internal from external. Thus, it is strongly connected with reality testing and it is the self-state that distinguishes the psychotic organization of personality from the others.

Self-Manifestation represents the actual consciousness in the present moment—it includes the experience of time and space, the perception of the environment, the affective and motivatinal system, the identification with social reality and cognitive functions such as thinking, imagining and mentalizing. It is particularly linked to the degree of integration of the self

and the significant others. When the manifestation of the self oscillates between incoherent and/or disaggregated self-states we are navigating in the field of borderline and/or (early) trauma related pathologies.

Self-Expansion is linked with the stable and integrated aspects of the self in time and space: (a) autobiographical self, (b) social self, (c) linguistic self, and (d) mental self. It refers to the capacity to inhibit behaviors and to tolerate the ambivalence of the affects considering the past, present and future. The higher the capacity to self-expand and bind information in perception and memory (Sui and Humphreys, 2015), the higher the integration of various aspects of the self and others. A difficulty in self-expansion may be related to a difficulty in elaborating an external stimulus or an internal conflict as in neuroticism.

How are these different states of the self linked to the intra-psychic structure of individuals?

Since the brain's intrinsic activity can be characterized by an individualized temporo-spatial structure, we suppose that all contents (whether affective, cognitive, social, or sensorimotor) and their underlying extrinsic activity must first and foremost be integrated within the brain's spontaneous (internal) activity. The degree and the way the contents and their activities are integrated into the brain's spontaneous activity determine how we perceive them and hence how we experience them, i.e., our subjective or self-conscious experience of reality (Northoff, 2016a,b,c; Northoff and Huang, 2017).

Psychotic personality organization (PPO) on a psychological level is characterized by identity diffusion, primitive defense mechanism, and loss of reality testing. On a neurobiological level we may find disturbances at a level of Self-Constitution, a disruption in the global organization of the brain's intrinsic activity (Northoff, 2015).

The whole topography over all the networks and frequency ranges are disrupted (Rotarska-Jagiela et al., 2010; Shim et al., 2010; Khadka et al., 2013) and, for instance, the usual negative correlation between the DMN and the Control Executive Network (CEN), that are usually characterized by anticorrelation, are in psychosis transformed into a positive correlation which in turn may lead to the breakdown of the rest-self overlap where there is a self-assignment to either internal or external stimuli (Carhart-Harris et al., 2012, 2013).

In this case there is no possibility to differentiate the internal world from the external reality. The relationship from the CMS and the somatosensory network is altered, ending up in a lack of differentiation in processing the intrinsic and extrinsic stimuli (Ebisch and Aleman, 2016; Northoff and Duncan, 2016), which results in identity diffusion or fragmentation of Self-constitution. We may hypothesize that this psychotic organization shows severe impairments at a pre-phenomenal level of experience on the spatiotemporal structure of the brain's intrinsic activity (Northoff, 2016b,c).

BPO is characterized by intact reality testing, primitive defense mechanism based on splitting and projective identification and identity diffusion. At a neurobiological level we hypothesize that the whole brain topography and organization between the networks are partially preserved but the balance between them consequently shows abnormalities, as in the case of bipolar disorder (Magioncalda et al., 2015; Martino et al., 2016), and that the subsequent relation with the external stimuli may be impaired. Indeed, a recent meta-analysis (Visintin et al., 2016) shows increased activity in the regions spanning across the midline core of DMN in patients with borderline personality disorder during the resting state, which may imply difficulties in self-referential, social and emotional processing (Van Overwalle, 2009; Etkin et al., 2011).

We may find abnormalities in the rest-stimulus interaction (e.g., in narcissistic personality features; Scalabrini et al., 2017b) and lack of integration in the brain's self-other networks (Herpertz et al., 2018): for example, in borderline personality disorders we can observe alterations in the orbitofrontal cortex and the connected subcortical regions (Minzenberg et al., 2007; Koenigsberg et al., 2009; Enzi et al., 2013). Moreover, other studies have described the functional neuroanatomy of borderline disorders that are associated with the hypersensitivity, intolerance for aloneness, and attachment fears typical of patients in this broad diagnostic group (Buchheim et al., 2008; King-Casas et al., 2008; Fertuck et al., 2009; Dziobek et al., 2011).

We may hypothesize that individuals with BPO show severe impairments at a pre-reflective level of experience, at a Self-manifestation state, where the implicit encoded information (Mucci, 2016) about the experiences of self, body, and others are related to the spatiotemporal structure of the brain's intrinsic activity.

Neurotic personality organization (NPO) is characterized by intact reality testing, mature defense mechanism based on repression, and integrated sense of self and identity. In NPO we may find impairments at the Self-Expansion state, where at a neurobiological level we hypothesize that the whole brain's topography, organization between networks and balance between them are preserved but their coherence is not given for granted. We may expect to find a decreased coherence within the networks and decreased cross-frequency coupling while the spatiotemporal structure by itself is well integrated. In detail, we hypothesize that the measures such as functional connectivity provide no information on the intrinsic neuronal activity (Lu and Stein, 2014; Raichle, 2015), while the measures such as regional of homogeneity (ReHo), low frequency oscillation (LFO), and measures of complexity (e.g., Power Law exponent, H-Hurst) are more related to the intrinsic local brain activity, so that they may be more fine-grained to detect the trait-features of personality, as in the case of neuroticism. Studies investigating neuroticism in the resting state fMRI found that the ReHo in the prefrontal cortex was negatively modulated by the neurotic personality features (Wei et al., 2011; Gentili et al., 2017), thereby supporting the hypothesis of neurotic DMN alterations in the resting state analysis, as well as during task (Wei et al., 2011, 2016; Forbes et al., 2014; Sampaio et al., 2014; Tzschoppe et al., 2014).

Thus, NPO individuals have difficulty to expand and finalize their selves over time because of their internal conflicts. We may hypothesize that a certain incoherence in the brain functioning is related to the difficulty of these individuals in processing certain contents at the reflective level of the experience (explicit

experience of cognitive, affective, social and sensorimotor functions).

CONCLUSION

Neuroscience has considerably advanced in revealing the neural correlates of the self, which are closely related to the cortical midline structure and their spontaneous activity. However, the relationship of self to its personality, as discussed in psychoanalysis and psychiatry, still remains to be further elucidated. The present article is a first attempt to bridge this gap. Based on the recent findings, we propose here a multi-layered neuronally-based model of the self with: (i) relational alignment; (ii) self-constitution; (iii) self-manifestation; and (iv) self-expansion. We suggest that these layers of self correspond to the different levels of personality organization including psychotic, borderline and neurotic. These levels can be distinguished from each other through their neuronal and defense mechanisms.

This amounts to a novel neuropsychodynamic model of personality organization that bridges the gap between self, as dealt with in neuroscience and psychology, and personality as conceptualized in psychoanalysis.

Our perspective opens not only novel doors to our understanding of the personality and its alterations but also novel forms of therapeutic intervention, due to the neuronal basis in spontaneous activity of the brain. Therapeutic interventions need to achieve, first and foremost, a relational alignment between the therapist and the patient in order to lead the self to expand and be more connected to the internal world and external reality.

AUTHOR CONTRIBUTIONS

AS, CM and GN wrote the article.

FUNDING

This work was supported by the Department of Psychological, Health and Territorial Sciences (DiSPuTer); by the Canadian Institute of Health Research, Michael Smith Foundation, EJLB-Canadian Institute of Health Research, Canada Research Chair to G. Northoff; by the National Natural Science Foundation of China (No. 31271195); by the grant from the Ministry of Science and Technology of China, National Key R&D Program of China (2016YFC1306700).

REFERENCES

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders (DSM-5®).* Washington, DC: American Psychiatric Association.

Bai, Y., Nakao, T., Xu, J., Qin, P., Chaves, P., Heinzel, A., et al. (2016). Resting state glutamate predicts elevated pre-stimulus α during self-relatedness: a combined EEG-MRS study on "rest-self overlap". *Soc. Neurosci.* 11, 249–263. doi: 10.1080/17470919.2015.1072582

Bartels, A., and Zeki, S. (2004). The neural correlates of maternal and romantic love. *Neuroimage* 21, 1155–1166. doi: 10.1016/j.neuroimage.2003.11.003

Bateman, A., and Fonagy, P. (2010). Mentalization based treatment for borderline personality disorder. *World Psychiatry* 9, 11–15. doi: 10.1002/j.2051-5545.2010.tb00255.x

Beebe, B., and Lachmann, F. M. (2014). *The Origins of Attachment: Infant Research and Adult Treatment.* New York, NY: Routledge.

Bender, D. S., Morey, L. C., and Skodol, A. E. (2011). Toward a model for assessing level of personality functioning in DSM-5, Part I: a review of theory and methods. *J. Pers. Assess.* 93, 332–346. doi: 10.1080/00223891.2011.583808

Borchardt, V., Surova, G., van der Meer, J., Bola, M., Frommer, J., Leutritz, A. L., et al. (2018). Exposure to attachment narratives dynamically modulates cortical arousal during the resting state in the listener. *Brain Behav.* 8:e01007. doi: 10.1002/brb3.1007

Bowlby, J. (1969). *Attachment and Loss, Vol.1: Attachment.* New York, NY: Basic Books.

Brauer, J., Xiao, Y., Poulain, T., Friederici, A. D., and Schirmer, A. (2016). Frequency of maternal touch predicts resting activity and connectivity of the developing social brain. *Cereb. Cortex* 26, 3544–3552. doi: 10.1093/cercor/bhw137

Brockman, R. (2002). Self, object, neurobiology. *Neuropsychoanalysis* 4, 89–101. doi: 10.1080/15294145.2002.10773382

Buchheim, A., Erk, S., George, C., Kächele, H., Kircher, T., Martius, P., et al. (2008). Neural correlates of attachment trauma in borderline personality disorder: a functional magnetic resonance imaging study. *Psychiatry Res.* 163, 223–235. doi: 10.1016/j.pscychresns.2007.07.001

Buckner, R. L., Andrews-Hanna, J. R., and Schacter, D. L. (2008). The brain's default network. *Ann. N Y Acad. Sci.* 1124, 1–38. doi: 10.1196/annals.1440.011

Carhart-Harris, R. L., Brugger, S., Nutt, D. J., and Stone, J. M. (2013). Psychiatry's next top model: cause for a re-think on drug models of psychosis and other psychiatric disorders. *J. Psychopharmacol.* 27, 771–778. doi: 10.1177/0269881113494107

Carhart-Harris, R. L., Leech, R., Erritzoe, D., Williams, T. M., Stone, J. M., Evans, J., et al. (2012). Functional connectivity measures after psilocybin inform a novel hypothesis of early psychosis. *Schizophr. Bull.* 39, 1343–1351. doi: 10.1093/schbul/sbs117

Cozolino, L. (2014). *The Neuroscience of Human Relationships: Attachment and the Developing Social Brain.* 2nd Edn. New York, NY: W.W. Norton & Company.

Damasio, A. R. (2010). *Self Comes to Mind: Constructing the Conscious Brain.* New York, NY: Random House.

Damasio, A. R. (2012). Neuroscience and psychoanalysis: a natural alliance. *Psychoanal. Rev.* 99, 591–594. doi: 10.1521/prev.2012.99.4.591

D'Argembeau, A., Collette, F., Van der Linden, M., Laureys, S., Del Fiore, G., Degueldre, C., et al. (2005). Self-referential reflective activity and its relationship with rest: a PET study. *Neuroimage* 25, 616–624. doi: 10.1016/j.neuroimage.2004.11.048

Davey, C. G., Pujol, J., and Harrison, B. J. (2016). Mapping the self in the brain's default mode network. *Neuroimage* 132, 390–397. doi: 10.1016/j.neuroimage.2016.02.022

de Greck, M., Rotte, M., Paus, R., Moritz, D., Thiemann, R., Proesch, U., et al. (2008). Is our self based on reward? Self-relatedness recruits neural activity in the reward system. *Neuroimage* 39, 2066–2075. doi: 10.1016/j.neuroimage.2007.11.006

Decety, J., and Sommerville, J. A. (2003). Shared representations between self and other: a social cognitive neuroscience view. *Trends Cogn. Sci.* 7, 527–533. doi: 10.1016/j.tics.2003.10.004

Duncan, N. W., Hayes, D. J., Wiebking, C., Tiret, B., Pietruska, K., Chen, D. Q., et al. (2015). Negative childhood experiences alter a prefrontal-insular-motor cortical network in healthy adults: a preliminary multimodal rsfMRI-fMRI-MRS-dMRI study. *Hum. Brain Mapp.* 36, 4622–4637. doi: 10.1002/hbm.22941

Dziobek, I., Preißler, S., Grozdanovic, Z., Heuser, I., Heekeren, H. R., and Roepke, S. (2011). Neuronal correlates of altered empathy and social cognition in borderline personality disorder. *Neuroimage* 57, 539–548. doi: 10.1016/j.neuroimage.2011.05.005

Ebisch, S. J., and Aleman, A. (2016). The fragmented self: imbalance between intrinsic and extrinsic self-networks in psychotic disorders. *Lancet Psychiatry* 3, 784–790. doi: 10.1016/s2215-0366(16)00045-6

Enzi, B., De Greck, M., Pröesch, U., Tempelmann, C., and Northoff, G. (2009). Is our self nothing but reward? Neuronal overlap and distinction between

reward and personal relevance and its relation to human personality. *PLoS One* 4:e8429. doi: 10.1371/journal.pone.0008429

Enzi, B., Doering, S., Faber, C., Hinrichs, J., Bahmer, J., and Northoff, G. (2013). Reduced deactivation in reward circuitry and midline structures during emotion processing in borderline personality disorder. *World J. Biol. Psychiatry* 14, 45–56. doi: 10.3109/15622975.2011.579162

Erikson, E. H. (1968). Psychoanalysis and theories of man. (Book reviews: identity: youth and crisis; Childhood and society (1950). *Science* 161, 257–258.

Etkin, A., Egner, T., and Kalisch, R. (2011). Emotional processing in anterior cingulate and medial prefrontal cortex. *Trends Cogn. Sci.* 15, 85–93. doi: 10.1016/j.tics.2010.11.004

Felitti, V. J., Anda, R. F., Nordenberg, D., Williamson, D. F., Spitz, A. M., Edwards, V., et al. (1998). Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: the Adverse Childhood Experiences (ACE) Study. *Am. J. Prev. Med.* 14, 245–258. doi: 10.1016/S0749-3797(98)00017-8

Fertuck, E. A., Jekal, A., Song, I., Wyman, B., Morris, M. C., Wilson, S. T., et al. (2009). Enhanced 'reading the mind in the eyes' in borderline personality disorder compared to healthy controls. *Psychol. Med.* 39, 1979–1988. doi: 10.1017/S003329170900600X

Fonagy, P., Gergely, G., and Target, M. (2007). The parent-infant dyad and the construction of the subjective self. *J. Child Psychol. Psychiatry* 48, 288–328. doi: 10.1111/j.1469-7610.2007.01727.x

Forbes, C. E., Poore, J. C., Krueger, F., Barbey, A. K., Solomon, J., and Grafman, J. (2014). The role of executive function and the dorsolateral prefrontal cortex in the expression of neuroticism and conscientiousness. *Soc. Neurosci.* 9, 139–151. doi: 10.1080/17470919.2013.871333

Frings, C., and Wentura, D. (2014). Self-priorization processes in action and perception. *J. Exp. Psychol. Hum. Percept. Perform.* 40, 1737–1740. doi: 10.1037/a0037376

Gallese, V. (2007). Before and below 'theory of mind': embodied simulation and the neural correlates of social cognition. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 362, 659–669. doi: 10.1098/rstb.2006.2002

Gentili, C., Cristea, I. A., Ricciardi, E., Vanello, N., Popita, C., David, D., et al. (2017). Not in one metric: neuroticism modulates different resting state metrics within distinctive brain regions. *Behav. Brain Res.* 327, 34–43. doi: 10.1016/j.bbr.2017.03.031

Gillihan, S. J., and Farah, M. J. (2005). Is self special? A critical review of evidence from experimental psychology and cognitive neuroscience. *Psychol. Bull.* 131, 76–97. doi: 10.1037/0033-2909.131.1.76

Granieri, A., Guglielmucci, F., Costanzo, A., Caretti, V., and Schimmenti, A. (2018). Trauma-related dissociation is linked with maladaptive personality functioning. *Front. Psychiatry* 9:206. doi: 10.3389/fpsyt.2018.00206

Granieri, A., La Marca, L., Mannino, G., Giunta, S., Guglielmucci, F., and Schimmenti, A. (2017). The relationship between defense patterns and DSM-5 maladaptive personality domains. *Front. Psychol.* 8:1926. doi: 10.3389/fpsyg.2017.01926

Gusnard, D. A., and Raichle, M. E. (2001). Searching for a baseline: functional imaging and the resting human brain. *Nat. Rev. Neurosci.* 2, 685–694. doi: 10.1038/35094500

Herpertz, S. C., Bertsch, K., and Jeung, H. (2018). Neurobiology of criterion a: self and interpersonal personality functioning. *Curr. Opin. Psychol.* 21, 23–27. doi: 10.1016/j.copsyc.2017.08.032

Hu, C., Di, X., Eickhoff, S. B., Zhang, M., Peng, K., Guo, H., et al. (2016). Distinct and common aspects of physical and psychological self-representation in the brain: a meta-analysis of self-bias in facial and self-referential judgements. *Neurosci. Biobehav. Rev.* 61, 197–207. doi: 10.1016/j.neubiorev.2015.12.003

Huang, Z., Obara, N., Davis, H. H. IV., Pokorny, J., and Northoff, G. (2016). The temporal structure of resting-state brain activity in the medial prefrontal cortex predicts self-consciousness. *Neuropsychologia* 82, 161–170. doi: 10.1016/j.neuropsychologia.2016.01.025

Huang, Z., Zhang, J., Longtin, A., Dumont, G., Duncan, N. W., Pokorny, J., et al. (2017). Is there a nonadditive interaction between spontaneous and evoked activity? Phase-dependence and its relation to the temporal structure of scale-free brain activity. *Cereb. Cortex* 27, 1037–1059. doi: 10.1093/cercor/bhv288

Iacoboni, M. (2009). *Mirroring People: The New Science of How we Connect with Others.* New York, NY: Macmillan.

Insel, T. R., and Young, L. J. (2001). The neurobiology of attachment. *Nat. Rev. Neurosci.* 2, 129–136. doi: 10.1038/35053579

Kernberg, O. F. (1967). Borderline personality organization. *J. Am. Psychoanal. Assoc.* 15, 641–685. doi: 10.1177/000306516701500309

Kernberg, O. F. (2015). Neurobiological correlates of object relations theory: the relationship between neurobiological and psychodynamic development. *Int. Forum Psychoanal.* 24, 38–46. doi: 10.1080/0803706X.2014.912352

Kernberg, O. F. (2016). What is personality? *J. Pers. Disord.* 30, 145–156. doi: 10.1521/pedi.2106.30.2.145

Kernberg, O. F., and Caligor, E. (2005). "A psychoanalytic theory of personality disorders," in *Major Theories of Personality Disorders*, 2nd Edn. eds J. F. Clarkin and M. F. Lenzenweger (New York, NY: Guilford Press), 114–156.

Keysers, C., Kaas, J. H., and Gazzola, V. (2010). Somatosensation in social perception. *Nat. Rev. Neurosci.* 11, 417–428. doi: 10.1038/nrn2833

Khadka, S., Meda, S. A., Stevens, M. C., Glahn, D. C., Calhoun, V. D., Sweeney, J. A., et al. (2013). Is aberrant functional connectivity a psychosis endophenotype? A resting state functional magnetic resonance imaging study. *Biol. Psychiatry* 74, 458–466. doi: 10.1016/j.biopsych.2013.04.024

King-Casas, B., Sharp, C., Lomax-Bream, L., Lohrenz, T., Fonagy, P., and Montague, P. R. (2008). The rupture and repair of cooperation in borderline personality disorder. *Science* 321, 806–810. doi: 10.1126/science.1156902

Knight, R. P. (1953). Borderline states. *Bull. Menninger Clin.* 17, 1–12.

Koenigsberg, H. W., Siever, L. J., Lee, H., Pizzarello, S., New, A. S., Goodman, M., et al. (2009). Neural correlates of emotion processing in borderline personality disorder. *Psychiatry Res.* 172, 192–199. doi: 10.1016/j.pscychresns.2008.07.010

Kohut, H. (1971). *The Analysis of the Self.* New York, NY: International Universities Press.

Krause, A. L., Borchardt, V., Li, M., van Tol, M. J., Demenescu, L. R., Strauss, B., et al. (2016). Dismissing attachment characteristics dynamically modulate brain networks subserving social aversion. *Front. Hum. Neurosci.* 10:77. doi: 10.3389/fnhum.2016.00077

Krause, A. L., Colic, L., Borchardt, V., Li, M., Strauss, B., Buchheim, A., et al. (2018). Functional connectivity changes following interpersonal reactivity. *Hum. Brain Mapp.* 39, 866–879. doi: 10.1002/hbm.23888

Laurita, A. C., Hazan, C., and Spreng, R. N. (2017). Dissociable patterns of brain activity for mentalizing about known others: a role for attachment. *Soc. Cogn. Affect. Neurosci.* 12, 1072–1082. doi: 10.1093/scan/nsx040

Laurita, A. C., Hazan, C., and Spreng, R. N. (2018). Neural signatures of chronic accessibility in parent—adult child attachment bonds. *Soc. Neurosci.* doi: 10.1080/17470919.2018.1494037 [Epub ahead of print].

Legrand, D., and Ruby, P. (2009). What is self-specific? Theoretical investigation and critical reviewof neuroimaging results. *Psychol. Rev.* 116, 252–282. doi: 10.1037/a0014172

Lingiardi, V., and McWilliams, N. (2017). *Psychodynamic Diagnostic Manual. Second Edition (PDM-2).* New York, NY: Guilford Press.

Liotti, G. (2017). Conflicts between motivational systems related to attachment trauma: key to understanding the intra-family relationship between abused children and their abusers. *J. Trauma Dissociation* 18, 304–318. doi: 10.1080/15299732.2017.1295392

Lorberbaum, J. P., Newman, J. D., Horwitz, A. R., Dubno, J. R., Lydiard, R. B., Hamner, M. B., et al. (2002). A potential role for thalamocingulate circuitry in human maternal behavior. *Biol. Psychiatry* 51, 431–445. doi: 10.1016/s0006-3223(01)01284-7

Lu, H., and Stein, E. A. (2014). Resting state functional connectivity: its physiological basis and application in neuropharmacology. *Neuropharmacology* 84, 79–89. doi: 10.1016/j.neuropharm.2013.08.023

Lyons-Ruth, K. (2003). Dissociation and the parent-infant dialogue: a longitudinal perspective from attachment research. *J. Am. Psychoanal. Assoc.* 51, 883–911. doi: 10.1177/00030651030510031501

Lyons-Ruth, K. (2008). Contributions of the mother-infant relationship to dissociative, borderline, and conduct symptoms in young adulthood. *Infant Ment. Health J.* 29, 203–218. doi: 10.1002/imhj.20173

Magioncalda, P., Martino, M., Conio, B., Escelsior, A., Piaggio, N., Presta, A., et al. (2015). Functional connectivity and neuronal variability of resting state activity in bipolar disorder—reduction and decoupling in anterior

cortical midline structures. *Hum. Brain Mapp.* 36, 666–682. doi: 10.1002/hbm.22655

Martino, M., Magioncalda, P., Huang, Z., Conio, B., Piaggio, N., Duncan, N. W., et al. (2016). Contrasting variability patterns in the default mode and sensorimotor networks balance in bipolar depression and mania. *Proc. Natl. Acad. Sci. U S A* 113, 4824–4829. doi: 10.1073/pnas.1517558113

Meltzoff, A. N., and Brooks, R. (2001). ""Like me" as a building block for understanding other minds: bodily acts, attention, and intention," in *Intentions and Intentionality: Foundations of Social Cognition*, eds B. F. Malle, L. J. Moses and D. A. Baldwin (Cambridge, MA: The MIT Press), 171–191.

Meltzoff, A. N., and Decety, J. (2003). What imitation tells us about social cognition: a rapprochement between developmental psychology and cognitive neuroscience. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 358, 491–500. doi: 10.1098/rstb.2002.1261

Messina, I., Bianco, F., Cusinato, M., Calvo, V., and Sambin, M. (2016a). Abnormal default system functioning in depression: implications for emotion regulation. *Front. Psychol.* 7:858. doi: 10.3389/fpsyg.2016.00858

Messina, I., Sambin, M., Beschoner, P., and Viviani, R. (2016b). Changing views of emotion regulation and neurobiological models of the mechanism of action of psychotherapy. *Cogn. Affect. Behav. Neurosci.* 16, 571–587. doi: 10.3758/s13415-016-0440-5

Metzinger, T., and Gallese, V. (2003). The emergence of a shared action ontology: building blocks for a theory. *Conscious. Cogn.* 12, 549–571. doi: 10.1016/s1053-8100(03)00072-2

Minzenberg, M. J., Fan, J., New, A. S., Tang, C. Y., and Siever, L. J. (2007). Fronto-limbic dysfunction in response to facial emotion in borderline personality disorder: an event-related fMRI study. *Psychiatry Res.* 155, 231–243. doi: 10.1016/j.pscychresns.2007.03.006

Moran, J. M., Macrae, C. N., Heatherton, T. F., Wyland, C. L., and Kelley, W. M. (2006). Neuroanatomical evidence for distinct cognitive and affective components of self. *J. Cogn. Neurosci.* 18, 1586–1594. doi: 10.1162/jocn.2006.18.9.1586

Morey, L. C., Berghuis, H., Bender, D. S., Verheul, R., Krueger, R. F., and Skodol, A. E. (2011). Toward a model for assessing level of personality functioning in DSM-5, Part II: empirical articulation of a core dimension of personality pathology. *J. Pers. Assess.* 93, 347–353. doi: 10.1080/00223891.2011.577853

Mucci, C. (2013). *Beyond Individual and Collective Trauma. Intergenerational Transmission, Psychoanalytic Treatment, and the Dynamics of Forgiveness.* London: Karnac Books.

Mucci, C. (2016). "Implicit memory, unrepressed uncosncious, and trauma theory: the turn of the screw between contemporary psychoanalysis and neuroscence," in *Unrepressed Unconscious, Implicit Memory and Clinical Work*, eds G. Craparo and C. Mucci (London: Karnac Books), 99–129.

Mucci, C. (2017). Ferenczi's revolutionary therapeutic approach. *Am. J. Psychoanal.* 77, 239–254. doi: 10.1057/s11231-017-9104-7

Mucci, C. (2018). *Borderline Bodies. Affect Regulation Therapy for Personality Disorders.* New York, NY: W.W. Norton & Company.

Murray, R. J., Debbane, M., Fox, P. T., Bzdok, D., and Eickhoff, S. B. (2015). Functional connectivity mapping of regions associated with self- and other-processing. *Hum. Brain Mapp.* 36, 1304–1324. doi: 10.1002/hbm.22703

Northoff, G. (2011). *Neuropsychoanalysis in Practice: Brain, Self and Objects.* New York, NY: Oxford University Press.

Northoff, G. (2015). Is schizophrenia a spatiotemporal disorder of the brain's resting state? *World Psychiatry* 14, 34–35. doi: 10.1002/wps.20177

Northoff, G. (2016a). Is the self a higher-order or fundamental function of the brain? The "basis model of self-specificity" and its encoding by the brain's spontaneous activity. *Cogn. Neurosci.* 7, 203–222. doi: 10.1080/17588928.2015.1111868

Northoff, G. (2016b). Spatiotemporal psychopathology I: no rest for the brain's resting state activity in depression? Spatiotemporal psychopathology of depressive symptoms. *J. Affect. Disord.* 190, 854–866. doi: 10.1016/j.jad.2015.05.007

Northoff, G. (2016c). Spatiotemporal psychopathology II: how does a psychopathology of the brain's resting state look like? Spatiotemporal approach and the history of psychopathology. *J. Affect. Disord.* 190, 867–879. doi: 10.1016/j.jad.2015.05.008

Northoff, G. (2017). Personal identity and cortical midline structure (CMS): do temporal features of CMS neural activity transform into "self-continuity"? *Psychol. Inq.* 28, 122–131. doi: 10.1080/1047840x.2017.1337396

Northoff, G., and Bermpohl, F. (2004). Cortical midline structures and the self. *Trends Cogn. Sci.* 8, 102–107. doi: 10.1016/j.tics.2004.01.004

Northoff, G., and Duncan, N. W. (2016). How do abnormalities in the brain's spontaneous activity translate into symptoms in schizophrenia? From an overview of resting state activity findings to a proposed spatiotemporal psychopathology. *Prog. Neurobiol.* 145–146, 26–45. doi: 10.1016/j.pneurobio.2016.08.003

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., and Panksepp, J. (2006). Self-referential processing in our brain—a meta-analysis of imaging studies on the self. *Neuroimage* 31, 440–457. doi: 10.1016/j.neuroimage.2005.12.002

Northoff, G., and Huang, Z. (2017). How do the brain's time and space mediate consciousness and its different dimensions? Temporo-spatial theory of consciousness (TTC). *Neurosci. Biobehav. Rev.* 80, 630–645. doi: 10.1016/j.neubiorev.2017.07.013

Northoff, G., and Panksepp, J. (2008). The trans-species concept of self and the subcortical-cortical midline system. *Trends Cogn. Sci.* 12, 259–264. doi: 10.1016/j.tics.2008.04.007

Northoff, G., Qin, P., and Nakao, T. (2010). Rest-stimulus interaction in the brain: a review. *Trends Neurosci.* 33, 277–284. doi: 10.1016/j.tins.2010.02.006

Northoff, G., Schneider, F., Rotte, M., Matthiae, C., Tempelmann, C., Wiebking, C., et al. (2009). Differential parametric modulation of self-relatedness and emotions in different brain regions. *Hum. Brain Mapp.* 30, 369–382. doi: 10.1002/hbm.20510

Panksepp, J. (1998a). The periconscious substrates of consciousness: affective states and the evolutionary origins of the SELF. *J. Conscious. Stud.* 5, 566–582.

Panksepp, J. (1998b). *Affective Neuroscience: The Foundations of Human and Animal Emotions.* New York, NY: Oxford University Press.

Panksepp, J., and Biven, L. (2012). *The Archaeology of Mind: Neuroevolutionary Origins of Human Emotions.* New York, NY: W. W. Norton & Company.

Pfeifer, J. H., and Peake, S. J. (2012). Self-development: integrating cognitive, socioemotional, and neuroimaging perspectives. *Dev. Cogn. Neurosci.* 2, 55–69. doi: 10.1016/j.dcn.2011.07.012

Phan, K. L., Taylor, S. F., Welsh, R. C., Ho, S. H., Britton, J. C., and Liberzon, I. (2004). Neural correlates of individual ratings of emotional salience: a trial-related fMRI study. *Neuroimage* 21, 768–780. doi: 10.1016/j.neuroimage.2003.09.072

Qin, P., and Northoff, G. (2011). How is our self related to midline regions and the default-mode network? *Neuroimage* 57, 1221–1233. doi: 10.1016/j.neuroimage.2011.05.028

Raichle, M. E. (2015). The restless brain: how intrinsic activity organizes brain function. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 370:20140172. doi: 10.1098/rstb.2014.0172

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., and Shulman, G. L. (2001). A default mode of brain function. *Proc. Natl. Acad. Sci. U S A* 98, 676–682. doi: 10.1073/pnas.98.2.676

Rizzolatti, G., and Sinigaglia, C. (2008). *Mirrors in the Brain: How Our Minds Share Actions and Emotions.* Oxford: Oxford University Press.

Rotarska-Jagiela, A., van de Ven, V., Oertel-Knöchel, V., Uhlhaas, P. J., Vogeley, K., and Linden, D. E. (2010). Resting-state functional network correlates of psychotic symptoms in schizophrenia. *Schizophr. Res.* 117, 21–30. doi: 10.1016/j.schres.2010.01.001

Sampaio, A., Soares, J. M., Coutinho, J., Sousa, N., and Gonçalves, Ó. F. (2014). The Big Five default brain: functional evidence. *Brain Struct. Funct.* 219, 1913–1922. doi: 10.1007/s00429-013-0610-y

Scalabrini, A., Cavicchioli, M., Fossati, A., and Maffei, C. (2017a). The extent of dissociation in borderline personality disorder: a meta-analytic review. *J. Trauma Dissociation* 18, 522–543. doi: 10.1080/15299732.2016.1240738

Scalabrini, A., Huang, Z., Mucci, C., Perrucci, M. G., Ferretti, A., Fossati, A., et al. (2017b). How spontaneous brain activity and narcissistic features shape social interaction. *Sci. Rep.* 7:9986. doi: 10.1038/s41598-017-10389-9

Schimmenti, A. (2017). The trauma factor: examining the relationships among different types of trauma, dissociation and psychopathology. *J. Trauma Dissociation* 1–20. doi: 10.1080/15299732.2017.1402400

Schimmenti, A., and Caretti, V. (2016). Linking the overwhelming with the unbearable: developmental trauma, dissociation, and the disconnected self. *Psychoanal. Psychol.* 33, 106–128. doi: 10.1037/a0038019

Schneider, F., Bermpohl, F., Heinzel, A., Rotte, M., Walter, M., Tempelmann, C., et al. (2008). The resting brain and our self: self-relatedness modulates resting state neural activity in cortical midline structures. *Neuroscience* 157, 120–131. doi: 10.1016/j.neuroscience.2008.08.014

Schore, A. N. (2000). Attachment and the regulation of the right brain. *Attach. Hum. Dev.* 2, 23–47. doi: 10.1080/146167300361309

Schore, A. N. (2001). Effects of a secure attachment relationship on right brain development, affect regulation, and infant mental health. *Infant Ment. Health J.* 22, 7–66. doi: 10.1002/1097-0355(200101/04)22:1<7::aid-imhj2>3.0.co;2-n

Schore, A. N. (2003). *Affect Dysregulation and Disorders of the Self (Norton Series on Interpersonal Neurobiology)*. New York, NY: W. W. Norton & Company.

Schore, A. N. (2005). Attachment, affect regulation, and the developing right brain: linking developmental neuroscience to pediatrics. *Pediatr. Rev.* 26, 204–217. doi: 10.1542/pir.26-6-204

Schore, A. N. (2012). *The Science of the Art of Psychotherapy (Norton Series on Interpersonal Neurobiology)*. New York, NY: W.W. Norton & Company.

Shim, G., Oh, J. S., Jung, W. H., Jang, J. H., Choi, C. H., Kim, E., et al. (2010). Altered resting-state connectivity in subjects at ultra-high risk for psychosis: an fMRI study. *Behav. Brain Funct.* 6:58. doi: 10.1186/1744-9081-6-58

Siegel, D. J. (2015). *The Developing Mind: How Relationships and The Brain Interact to Shape Who We Are*. 2nd Edn. New York, NY: Guilford Publications.

Stern, D. N. (1985). *The Interpersonal World of the Infant: A View from Psychoanalysis and Developmental Psychology*. London: Karnac Books.

Strathearn, L., Li, J., Fonagy, P., and Montague, P. R. (2008). What's in a smile? Maternal brain responses to infant facial cues. *Pediatrics* 122, 40–51. doi: 10.1542/peds.2007-1566

Sui, J., Chechlacz, M., and Humphreys, G. W. (2012). Dividing the self: distinct neural substrates of task-based and automatic self-prioritization after brain damage. *Cognition* 122, 150–162. doi: 10.1016/j.cognition.2011.10.008

Sui, J., and Humphreys, G. W. (2015). The integrative self: how self-reference integrates perception and memory. *Trends Cogn. Sci.* 19, 719–728. doi: 10.1016/j.tics.2015.08.015

Sui, J., Liu, M., Mevorach, C., and Humphreys, G. W. (2015). The salient self: the left intraparietal sulcus responds to social as well as perceptual-salience after self-association. *Cereb. Cortex* 25, 1060–1068. doi: 10.1093/cercor/bht302

Sui, J., Rotshtein, P., and Humphreys, G. W. (2013). Coupling social attention to the self forms a network for personal significance. *Proc. Natl. Acad. Sci. U S A* 110, 7607–7612. doi: 10.1073/pnas.1221862110

Swain, J. E., Lorberbaum, J. P., Kose, S., and Strathearn, L. (2007). Brain basis of early parent-infant interactions: psychology, physiology and *in vivo* functional neuroimaging studies. *J. Child Psychol. Psychiatry* 48, 262–287. doi: 10.1111/j.1469-7610.2007.01731.x

Trevarthen, C. (2001). Intrinsic motives for companionship in understanding: their origin, development, and significance for infant mental health. *Infant Ment. Health J.* 22, 95–131. doi: 10.1002/1097-0355(200101/04)22:1<95::aid-imhj4>3.0.co;2-6

Trevarthen, C., and Aitken, K. J. (2001). Infant intersubjectivity: research, theory, and clinical applications. *J. Child Psychol. Psychiatry* 42, 3–48. doi: 10.1017/s0021963001006552

Tronick, E. (2007). *The Neurobehavioral and Social-Emotional Development of Infants and Children*. New York, NY: W.W. Norton & Company.

Tzschoppe, J., Nees, F., Banaschewski, T., Barker, G. J., Büchel, C., Conrod, P. J., et al. (2014). Aversive learning in adolescents: modulation by amygdala-prefrontal and amygdala-hippocampal connectivity and neuroticism. *Neuropsychopharmacology* 39:875. doi: 10.1038/npp.2013.287

Van Overwalle, F. (2009). Social cognition and the brain: a meta-analysis. *Hum. Brain Mapp.* 30, 829–858. doi: 10.1002/hbm.20547

Visintin, E., De Panfilis, C., Amore, M., Balestrieri, M., Wolf, R. C., and Sambataro, F. (2016). Mapping the brain correlates of borderline personality disorder: a functional neuroimaging meta-analysis of resting state studies. *J. Affect. Disord.* 204, 262–269. doi: 10.1016/j.jad.2016.07.025

Wei, L., Duan, X., Yang, Y., Liao, W., Gao, Q., Ding, J. R., et al. (2011). The synchronization of spontaneous BOLD activity predicts extraversion and neuroticism. *Brain Res.* 1419, 68–75. doi: 10.1016/j.brainres.2011.08.060

Wei, S., Su, Q., Jiang, M., Liu, F., Yao, D., Dai, Y., et al. (2016). Abnormal default-mode network homogeneity and its correlations with personality in drug-naive somatization disorder at rest. *J. Affect. Disord.* 193, 81–88. doi: 10.1016/j.jad.2015.12.052

Whitfield-Gabrieli, S., Moran, J. M., Nieto-Castañón, A., Triantafyllou, C., Saxe, R., and Gabrieli, J. D. (2011). Associations and dissociations between default and self-reference networks in the human brain. *Neuroimage* 55, 225–232. doi: 10.1016/j.neuroimage.2010.11.048

Wicker, B., Ruby, P., Royet, J. P., and Fonlupt, P. (2003). A relation between rest and the self in the brain? *Brain Res. Rev.* 43, 224–230. doi: 10.1016/j.brainresrev.2003.08.003

Zhu, Y. (2004). Neuroimaging studies of self-reflection. *Prog. Nat. Sci.* 14, 296–302. doi: 10.1080/10020070412331343511

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

PERSPECTIVE
published: 05 November 2018
doi: 10.3389/fpsyg.2018.02054

Dysregulated Anxiety and Dysregulating Defenses: Toward an Emotion Regulation Informed Dynamic Psychotherapy

*Jon Julius Frederickson[1], Irene Messina[2] and Alessandro Grecucci[3]**

[1] Washington School of Psychiatry, Washington, DC, United States, [2] Department of Philosophy, Sociology, Education and Applied Psychology, University of Padua, Padova, Italy, [3] Department of Psychology and Cognitive Sciences, University of Trento, Trento, Italy

One of the main objectives of psychotherapy is to address emotion dysregulation that causes pathological symptoms and distress in patients. Following psychodynamic theory, we propose that in humans, the combination of emotions plus conditioned anxiety due to traumatic attachment can lead to dysregulated affects. Likewise, defenses can generate and maintain dysregulated affects (altogether Dysregulated Affective States, DAS). We propose the Experiential-Dynamic Emotion Regulation methodology, a framework to understand emotion dysregulation by integrating scientific evidence coming from the fields of affective neuroscience and Experiential-Dynamic Psychotherapy aimed at resolving DAS. This method and the techniques proposed can be integrated within other approaches. Similarities and differences with the Cognitive model of emotion regulation and cognitive-behavioral approaches are discussed within the paper.

Keywords: emotion regulation, anxiety, emotion, defense mechanisms, dynamic psychotherapy, psychoanalysis

OPEN ACCESS

Edited by:
Anatolia Salone,
Università degli Studi "G. d'Annunzio" Chieti - Pescara, Italy

Reviewed by:
Christiane Montag,
Charité – Universitätsmedizin Berlin, Germany
Luisa De Risio,
Università Cattolica del Sacro Cuore, Italy

****Correspondence:***
Alessandro Grecucci
alessandro.grecucci@unitn.it

Specialty section:
This article was submitted to Psychoanalysis and Neuropsychoanalysis, a section of the journal Frontiers in Psychology

Received: *14 May 2018*
Accepted: *05 October 2018*
Published: *05 November 2018*

Citation:
Frederickson JJ, Messina I and Grecucci A (2018) Dysregulated Anxiety and Dysregulating Defenses: Toward an Emotion Regulation Informed Dynamic Psychotherapy. Front. Psychol. 9:2054. doi: 10.3389/fpsyg.2018.02054

INTRODUCTION: REGULATING EMOTIONS FROM NEUROSCIENCE TO PSYCHOTHERAPY

According to Gross (1998), emotion regulation refers to "*processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions*." Theories of emotional regulation have their roots in the study of psychological defenses (Freud, 1936, 1959a,b; Paulhus et al., 1997), psychological stress and coping (Lazarus and Folkman, 1984), and theory of emotions (Frijda, 1986; Damasio, 1999; Ekman, 2003). Today, the field of emotion regulation integrates experimental research, clinical psychology, and neuroscience to study how emotions are generated and regulated to facilitate adaptation to the environment.

In traditional emotion regulation studies, participants are asked to apply a defined strategy when observing emotion-eliciting stimuli (regulation condition) or alternatively to observe the same emotional stimuli without applying any strategy (control condition). Results clearly show a marked reduction in the perceived intensity of emotional experience and dampened neural activation (for a review see Ochsner and Gross, 2005). Emotion regulation can affect the subjective emotional experience and the associated psychophysiological processes, such as heart rate, skin conductance,

and neural activity (Jackson et al., 2000; Eippert et al., 2007). According to neuroimaging studies of emotion regulation (Ochsner and Gross, 2005; Buhle et al., 2013; Gross, 2014; Messina et al., 2015), the prefrontal cortex is thought to have an inhibitory effect on areas associated with emotional reactivity, such as the amygdala, resulting in decreased emotional experience in participants. Moreover, also temporal areas appear to be involved in emotion perception regulation, especially in the case of complex emotions in social situations in normal and abnormal populations (Grecucci et al., 2013a,b,c, 2016b; Grecucci and Sanfey, 2014; Pappaianni et al., 2018). These investigations into the regulation of social and complex emotions and the resulting emotion regulation theories provide a new understanding of mental disorders and their treatment.

After a decade of experimental studies, researchers have succeeded in gathering evidence to generate consensus about the key role of emotion regulation for healthy psychological functioning. The capacity to adaptively regulate negative emotion is considered a protective factor against the development and maintenance of psychopathology (Aldao and Nolen-Hoeksema, 2010; Aldao et al., 2010). On the other hand, difficulties in ER have been identified as putative risk and maintaining factors for several disorders (Gratz et al., 2013). Poor emotion regulation has been linked to psychiatric disorders (Barlow, 2002; Werner and Gross, 2010; Grecucci, 2012; Ehring, 2013; Mennin and Fresco, 2014; Messina et al., 2016a), and more than 75% of psychiatric disorders are characterized by deficits in emotion regulation (Kring and Werner, 2004). For example, anxiety, depression, and personality disorders are associated with specific dysregulated emotions (Thayer and Lane, 2000; Mennin and Fresco, 2009; Schulze et al., 2011). Moreover, emotion regulation strategies may differently influence psychological health. The most investigated strategy is reappraisal, an adaptive form of regulation that consists of the generation of new interpretations of stressful situations to decrease the emotional response they would otherwise elicit (Gross, 1998). Among the less adaptive strategies, suppression is one of the most investigated. It consists in controlling emotional expression, and it functions as a conscious defense mechanism (see Dysregulated Affective States Due to Defensive Affects). Compared to reappraisal, suppression has been negatively associated to the expression of positive emotion, effective interpersonal functioning, and well-being (Gross, 2002; Gross and John, 2003) and it negatively correlates with mental health indicators (Aldao and Nolen-Hoeksema, 2010; Hu et al., 2014). Taken together, these findings support the validity of a core construct of emotional dysregulation applicable to affective disorders and their therapy (Messina et al., 2013, 2016b). In line with this construct, techniques based on emotion regulation principles have been incorporated into cognitive-behavioral approaches. For example, Linehan (1993a,b) teaches a set of behavioral skills to help borderline patients cope with their dysregulated emotions. The implementation of cognitive and behavioral techniques – such as reappraisal and emotional avoidance – has been proposed as part of a unified protocol for proposed by Barlow et al. (2011). Moreover, specific emotion regulation trainings have been developed to treat emotional difficulties (Berking et al., 2008; Mennin and Fresco, 2009).

According to the experimental literature and the cognitive-behavioral tradition, emotions and anxiety are regulated by manipulating the thinking style (reappraisal strategy), or attention (distraction strategy) (Ochsner and Gross, 2005). The cognitive tradition has emphasized the conscious causes of emotion dysregulation and their conscious regulation and it does not clearly differentiate between what should be encouraged to express or to regulate. We believe that some psychodynamic principles can be used as a guide for the therapist to select what should be expressed or regulated. In the psychodynamic view, emotions are the fundamental way we make sense of the world. They tell us what we want and what we do not, what gives us pleasure and what gives us pain. They mobilize us to act adaptively on our own behalf, to pursue our goals in life (Tomkins, 1962). Like a GPS system, feelings tell us where we are, where we want to go, and how to get there (Frederickson, 2013). In everyday life, a stimulus triggers emotion (the "original emotion"), which is adaptive and proportionate to the stimulus, motivating the person to engage in adaptive behavior (Grecucci and Job, 2015). The function of conscious but also unconscious emotions as the primary motivators of behavior is widely recognized in psychoanalysis (Freud, 1959b; Kernberg, 1984, 1996), as well as in affective neuroscience (Panksepp, 1998; Damasio, 1999).

In psychodynamic therapy, patients are encouraged to experience emotions (sometimes even up-regulate them) and the associated impulse physically in the body, rather than downregulating them through cognitive or attentional strategies (Davanloo, 1990; Coughlin della Selva, 1996; Davanloo, 2000; Frederickson, 2013).

What should be regulated according to psychodynamic therapists by contrast, is the case of excessive anxiety or affects created by dysregulating defenses, so that the patient can be helped to express the underlying emotion (Hartmann, 1964).

In the present paper, starting from the above considerations, we propose that emotions, as evolutionary products, are not inherently dysregulated (as assumed by cognitive models of emotion regulation), and dysregulation can be better understood as the result of: (1) emotions plus dysregulated anxiety, or (2) defensive affects resulting from dysregulating defenses. We have defined these states as Dysregulated Affective States (DAS; Grecucci et al., 2015, 2016a). Second, we provide a framework and methodology for an Experiential-Dynamic Emotion Regulation Methodology (EDER) that integrates Experiential-Dynamic Therapy techniques and emotion regulation science principles for the clinical treatment of DAS.

DYSREGULATED AFFECTIVE STATES

Dysregulated Affective States Due to Anxiety

Sometimes emotional responses are no longer proportional to the stimulus. Why? In some cases, the patient is overwhelmed by anxiety associated with a given emotion, and he/she may not be aware of the emotion covered by anxiety. According to the psychodynamic view, in such situations what becomes

dysregulated and should be regulated is not the emotion itself, but *anxiety*. We call an emotion plus overwhelming anxiety a Dysregulated Affective State (DAS, Grecucci et al., 2015). Signal anxiety (Freud, 1959a) signals the emergence of relational and internal danger situations that would repeat earlier traumatic experiences. Psychodynamic theories describe how DASs originate in early relationships with caregivers, upon whom infants depend for their survival. Any emotion that triggers anxiety in the caregiver will be experienced as a danger to a relationship necessary for survival, causing a conflict between affect expression toward the caregiver and the need to be cared for by the caregiver (Sullivan, 1953; Bowlby, 1980). Through multiple experiences in early relationships, the infant, and later the child, learns unconsciously which emotions pose a danger to the relationship (Bowlby, 1980). Emotions trigger unconscious anxiety, based on memories of earlier conflictual relationships. Thus, anxiety becomes a conditioned response indicating that a rising feeling could endanger a relationship in the present, even though this is based on unconscious learning in the past (Bowlby, 1980). This psychoanalytic view of anxiety converges with neuroscience and neurobiology (Schore, 2003). According to affective neuroscience, when unconscious emotion rises, neuroperception of threat occurs triggering signal anxiety based on the inborn neurological fear circuit (Panksepp, 1998). Following the non-conscious perception of threat in the brain, a message is sent to the amygdala (LeDoux, 1998; Panksepp, 1998; Damasio, 1999). The amygdala activates the somatic and autonomic nervous systems, mobilizing the body to deal with a threat (Robertson et al., 2004; Porges, 2011).

When anxiety is discharged into the autonomic nervous system, it can be channeled into either the sympathetic or the parasympathetic nervous systems (Robertson et al., 2004) (see **Table 1**). As shown in **Table 1**, the sympathetic nervous system creates the symptoms of increased heart rate, blood pressure, and respiration; sweating, cold hands and feet, dry mouth, fainting from hyperventilation, and blushing. The parasympathetic nervous system creates the symptoms of decreased heart rate, blood pressure, and respiration; nausea, vomiting, diarrhea, migraines, dizziness, blurry vision, ringing in the ears, limpness, bodily anesthesia, and difficulty thinking. When patients experience emotions accompanied by the anxiety symptoms of the parasympathetic nervous system, they become dysregulated. They are not dysregulated by the emotion, but by the severe anxiety symptoms, including problems thinking and loss of reality testing. The problems of thinking and reality testing might seem unrelated to anxiety. However, activation of the parasympathetic nervous system releases neurohormones which inhibit the functioning of the hippocampus, responsible for storing short term memory (Sapolsky et al., 1990), and the prefrontal cortex, essential for higher order thinking (Wehrenberg and Prinz, 2007).

Notably, the pathway of anxiety discharge informs the therapist on how to intervene (see **Table 1**). In sum, when anxiety is mild, emotions can be encouraged. When anxiety is too high, the therapist needs to regulate the resulting DAS before getting into the underlying emotion. With the therapist's help, the patient can become aware of these physical activations as emotions (Damasio, 1999). Once the patient is conscious of her emotions, those conscious emotions can mobilize conscious adaptive action (Damasio, 1999), and anxiety becomes regulated.

Dysregulated Affective States Due to Defensive Affects

Much as we would like anxiety to be regulated easily, in many cases anxiety does not come down. Why? The patient may use defense mechanisms which create or perpetuate dysregulated affects. In earlier relational experiences the patient learned to avoid or cover certain emotions (e.g., anger toward the mother) through defenses, thus hiding feelings that might endanger a relationship (Sullivan, 1953). In a previous Section "Introduction: Regulating Emotions From Neuroscience to Psychotherapy," we described an integrative theory of emotions as the primary motivators of behavior. Then we showed how anxiety is a biophysiological activation of the body paired through conditioning with emotions, and how dysregulated anxiety can create dysregulated affects (see Dysregulated Affective States). Now we will show how dysregulating defenses create dysregulated defensive affects.

In psychodynamic theory, defenses are understood as unconscious psychological mechanisms that reduce anxiety arising from unacceptable or potentially harmful thoughts, emotions or impulses (Freud, 1959a,b). Defenses are forms of adaptation to the environment that act by protecting individual self-esteem or self-integrity (Hartmann, 1964; Cramer, 1998), or important relationships (Sullivan, 1953; Bowlby, 1980). Although defenses are useful adaptations to damaging environments, once they become conditioned reactions to emotions or anxiety, they become generalized to other environments where they are unhelpful and even harmful. Thus, defenses which are useful in the here and now are adaptive. But, when they become conditioned reactions which are generalized, they create dysregulated defensive affects, or secondary affects, which cover or replace the original emotion. These defensive affects create a second type of DAS (due to the intervention of defenses).

When a stimulus occurs, we react with emotions. For example, if a boss does not give a promotion, this may trigger anger, and anger may trigger adaptive action. However, what if defenses block us from channeling our anger into adaptive action? If the patient's anger triggers too much anxiety, he may use a defense to manage anxiety. Angry with the boss, but unable to own it, suppose he projects his anger onto the boss (defense mechanism). This does not reduce his anxiety. In fact, now he is afraid of his boss' imaginary anger. As a result, he can't channel his anger into effective assertion. This fear, dysregulated due to a projection, cannot come down until the projection comes down (see **Table 2**, "fear due to projective anger"). Further, let's suppose he becomes further enraged at this boss who supposedly wants to hurt him, the anger toward this projection

TABLE 1 | Emotion dysregulation as a function of the pathways of anxiety discharge.

	Path of anxiety discharge	Symptoms/Signs	Level of emotional dysregulation	Therapeutic action
Emotion without anxiety	NA	NA	No dysregulation	Express feeling
Emotion plus mild anxiety	Somatic nervous system	-Hand clenching -Tension in the intercostal muscles of the chest, the patient sighs -Tension in arms, shoulders, neck, legs and feet -Jaw clenching, biting. . .	No dysregulation	Watch anxiety while encouraging the patient to express feeling
Emotion plus dysregulating anxiety	Parasympathetic nervous system	-Bladder urgency and frequency -Gastrointestinal spasm -Irritable bowel syndrome, nausea, vomiting Vascular—migraine, hypertension Bronchi—asthma "Jelly legs" -Drifting -Dissociation -Confusion	Moderate to severe dysregulation	Regulate anxiety and then explore feeling
Emotion plus dysregulating anxiety	Cognitive- Perceptual system	-Hallucinations -Dissociation -Blocking of thought -Tunnel vision -Tinnitus	Severe dysregulation	Regulate anxiety and then explore feeling

TABLE 2 | Defensive affects.

	Original emotions			Defensive affects		
	Emotions	Dysregulation	Therapeutic action	Defensive affect	Dysregulation	Therapeutic action
Anger	"Normal anger"	No	Express	"Anger in response to a projection" "Fear due to projective anger—the supposedly angry boss"	Yes	Block
Grief/crying	"Good crying"	No	Express	"Weepiness" "Protest crying" "Infantile crying" "Anger to cover grief"	Yes	Block
Guilt	Healthy guilt	No	Express	"Neurotic guilt"	Yes	Block

will be limitless too (see **Table 2**, "anger due to a projection"), dysregulated, and cannot come down until projection comes down.

Thus, when patients use defenses that create defensive affects, blocking the defense is the first step to regulate the DAS. Restructuring the defenses (Frederickson, 2013) can be helpful for such patients. In our example, if the patient can learn to see the boss, rather than his projection, the projection drops, and the fear or anger resulting from the projection drops as well.

In sum, original (primary) emotions, elicited by and proportional to the stimulus, lead to a proportional, adaptive emotional response. Emotions due to real stimuli are usually limited in activation and time (Grecucci and Job, 2015). For instance, a boss makes an unfair comment that lasts 10 s. In response, the patient feels angry for 10 s. This allows him to respond adaptively to the problem. Then the anger drops, having fulfilled its function. However, when patients use defenses (for example, projection), the resulting defensive affects will be proportional to the defense (projection), not to the stimulus itself. Thus, a projection, which lasts 5 h, causes anger for 5 h. This is why defensive affects have a different shape of activation. Emotions triggered by a stimulus in reality have the shape of a wave: they rise after the stimulus and fall after the stimulus has ended or adaptive action has occurred. Defensive

affects rise rapidly in response to a defense like projection and remain high as long as the patient uses the defense (in this example, projection). In **Table 2**, we report different examples, and we outline optimal therapist responses to regulate patients' emotions.

EXPERIENTIAL-DYNAMIC EMOTION REGULATION

In this section, we describe Experiential-Dynamic Emotion Regulation (EDER) as a set of core concepts and associated therapeutic prescriptions for the treatment of DASs. EDER is connected with a psychodynamic theory of mind and in particular with some observations derived from Intensive Short-Term Dynamic Psychotherapy (ISTDP), proposed in the 1970's by Davanloo (1990, 2000) and further developed by others (Coughlin della Selva, 1996; Ten Have-de Labije and Neborsky, 2012; Frederickson, 2013; Abbass, 2015). Based on psychodynamic theories described in the previous section, ISTDP starts with the assumption that stimuli in life trigger emotions, which trigger anxiety and defenses. The unconscious defenses cause the symptoms and presenting problems from which patients suffer. Since anxiety and defenses cause the presenting problems and symptoms, the therapist helps the patient face his feelings – what makes him anxious – and let go of the defenses, which cause his symptoms. So, like other psychodynamic therapies, ISTDP relies on defense analysis and transference analysis to access feelings, which are avoided through defenses and the transference. (Note that interventions which mobilize feelings quickly are especially useful for high functioning patients with mature defenses. In contrast, lower functioning patients with primitive defenses require a slower exposure to feelings accompanied by anxiety regulation, plus deactivation of defenses that compromise reality testing. The patient's levels of affect tolerance, anxiety regulation, and reality testing determine the therapeutic strategy that would be most helpful.)

Core Principles of Experiential-Dynamic Emotion Regulation

EDER methodology can be expressed in three core principles (Grecucci, 2012; Grecucci et al., 2015, 2016a, 2017; Dadomo et al., 2016).

Regulation Versus Expression

To reduce a pathological affective state, we need to either: (a) promote the full expression of a true feeling, or, (b) down regulate anxiety and deactivate the defenses that create a DAS, and then promote the expression of the warded off true feeling. Once anxiety is regulated or a defensive affect is deactivated, patients must fully experience and express their adaptive feelings (Grecucci, 2012; Grecucci et al., 2015). We clearly distinguish what must be expressed (adaptive feelings) from what must be down-regulated (anxiety) or deactivated (defensive affects). When a feeling is accompanied by excessive anxiety, the therapist must regulate the anxiety to end the state of dysregulation. Then the therapist promotes the full experience and expression of the adaptive feelings. When a defense creates a defensive affect, the therapist must deactivate the defense, and then the defensive affect will disappear.

TABLE 3 | Phases and steps of the EDER methodology.

Phases	Steps for each Phase
(1) Emotion elicitation	(a) Ask for a specific example (b) Invite feelings. (c) If necessary, regulate anxiety and then invite feelings again. (d) Identify and help the patient let go of defenses that block the emergence of feeling.
(2) Regulatory mechanism enhancement (Awareness, attention and causality)	(a) Enhance awareness of the stimulus (b) Enhance observing capacity. (c) Pay attention to feeling. (d) Differentiate feeling from anxiety and defenses. (e) Understand causality (feelings→anxiety→defenses→symptoms).
(3) Dysregulatory mechanisms reduction or blocking (DAS)	(a) Understand causality of anxiety (feelings emerge→anxiety rises→DAS) (b) Reduce anxiety (restructure the pathway of anxiety discharge) (c) Understand causality of dysregulated affects (feelings→anxiety rises→defenses→defensive affects→DAS) (d) Block and restructure defenses which cause defensive affects
(4) Full emotional experience and elaboration	(a) Label the true feeling (subjective level). (b) Experience the feeling physically in the body. (c) Experience the impulse physically in the body. (d) Express the feeling (portray the associated impulse-action).

Focus on Emotional Experience

Constantly focus on and process emotions and dysregulatory mechanisms during the session. While patients experience an emotion, the therapist helps them observe dysregulatory mechanisms, regulate anxiety, and deactivate the defenses that create DAS moment by moment. The therapist encourages the experience of adaptive feelings but not the experience of defensive affects.

Use of Experiential Strategies

Experiential strategies act not only at the cognitive level, but facilitate the full experience of emotions while reducing or blocking dysregulatory mechanisms (anxiety and defensive affects). The patient is encouraged to experience emotion (Davanloo, 1990; Coughlin della Selva, 1996; Davanloo, 2000; Frederickson, 2013), rather than avoid them through cognitive or attentional strategies. During the phase of promoting feeling experience, cognitive strategies ward off feelings and are counterproductive. For example, it has been shown that in certain circumstances "reappraisal" can increase rumination (Ray et al., 2005), while rationalizing about the emotion (Freud, 1936), or "distraction" can avoid the experience of emotion (Freud, 1959a,b). Thus, when the therapist blocks defenses which prevent the patient from becoming aware of and experiencing his feelings, cognitive-attentive strategies may be detrimental. Since cognitions ward off feelings, we focus on the feelings underneath, not the cognitions. The goal of experiential techniques is not to restructure cognitions, but to help patients let go of cognitions as a defense so they can face the feeling underneath. Then patients can feel and deal rather than detach and defend. Once patients experience their original emotions, it is possible to show the causality of feelings triggering anxiety, then defenses, and then symptoms. Then we show how that pattern of causality plays out in the past, current, and therapy relationships (Malan, 1979). This process integrates their cognitions with affective experience.

Methodology of Experiential-Dynamic Emotion Regulation

Building on previously described core principles, a general methodology for a dynamic emotion regulation can be designed as follows (see **Tables 3**, **4**)[1] (Grecucci, 2012).

Phase 1: Emotion Elicitation

To elicit the precise emotion that causes affective dysregulation, the therapist asks for a specific example. In response, the patient often offers defenses (e.g., rationalizing thoughts) rather than

[1]This methodology for Experiential-Dynamic emotion regulation can be integrated in approaches other than psychodynamic.

TABLE 4 | Experiential-dynamic techniques to regulate emotions.

Process	Target and scope	Strategies	Model of therapy and references
Anxiety regulation	Enhancing awareness of the physiological signs of anxiety in the body	Identification, Enhancing bodily awareness, differentiating feeling from anxiety, introducing isolation of affect, changing the pathway of unconscious anxiety discharge	ISTDP (Davanloo, 1990, 2000; Coughlin della Selva, 1996; Frederickson, 2013)
Defense restructuring (experiential)	Undo the defense that creates dysregulated affects	Blocking the defense, identifying the defense, clarifying the price of the defense, clarifying the function of the defense, pointing out causality, differentiating reality from fantasy, then focusing on the true feeling that is underneath the defense	ISTDP (Davanloo, 1990, 2000; Coughlin della Selva, 1996; Frederickson, 2013)
Defense Restructuring (cognitive)	Promote meta-cognition	Point out cognitive errors	Mentalization (Bateman and Fonagy, 2006); ISTDP (Davanloo, 1990, 2000; Coughlin della Selva, 1996; Frederickson, 2013)
Emotion recognition	Enhancing awareness of emotions	- Identification, Labeling - Enhancing bodily awareness - Helping to observe emotions - Differentiating feelings from anxiety and defenses - Differentiating true feelings from defensive affects	Emotion Focused Therapy, EFT (Greenberg and Watson, 2005) AEDP (Fosha, 2000) ISTDP (Davanloo, 1990, 2000; Coughlin della Selva, 1996; Frederickson, 2013)
Emotion expression	Enhance capacity to express feelings while feeling them	- Experiencing feeling physically in the body - Experiencing the impulse physically in the body - Building affect tolerance - Imaginative portraiting of the impulse	ISTDP (Davanloo, 1990, 2000; Coughlin della Selva, 1996; Frederickson, 2013)

a specific example where his feelings were dysregulated. The therapist helps patients see and let go of these defenses until they offer a clear, specific example (Frederickson, 2013). This task requires specific skills: maintaining an effective focus, recognizing defenses, regulating anxiety when necessary, identifying the price of the defenses, and encouraging the patient to stay on task: offering a specific example (see **Table 3** and Frederickson, 2013, for a review of these techniques).

Phase 2: Regulatory Mechanism Enhancement

Once the patient offers a specific example, the therapist explores feelings. In response, the patient responds with either anxiety or defenses. By assessing the activation of the somatic and autonomic nervous systems described above in **Table 1**, the therapist can: (1) assess when anxiety is too high: it goes out of the somatic nervous system into the parasympathetic branch of the autonomic nervous system; (2) know when affect is dysregulated by anxiety: feeling is accompanied by the symptoms generated by the parasympathetic nervous system; (3) differentiate physiological activation of feeling from anxiety symptoms to help the patient become more regulated; and (4) assess the degree of anxiety the patient is suffering by noticing the physical symptoms: low-somatic nervous system activation; too high–parasympathetic nervous system activation.

Phase 3: Dysregulatory Mechanism Reduction or Blocking

Once the emotion has been unconsciously elicited in session, anxiety and defenses will result. Patients with DASs will experience either excessive anxiety which dysregulates or defenses which create dysregulated defensive affects. In this phase, the therapist may: (1) helps patient regulate their anxiety so true feelings can be experienced; (2) block the defenses that ward off feelings; (3) help patients differentiate feeling from anxiety and from defense (4) help patients differentiate a true feeling from a defensive affect. Dynamic-experiential techniques can be used to regulate anxiety or deactivate dysregulating defenses that cause DAS (See **Table 4**; Frederickson, 2013).

Phase 4: Full Emotional Expression and Elaboration

Once the DAS are resolved, the underlying true feelings which trigger anxiety should be fully experienced and expressed. During phase four, patients must be encouraged to experience their emotions in the body and to express the associated impulse (see Davanloo, 1990; Coughlin della Selva, 1996; McCullough, 1997; Davanloo, 2000; McCullough et al., 2003; Frederickson, 2013). Then patients can feel their feelings without being dysregulated.

CONCLUSION

In the present paper, we explored the issue of emotion regulation inside psychodynamic approaches and how concepts of anxiety and defenses may be useful to understand patients' DAS and we provided a framework and methodology for an Experiential-Dynamic Emotion Regulation Methodology (EDER) that incorporate emotion regulation science principles into psychodynamic psychotherapy.

A number of studies in the field of experimental psychology and affective neuroscience have collected evidence that emotion regulation strongly contributes to psychological health (Aldao et al., 2010; Hu et al., 2014) and that some strategies produce better health outcome than others (Gross, 2002; Gross and John, 2003). Here, we extend these studies by considering another important element that determines the adaptiveness of emotion regulation: the differentiation between original emotion and DAS. Physiological emotions should be expressed and a regulatory function is not necessarily required, whereas dysregulated states require regulation due to their negative contribution to individual adaptation to the environment. At the clinical level, this has important implications. The therapist should promote the expression of original emotions and block DASs.

Thus, the concepts of emotion regulation and dysregulation are consistent with the psychodynamic view of affective disorders and their therapy. In addition to cognitive-behavioral methods of emotion regulation, we include psychodynamic forms of emotion regulation. We noted that the use of techniques that implicitly involve emotion regulation could be more effective than the use of voluntary emotion regulation strategies. Indeed, in some cases voluntary emotion regulation strategies may compromise the free expression of original emotions.

Despite the explicit reference to ISTDP, we consider that the EDER concepts and techniques may be usefully incorporated into any other psychotherapy models when working with patients suffering from DASs. EDER principles offer a trans-theoretical approach for the understanding of situations that require the building of the capacities for emotion tolerance and regulation, and anxiety regulation. EDER techniques may be used to enhance emotion tolerance as an alternative to cognitive control techniques that may be detrimental when they support emotion avoidance.

Despite such interesting insights concerning theoretical models of psychotherapy, the clinical recommendation of EDER would require an empirical evaluation of the efficacy and tolerability of the model in clinical studies. Other brief psychodynamic approaches have been consistently affirmed as evidence-based therapies (Abbass et al., 2006, 2009; Driessen et al., 2010). Comparative studies are strongly recommended to add to the scientific evidence for the EDER approach, and to identify its specific change mechanisms when compared with other psychodynamic approaches.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

FUNDING

AG has been supported by a grant awarded by The Neuropsychoanalysis Foundation, New York, NY, United States.

REFERENCES

Abbass, A. (2015). *Reaching Through Resistance: Advanced Psychotherapy Techniques*. Kansas: Seven Leaves Press.

Abbass, A., Kisely, S., and Kroenke, K. (2009). Short-term psychodynamic psychotherapy for somatic disorders. *Psychother. Psychosom.* 78, 265–274. doi: 10.1159/000228247

Abbass, A. A., Hancock, J. T., Henderson, J., and Kisely, S. R. (2006). Short-term psychodynamic psychotherapies for common mental disorders. *Cochrane Database Syst. Rev.* 4:CD004687. doi: 10.1002/14651858.CD004687.pub3

Aldao, A., and Nolen-Hoeksema, S. (2010). Specificity of cognitive emotion regulation strategies: a transdiagnostic examination. *Behav. Res. Ther.* 48, 974–983. doi: 10.1016/j.brat.2010.06.002

Aldao, A., Nolen-Hoeksema, S., and Schweizer, S. (2010). Emotion-regulation strategies across psychopathology: a meta-analytic review. *Clin. Psychol. Rev.* 30, 217–237. doi: 10.1016/j.cpr.2009.11.004

Barlow, D. H. (2002). *Anxiety and Its Disorders*, 2nd Edn. New York, NY: Guilford Press.

Barlow, D. H., Farchione, T. J., Fairholme, C. P., Ellard, K. K., Boisseau, C. L., Allen, L. B., et al. (2011). *Unified Protocol for Transdiagnostic Treatment of Emotional Disorders: Therapist Guide*. New York, NY: Oxford University Press.

Bateman, A., and Fonagy, P. (2006). *Mentalization Based Treatment of Borderline Personality Disorder*. Oxford: Oxford University Press. doi: 10.1093/med/9780198570905.001.0001

Berking, M., Wupperman, P., Reichardt, A., Pejic, T., Dippel, A., and Znoj, H. (2008). Emotion regulation skills as a treatment target in psychotherapy. *Behav. Res. Ther.* 46, 1230–1237. doi: 10.1016/j.brat.2008.08.005

Bowlby, J. (1980). *Attachment and Loss, Volume Two: Separation—Anxiety and Anger*. New York, NY: Basic Books.

Buhle, J. T., Silvers, J. A., Wager, T. D., Lopez, R., Onyemekwu, C., Kober, H., et al. (2013). Cognitive reappraisal of emotion: a meta-analysis of human neuroimaging studies. *Cereb. Cortex* [Epub ahead of print].

Coughlin della Selva, P. (1996). *Intensive Short-term Dynamic Psychotherapy. Theory and practice*. New York, NY: John Wiley & Sons.

Cramer, P. (1998). Defensiveness and defense mechanisms. *J. Pers.* 66, 879–894. doi: 10.1111/1467-6494.00035

Dadomo, H., Grecucci, A., Giardini, I., Ugolini, E., Carmelita, A., and Panzeri, M. (2016). Schema therapy for emotional dysregulation: theoretical implication and clinical application. *Front. Psychol.* 7:1987. doi: 10.3389/fpsyg.2016.01987

Damasio, A. (1999). *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*. New York, NY: Harcourt Press.

Davanloo, H. (1990). *Unlocking the Unconscious*. Chichester: John Wiley & Sons.

Davanloo, H. (2000). *Intensive Short-term Dynamic Psychotherapy: Selected Papers of Habib Davanloo*. Chichester: John Wiley & Sons.

Driessen, E., Cuijpers, P., de Maat, S. C., Abbass, A. A., de Jonghe, F., and Dekker, J. J. (2010). The efficacy of short-term psychodynamic psychotherapy for depression: a meta-analysis. *Clin. Psychol. Rev.* 30, 25–36. doi: 10.1016/j.cpr.2009.08.010

Ehring, T. (2013). Editorial special issue: 'emotion regulation and psychopathology'. *J. Exp. Psychopathol.* 4, 448–450. doi: 10.1177/204380871300400501

Eippert, F., Veit, R., Weiskopf, N., Erb, M., Birbaumer, N., and Anders, S. (2007). Regulation of emotional responses elicited by threat-related stimuli. *Hum. Brain Mapp.* 28, 409–423. doi: 10.1002/hbm.20291

Ekman, P. (2003). *Emotions Revealed: Recognizing Faces and Feelings to Improve Communication and Emotional Life*. New York, NY: Oxford University Press.

Fosha, D. (2000). *The Transforming Power of Affect*. New York, NY: W.W. Norton.

Frederickson, J. (2013). *Co-Creating Change: Effective Dynamic Therapy Techniques*. Kansas, MO: Seven Leaves Press.

Freud, A. (1936). *The Ego and the Mechanisms of Defense*. Madison, CT: International Universities Press.

Freud, S. (1959a). *Inhibitions, Symptoms, Anxiety*, ed. J. Strachey (New York, NY: Norton).

Freud, S. (1959b). *The Ego and the Id*, ed. J. Strachey (New York, NY: Bantam Books).

Frijda, N. (1986). *The Emotions*. Cambridge: Cambridge University Press.

Gratz, K. L., Tull, M. T., Matusiewicz, A. M., Breetz, A. A., and Lejuez, C. W. (2013). Multimodal examination of emotion regulation difficulties as a function of co-occurring avoidant personality disorder among women with borderline personality disorder. *Pers. Disord.* 4, 304–314. doi: 10.1037/per0000020

Grecucci, A. (2012). *Il Conflitto Epistemologico. Psicoanalisi e Neuroscienze Dei Processi Anticonoscitivi*. Francavilla: Edizioni Psiconline.

Grecucci, A., Chiffi, D., Di Marzio, F., Frederickson, J., and Job, R. (2016a). *Anxiety and Its Regulation: Neural Mechanisms and Regulation Techniques According to the Experiential-Dynamic Approach, in Anxiety Disorders*, ed. F. Durbano (Rijeka: InTech publishing).

Grecucci, A., Rubicondo, D., Siugzdaite, R., Surian, L., and Job, R. (2016b). Uncovering social deficits in autistic individuals: a source-based morphometry study. *Front. Neurosci.* 31:388. doi: 10.3389/fnins.2016.00388

Grecucci, A., Frederickson, J., and Job, R. (2017). Editorial: advances in emotion regulation: from neuroscience to psychotherapy. *Front. Psychol.* 8:985. doi: 10.3389/fpsyg.2017.00985

Grecucci, A., Giorgetta, C., Bonini, N., and Sanfey, A. G. (2013a). Living emotions, avoiding emotions: behavioral investigation of the regulation of socially driven emotions. *Front. Psychol.* 3:616. doi: 10.3389/fpsyg.2012.00616

Grecucci, A., Giorgetta, C., Bonini, N., and Sanfey, A. G. (2013b). Reappraising social emotions: the role of inferior frontal gyrus, temporo-parietal junction and insula in interpersonal regulation. *Front. Hum. Neurosc.* 7:523. doi: 10.3389/fnhum.2013.00523

Grecucci, A., Giorgetta, C., van Wout, M., Bonini, N., and Sanfey, A. G. (2013c). Reappraising the ultimatum: an fMRI study of emotion regulation and decision-making. *Cereb. Cortex* 23, 399–410. doi: 10.1093/cercor/bhs028

Grecucci, A., and Job, R. (2015). Rethinking reappraisal: insights from affective neuroscience. *Behav. Brain Sci.* 38:e102. doi: 10.1017/S0140525X14001538

Grecucci, A., and Sanfey, A. G. (2014). "Emotion regulation and decision making," in *Handbook of Emotion Regulation*, ed. J. J. Gross (New York, NY: Guilford Press), 140–153.

Grecucci, A., Thneuick, A., Frederickson, J., and Job, R. (2015). "Mechanisms of social emotion regulation: from neuroscience to psychotherapy," in *Handbook on Emotion Regulation: Processes, Cognitive Effects and Social Consequences*, ed. M. L. Bryant (New York, NY: Nova Publishing).

Greenberg, L. S., and Watson, J. C. (2005). *Emotion-Focused Therapy for Depression*. Washington, DC: American Psychological Association.

Gross, J. J. (1998). The emerging field of emotion regulation: an integrative review. *Rev. Gen. Psychol.* 2, 271–299. doi: 10.1037/1089-2680.2.3.271

Gross, J. J. (2002). Emotion regulation: affective, cognitive, and social consequences. *Psychophysiology* 39, 281–291. doi: 10.1017/S0048577201393198

Gross, J. J. (ed.) (2014). *Handbook of Emotion Regulation*, 2nd Edn. New York, NY: Guilford Press.

Gross, J. J., and John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and wellbeing. *J. Pers. Soc. Psychol.* 85, 348–362. doi: 10.1037/0022-3514.85.2.348

Hartmann, H. (1964). *Ego Psychology and the Problem of Adaptation*. New York, NY: International Universities Press.

Hu, T., Zhang, D., Wang, J., Mistry, R., Ran, G., and Wang, X. (2014). Relation between emotion regulation and mental health: a meta-analysis review. *Psychol. Rep.* 114, 341–362. doi: 10.2466/03.20.PR0.114k22w4

Jackson, D. C., Malmstadt, J. R., Larson, C. L., and Davidson, J. (2000). Suppression and enhancement of emotional responses to unpleasant pictures. *Psychophysiology* 37, 515–522. doi: 10.1017/S0048577200990401

Kernberg, O. F. (1984). *Severe Personality Disorders*. New Haven, CT: Yale University Press.

Kernberg, O. F. (1996). "A psychoanalytic theory of personality disorder," in *Major Theories of Personality Disorders*, eds J. F. Clarkin and M. Lenzenweger (New York, NY: Guilford Press).

Kring, A. M., and Werner, K. H. (2004). "Emotion regulation and psychopathology," in *The Regulation of Emotion*, eds P. Philippot and R. S. Feldman (Hove: Psychology Press), 359–385.

Lazarus, R. S., and Folkman, S. (1984). *Stress, Appraisal and Coping*. New York, NY: Springer.

LeDoux, J. (1998). *The Emotional Brain*. London: Weidenfeld and Nicolson.

Linehan, M. (1993a). *Cognitive-Behavioral Treatment of Borderline Personality Disorder*. New York, NY: Guilford Press.

Linehan, M. (1993b). *Skills Training Manual for Treating Borderline Personality Disorder*. New York, NY: Guilford Press.

Malan, D. H. (1979). *Individual Psychotherapy and the Science of Psychodynamics*. London: Butterworth-Heinemann.

McCullough, L. (1997). *Changing Character: Short-term Anxiety-regulating Psychotherapy for Restructuring Defenses, Affects, and Attachment*. New York, NY: Basic Books.

McCullough, L., Kuhn, N., Andrews, S., Kaplan, A., Wolf, J., and Hurley, C. (2003). *Treating Affect Phobia: A Manual for Short-Term Dynamic Psychotherapy*. New York, NY: Guilford Press.

Mennin, D. S., and Fresco, D. M. (2009). "Emotion regulation as an integrative framework for understanding and treating psychopathology," in *Emotion Regulation in Psychopathology: A Transdiagnostic Approach to Etiology and Treatment*, eds A. M. Kring and D. M. Sloan (New York, NY: Guildford Press), 356–379.

Mennin, D. S., and Fresco, D. M. (2014). "Emotion Regulation Therapy," in *Handbook of Emotion Regulation*, 2nd Edn, ed. J. J. Gross (New York, NY: The Guilford Press), 469–490.

Messina, I., Bianco, F., Cusinato, M., Calvo, V., and Sambin, M. (2016a). Abnormal default system functioning in depression: implications for emotion regulation. *Front. Psychol.* 7:858. doi: 10.3389/fpsyg.2016.00858

Messina, I., Sambin, M., Beschoner, P., and Viviani, R. (2016b). Changing views of emotion regulation and neurobiological models of the mechanism of action of psychotherapy. *Cogn. Affect. Behav. Neurosci.* 16, 571–587. doi: 10.3758/s13415-016-0440-5

Messina, I., Bianco, S., Sambin, M., and Viviani, R. (2015). Executive and semantic processes in reappraisal of negative stimuli: insights from a meta-analysis of neuroimaging studies. *Front. psychol.* 6:956. doi: 10.3389/fpsyg.2015.00956

Messina, I., Sambin, M., Palmieri, A., and Viviani, R. (2013). Neural correlates of psychotherapy in anxiety and depression: a meta-analysis. *PLoS One* 8:e74657. doi: 10.1371/journal.pone.0074657

Ochsner, K. N., and Gross, J. J. (2005). The cognitive control of emotion. *Trends Cogn. Sci.* 9, 242–249. doi: 10.1016/j.tics.2005.03.010

Panksepp, J. (1998). *The Origins of Affective Neuroscience: The Foundations of Human and Animal Emotions*. Oxford: Oxford University Press.

Pappaianni, E., Siugzdaite, R., Vettori, S., Venuti, P., Job, R., and Grecucci, A. (2018). Three shades of grey: detecting brain abnormalities in children with autism by using Source-, Voxel- and Surface-based Morphometry. *Eur. J. Neurosci.* 47, 690–700. doi: 10.1111/ejn.13704

Paulhus, D. L., Fridhandler, B., and Hayes, S. (1997). "Psychological defense: contemporary theory and research," in *Handbook of Personality Psychology*, eds R. Hogan, J. A. Johnson, and S. R. Briggs (New York, NY: Guilford Academic Press), 543–579. doi: 10.1016/B978-012134645-4/50023-8

Porges, S. (2011). *The Polyvagal Theory: Neurophysiological Foundations of Emotions, Attachment, Communication, and Self-regulation*. New York, NY: W.W. Norton.

Ray, R. D., Ochsner, K. N., Cooper, J. C., Robertson, E. R., Gabrieli, J. D., and Gross, J. J. (2005). Individual differences in trait rumination and the neural systems supporting cognitive reappraisal. *Cogn. Affect. Behav. Neurosci.* 5, 156–168. doi: 10.3758/CABN.5.2.156

Robertson, D., Biaggioni, I., Burnstoc, G., Low, P. A., and Paton, J. F. R. (eds) (2004). *Primer on the Autonomic Nervous System*. Amsterdam: Elsevier Academic Press.

Sapolsky, R., Uno, H., Rebert, C., and Finch, C. (1990). Hippocampal damage with prolonged glucocorticoid exposure in primates. *J. Neurosci.* 10, 2897–2902. doi: 10.1523/JNEUROSCI.10-09-02897.1990

Schore, A. (2003). *Affect Regulation and the Repair of the Self*. New York, NY: W.W. Norton and Co.

Schulze, L., Domes, G., Kruger, A., Berger, C., Fleischer, M., Prehn, K., et al. (2011). Neuronal correlates of cognitive reappraisal in borderline patients with affective instability. *Biol. Psychiatry* 69, 564–573. doi: 10.1016/j.biopsych.2010.10.025

Sullivan, H. S. (1953). *The Interpersonal Theory of Psychiatry*. New York, NY: W W Norton & Co.

Ten Have-de Labije, J., and Neborsky, R. (2012). *Mastering Intensive Short-term Dynamic Psychotherapy: A roadmap to the Unconscious*. London: Karnac Books.

Thayer, J. F., and Lane, R. D. (2000). A model of neurovisceral integration in emotion regulation and dysregulation. *J. Affect. Disord.* 61, 201–216. doi: 10.1016/S0165-0327(00)00338-4

Tomkins, S. (1962). *Affect, Imagery, Consciousness, Volume One: The Positive Affects*. New York, NY: Springer.

Wehrenberg, M., and Prinz, S. (2007). *The Anxious Brain: The Neurobiological Basis of Anxiety Disorders and how to Effectively Treat them*. New York, NY: W.W. Norton.

Werner, K., and Gross, J. J. (2010). "Emotion regulation and psychopathology: A conceptual framework," in *Emotion Regulation and Psychopathology*, eds A. Kring and D. Sloan (New York, NY: Guilford Press), 13–37.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

HYPOTHESIS AND THEORY
published: 14 January 2019
doi: 10.3389/fpsyg.2018.02475

Psychoanalysis and Affective Neuroscience. The Motivational/Emotional System of Aggression in Human Relations

Teodosio Giacolini and Ugo Sabatello*

Department of Human Neuroscience, Sapienza University of Rome, Rome, Italy

This article highlights the evolutionary biological epistemology in Freud psychoanalytic theory. The concepts of aggressive and sexual drives are cornerstones of the psychoanalytic epistemological system, concerning the motivational/emotional roots of mental functioning. These biological roots of mental functioning, especially with regard to aggressive drive, have gradually faded away from psychoanalytic epistemology, as we show in this article. Currently, however, Neurosciences, and in particular Affective Neuroscience (Panksepp, 1998), can help us to have a better understanding of the biological roots of human mental functioning. The motivational/emotional systems studied by Affective Neuroscience can give a new epistemological foundation to the aggressive drive concept in psychoanalytic theory. Over the course of human evolution, motivational/emotional systems have played a role in social relationships and also in mental functioning. In this regard, among the various types of aggression (ANGER in Panksepp taxonomy 1998) that we consider in our article, *inter-male* aggression, also named *Dominance motivational/emotional system*, is that which regulates social interactions between sexually matured adults. This type of aggression acts in complementary connection with FEAR motivational/emotional system that regulate submissive behavior and social defeat, and the latter one is of the more important stressors. The interaction between aggression and FEAR motivational/emotional systems gives rise to agonistic behavior or dominance/submission motivational/emotional system, as we propose in our article. There is now a large literature that identifies in the dynamic of *Competitive behavior*, which is one of the main factors of mental illness. When social interactions activate the competitive behavior, the subject can perceive himself as "destined to victory" or "destined to defeat," activating either behaviors or emotions connected to the *Involuntary Defeat Strategy* or *Involuntary Dominant Strategy* (Sloman, 2002), which we can find in many types of mental disorders, for example, mood disorders or anxiety disorders.

Keywords: adolescence, aggression, motivational system, dominance, submission

OPEN ACCESS

Edited by:
Anatolia Salone,
Università degli Studi G. d'Annunzio Chieti e Pescara, Italy

Reviewed by:
Brian Johnson,
Upstate Medical University, United States
Andrea Clarici,
University of Trieste, Italy

****Correspondence:***
Teodosio Giacolini
teodosio.giacolini@uniroma1.it

Specialty section:
This article was submitted to Psychoanalysis and Neuropsychoanalysis, a section of the journal Frontiers in Psychology

Received: *28 August 2018*
Accepted: *21 November 2018*
Published: *14 January 2019*

Citation:
Giacolini T and Sabatello U (2019) Psychoanalysis and Affective Neuroscience. The Motivational/Emotional System of Aggression in Human Relations. Front. Psychol. 9:2475. doi: 10.3389/fpsyg.2018.02475

INTRODUCTION

In the history of psychoanalysis, *aggression* has progressively acquired a central importance. The psychodynamics of *libido* dominated and characterized the very identity of the psychoanalytic movement from the beginning (Freud, 1895, 1905). Very soon after the initial study of *libido, aggression* (Freud, 1920) became the ineradicable complement, an element of mental functioning fundamental to understand both normal and pathological functioning. Between the two concepts, however, there was a profound difference from the beginning. Libido has been a concept that has derived its heuristic strength from having its biological base in sexuality. Aggressiveness, on the other hand, has implicated in psychoanalytic theory an initial tendency to trace back into the biological sciences the roots of its presence in the human species, as will be highlighted in the present work, but only then to be clearly eradicated in favor of an option not shared by the biological sciences and which has increased the psychological vertex of psychoanalysis. The trend of the theorization of *aggression* in Freud proposes, in some respects, the parable of the theory of normal and pathological mental functioning in his thought, first based on a biological assumption, the instinctual and neurological one (Freud, 1895), subsequently largely abdicated and replaced by the psychological *structural model* (Freud, 1923). The latter was affirmed on the assumption, increasingly supported by Freud after the famous assertion of inability to pursue a neurological vertex (1895) in the study of unconscious dimension of the mind, and the only way it could be explored would be through the elaboration of psychological theories, that are definable and verifiable through clinical work. This methodological position of Freud, understandable and shareable for the historical period in which he operated, has become a *dogma* for the psychoanalytic community. Hence the difficulties that psychoanalytic theory currently has in receiving and using neuroscientific discoveries, which mainly reside in the lack of *epistemology*, thus preventing the link of psychopathological and clinical theories with the new discoveries of basic research.

An important contribution to the construction of this *epistemological ring* was given by the work of Bowlby (1969). Bowlby, as he is known, wanted to refound the psychoanalytic theory starting from the instincts from which Freud had started and from Darwin's lesson that is the *comparative psychology*. It should be remembered, as already indicated by Bowlby (1969), that in the second half of the twentieth century, disciplines were established that did not exist at the time of Freud, that is, ethology and neuroethology (from which derives *Affective Neuroscience*; Panksepp, 1998). These disciplines share an element that can be traced even in the foundations of psychoanalysis, the rooting in the evolutionary format. The evolutionary epistemology (Campbell, 1975; Lorenz, 1977) has demonstrated, especially now with the rapid development of neuroscience, to have an exceptional heuristic power, able to provide that link between the *BrainMind* (Panksepp, 1998) physiological functioning and the psychopathology.

Freud and Evolution

Freud began the study of psychopathology as a convinced environmentalist, believing that the external environment provoked mental disturbances, especially *via* sexual experiences (see Freud's seduction theory). This theory coincided with similar theories stated by other psychiatrists and sexologists of the same era (Von Krafft-Ebing, Binet, Havelock Ellis, Moll, etc.) that suggested that sexuality was the principle cause of mental disorders (Sulloway, 1979). Why the sexual experiences were considered potential origin of mental disorders? The sexual instinct, considered responsible for psychopathologies, was a theory derived by Darwin during the late nineteenth century. The great English biologist had identified and brought to the attention of the scientific world two factors that regulate the relational life of the animals and also of the human species: *natural selection* (Darwin, 1859) based on the *instinct of self-preservation* and *sexual selection* (Darwin, 1871). In the dynamic between these two instincts, post-Darwinian psychiatry identified the genesis of the various forms of psychopathology. Toward the end of the nineteenth century, however, the interest in the study of sexual instinct became more and more prevalent. Hence, the development of sexology and the parallel tendency is to see the primary cause of mental distress in the sexual instinct. The explanation of this point of view is attributable, at least in part, to the work of Darwin (Sulloway, 1979), who had argued that the reproductive system was that particularly subject to variation: "Several reasons make me believe in this; but the chief one is the remarkable effect which confinement or cultivation has on the functions of the reproductive system; nothing is more easy than to tame an animal, and few things more difficult than to get it to breed freely under confinement, even in the many cases when the male and female unite" (Darwin, 1859, p. 8).

Freud was profoundly influenced by the Darwinian and post-Darwinian culture of his time. We summarize some dates and events. Freud was born in 1856. In 1859, Darwin published the *Origin of the species*; in 1871, *Origin of man*; and in 1872, *The expression of emotions in humans and animals*. In 1873, Freud enrolled in the medical faculty of the University of Vienna and the first voluntary course he followed was entitled "General Biology and Darwinism" (Sulloway, 1979). The interest in Darwinian biology prompted Freud's desire, at the beginning of his scientific training, to become a research biologist (Jones, 1953; Anzieu, 1976). Freud spent many years in the laboratory of Professor Ernst Brücke (1819–1892), biologist and physiologist, with the hope of becoming a researcher at his university chair, but unfortunately came to no avail. During those years, Freud carried out some important research on the neuroanatomy of the *ammocoete (Petromyzon planeri)* larval form of stream lamprey, on the structure of the eel gonads, and a study of the *crayfish* nerve cells, as well as the processing of cell staining methods for histological research. Freud devoted a lot of time and study to *comparative biology* subsequently failing to reach a professional level in medicine. Hence, his orientation is toward the more limited field of neurology and psychiatry. Psychoanalysis was born, therefore, "from a failed biologist" (Sulloway, 1979). But it was during this psychoanalytic prehistory of Freud's intellectual life that the neurobiological and evolutionary format of his psychotherapeutic creature took root, roots that can be powerfully revived by current neuroscience.

Darwin's influence on Freud's thoughts is particularly visible in his dual instinctual theory. In fact, Freud elaborated a motivational

theory of dual-type drives, analogous to that of the English biologist. This drive dualism would be present transversely throughout his work.

Freud very soon opposed the *sexual libido* (which pushes the subject to sexual satisfaction even at the risk of one's own personal protection) to *the instincts of self-preservation*. With this last term, Freud designated the set of needs linked to the somatic functions necessary for the individual preservation of the life. The prototype of such drives is hunger. In *The Psycho-Analytic View of Psychogenic Disturbance of Vision* (Freud, 1910), Freud speaks briefly, for the first time, of both *sexual drive* and *the instincts of self-preservation*. Freud in his work *Three Essays on Sexuality* (Freud, 1905) had already pointed out how: "…sexual instincts. At their first appearance they are attached to the instincts of self-preservation…" (Freud, 1915a, p. 125), like the feeding instinct. Freud has never extensively discussed *the instincts of self-preservation* (see Laplanche and Pontalis, 1967), merely referring to hunger and other great somatic functions such as defecation, urination, muscular activity, etc. In 1911, Freud in *Formulations on the Two Principles of Mental Functioning* states that *the instincts of self-preservation* can be satisfied only with a real object, making a rapid transition from the *Pleasure Principle* to *Reality Principle*, while the sexual drives can continue to be satisfied also by fantasy (Freud, 1911, p. 222). One aspect of *the instincts of self-preservation*, connected to the one described above, is characterized by *fixed objects* and *instinctual aims* (see "fixed action patterns" Tinbergen, 1951; Lorenz, 1981), and this feature brings them closer to the concept of *Instinkt* than to that of *Trieb* (drive). Freud quotes "If inherited mental formations exist in the human being—something analogous to instinct in animals—these constitute the nucleus of the Ucs" (Freud 1915b, p. 194). (In German tradition, Tribe is the term for naming instinct in humans, whereas Instinkt is reserved to nominate instinct in animals). On the contrary, for Freud, the sexual drives (*Trieb*) are characterized by a relative indeterminate pressure that can be expressed in different ways, and its aim can be achieved through different actions. *The self-preservation instincts* for maintaining the physical integrity of the individual were named *Ego instincts* (Freud, 1910) by Freud, who emphasized their being in conflict with sexual drives. Freud quotes "From the point of view of our attempted explanation, a quite especially important part is played by the undeniable opposition between the instincts which subserve sexuality, the attainment of sexual pleasure, and those other instincts, which have as their aim the self-preservation of the individual—the ego-instincts. As the poet has said, all the organic instincts that operate in our mind may be classified as 'hunger' or 'love'" (Freud, 1910, pp. 213–214). With the conflict between ego and sexuality, Freud reiterated the Darwinian dialectic between natural selection, which is concerned with the preservation of the fittest individual, and the sexual one, which aims to conserve the species: "The individual does actually carry on a twofold existence: one to serve his own purposes and the other as a link in a chain, which he serves against his will, or at least involuntarily… The separation of the sexual instincts from the ego-instincts would simply reflect this twofold function of the individual" (Freud, 1914, p. 78).

And, in another famous passage, Freud points out to be deeply permeated by Darwinian ideas, he states "I should like at this point expressly to admit that the hypothesis of separate ego-instincts and sexual instincts (that is to say, the libido theory) rests scarcely at all upon a psychological basis, but derives its principal support from biology" (Freud, 1914, p. 79).

In the years between 1910 and 1915, Freud completed his *First Drive Theory*, and during this period, he wrote an important book *Totem and Taboo* (Freud, 1912–13). In this work, and also in latter books such as *The Future of an Illusion* (Freud, 1927) and *Moses and Monotheism* (Freud, 1939), Freud showed his interest in the *evolutionary-anthropological thought* (Sulloway, 1979) and for the possibilities that it provides to be able to reconstruct the roots of human mental operations. In *Totem and Taboo*, Freud takes up the hypothesis formulated by Darwin in *The origin of man* (Darwin, 1871), on the beginnings of *homination*, in which the human species must have lived in hordes, led by a strong and powerful male, who controlled access to females of younger and subordinate males. The young and subordinate males were forced to move away from the group in order to copulate and consequently form new hordes. It was hypothesized that the birth of exogamy, which practically characterizes most cultures, was a derivative of these interactive dynamics. Freud made this reconstruction his own, which he enriched with the hypothesis of parricide by the group of young allied males, from which the birth of the totemic religion as a remedial act of the primordial event. *Totem and taboo*, therefore, highlights in an extremely clear way, Freud's effort to build clinical psychoanalysis on the foundation of an *evolutionary-anthropological thought*, enabling Freud to answer crucial questions on both clinical work and the development of psychoanalytic theory. Previous attempts to respond to these problems through a purely neurophysiological explanation precociously failed, as evidenced by the *Project for a Scientific Psychology* (Freud, 1950 [1895]). From that moment on, Freud sought answers to these and other problems, no longer in a neurophysiological reductionism, impossible to practice in his time, but in a historical-evolutionary model (Sulloway, 1979). Freud writes about the question on the causes of neurosis: "I am prepared with an answer which I know will seem daring to you. I believe these primal phantasies, as I should like to call them, and no doubt a few others as well, are a phylogenetic endowment. In them the individual reaches beyond his own experience into primaeval experience at points where his own experience has been too rudimentary. It seems to me quite possible that all the things that are told to us today in analysis as phantasy—the seduction of children, the inflaming of sexual excitement by observing parental intercourse, the threat of castration (or rather castration itself)—were once real occurrences in the primaeval times of the human family, and that children in their phantasies are simply filling in the gaps in individual truth with prehistoric truth. I have repeatedly been led to suspect that the psychology of the neuroses has stored up in it more of the antiquities of human development than any other source" (Freud, 1916, pp. 370–371). This model was strongly impregnated, as we see, from the *Second Law of Inheritance of acquired characteristics*, the pre-Darwinian evolutionary theory of Lamarck's (1744–1829), that is, the repeated historical experiences are deposited in the hereditary patrimony of the species. Thus, Freud identified the roots of the current *Oedipus complex*, at the base of man's neurosis,

in distant human prehistory. Freud wrote about it, also identifying the roots of the mechanism of *repression*: "the children have entered upon a new phase of development in which they are compelled to recapitulate from the history of mankind the repression of an incestuous object-choice, just as at an earlier stage they were obliged to affect an object-choice of that very sort" (Freud, 1919, p. 108).

In *Totem and Taboo* (Freud, 1912–13), Freud does not discuss the problem of *aggression*, but nevertheless he gives an extremely significant evolutionary representation of it. The *story* begins with a dyadic comparison between two males in which the defeated (the young adolescent son) is forced to leave the territory in favor of the stronger one, the father, leader of the group, which we could define as territorial aggressiveness (Archer, 2009). Later on, the *story* tells of "the brothers" allying against the leader, that is, Freud described a new type of competition in which the *aggression* is modulated by the capacity of the contenders in order to create alliances against a common enemy (Flinn et al., 2012). Only after *Totem and Taboo* (Freud, 1912–13), Freud would come to define the problem of *aggression* as explicitly relevant for the self-preservation instincts in *Instincts and their vicissitudes* (Freud, 1915a).

Freud and Aggression

Until 1915, Freud had theorized about *aggression* by linking it to sexuality. Freud was interested in aggressiveness that he was finding in the study of sexual perversions, a topic of extreme relevance in psychiatry of the late nineteenth century, with the famous terms *sadism* and *masochism* coined by the psychiatrist and sexologist R. von Krafft-Ebing (1840–1902). Freud writes "1 [The last two sentences were given their present form in 1915. In 1905 and 1910 they read as follows: 'It may be assumed that the impulses of cruelty arise from sources which are in fact independent of sexuality, but may become united with it at an early stage owing to an anastomosis [cross-connection] near their points of origin. Observation teaches us, however, that sexual development and the development of the instinct of scopophilia and cruelty are subject to mutual influences which limit this presumed independence of the two sets of instincts.']" (Freud, 1905, p. 193). And about the sadism Freud writes "As regards active algolagnia, sadism, the roots are easy to detect in the normal. The sexuality of most male human beings contains an element of aggressiveness—a desire to subjugate; the biological significance of it seems to lie in the need for overcoming the resistance of the sexual object by means other than the process of wooing. Thus sadism would correspond to an aggressive component of the sexual instinct which has become independent and exaggerated and, by displacement, has usurped the leading position" (Freud, 1905, pp. 157–158).

Only in 1913, Freud returned to the problem of *aggression* in *The Disposition to Obsessional Neurosis, a Contribution to the Problem of the Choice of Neurosis* (Freud, 1913), where he introduces the concept of *pre-genital organization*. In it, Freud, speaking of the phase of sexual development in which the subject, who develops later an obsessional neurosis, is fixated, identifies this libidinal stage in the *sadistic-anal organization*. At this stage of the sexual libido development, it is not yet possible to talk about female or male object choice because we are still at a level of pre-genital organization, so it is only possible to talk about trends with an active goal and trends with a passive goal, which will go subsequently to characterize the male and female gender identity. Freud quotes: "Activity is supplied by the common instinct of mastery, which we call sadism when we find it in the service of the sexual function; and even in fully developed normal sexual life it has important subsidiary services to perform. The passive trend is fed by anal erotism, whose erotogenic zone corresponds to the old, undifferentiated cloaca" (Freud, 1913, p. 322). Until then Freud had dealt with the theme of *aggression*, linking it primarily to its function in relation to the sexual drive, which determines its sadistic and secondarily masochistic modalities.

In 1915, Freud in *Instincts and their Vicissitudes* came to the important conclusion about the belonging of the *aggression* to *the instincts of self-preservation* or *Ego instincts*: "Indeed, it may be asserted that the true prototypes of the relation of hate are derived not from sexual life, but from the ego's struggle to preserve and maintain itself" (Freud, 1915a, p. 137). *Aggression* considered as an *instinct of self-preservation* or *Ego instincts* is a conceptual position that completely keeps up with a Darwinian biology viewpoint. But at the same time, Freud describes what he means by hatred, being an effect of unpleasant sensations that are perceived by the ego due to the presence of the external reality objects. During these times, he completely developed the theorization of the first phases of libidinal development through the conceptualization of *narcissism* (Freud, 1914). *Narcissism* is formed at the beginning by pleasurable sensations and followed by identifying gratifying objects of external reality. Freud quotes "Hate, as a relation to objects, is older than love. It derives from the narcissistic ego's primordial repudiation of the external world with its outpouring of stimuli. As an expression of the reaction of unpleasure evoked by objects, it always remains in an intimate relation with the self-preservative instincts; so that sexual and ego-instincts can readily develop an antithesis which repeats that of love and hate. When the ego-instincts dominate the sexual function, as is the case at the stage of the sadistic-anal organization, they impart the qualities of hate to the instinctual aim as well" (Freud, 1914, p. 139). *Aggression* is thus conceptualized as a drive of primary and biological self-preservation, functional to survival for the human organism. At the same time, *aggression* is equated with the effect of hate, a consequence of the external world objects that are a source of perturbation stimuli for the subject. Here, we notice Freud's difficulty in combining a biological-evolutionary vertex with the psychological-speculative one.

In the following years, Freud revised the theory of *drives, second drive theory* being mentioned in the book *Beyond the Pleasure Principle* (Freud, 1920). In this work, Freud shifts *aggression* from the drives of self-preservation to a new drive organization that can be identified with the *Death instincts*. The *instincts of self-preservation* or *Ego instincts*, instead, converge together with the sexual drives in a new great grouping called *Life drives*. Without wishing to enter into a work as controversial as *Beyond the Pleasure Principle* (Freud, 1920), it needs to be mentioned that it was the logical consequence of H. Haeckel's fundamental *Biogenetic law* for which ontogenesis recapitulates phylogeny. Freud pushed these assumptions of the biogenetic theory to the extreme, inferring that if an organism in its development is forced to recross phases of a distant evolution, this implies that an aspect inherent in organic life itself and of the drive

in particular is that of restoring the previous state of things. Freud quotes "It seems, then, that an instinct is an urge inherent in organic life to restore an earlier state of things which the living entity has been obliged to abandon under the pressure of external disturbing forces; that is, it is a kind of organic elasticity, or, to put it another way, the expression of the inertia inherent in organic life" (Freud, 1920, p. 36). In this new theory, the sexual drives no longer conflicted with *the instincts of self-preservation*, but both are part of the *Life drives* except, however, *aggression*. It was removed from *the instincts of self-preservation* and inserted into the *Death instincts,* but with a peculiarity. Only after the combination of *Death instincts* with libidinal ones aimed at the outside world, the disintegrating tendency inherent in the *Death instincts* becomes *aggression* turned toward the objects of the external world. The *Second drive theory* and the concept of the *Death instincts*, therefore, show how Freud thought, while affirming the primacy of the psychological dimension for psychoanalysis, concealing intellectual binary tracks constituted by biological interests and constructs, such as that represented by the *biogenetic law* (Sulloway, 1979). The problem was that these biological assumptions at the base of these last works of Freud not only constitute a kind of cryptobiology (Sulloway, 1979), but also above all they were not shared by the biological sciences contemporary to him.

Aggression in Post-Freudians

The problem of *aggression* has become, as considered above, ever more important in psychoanalytic thinking, as more and more complex mental operations were described, and so more problematic psychopathologies were treated. Let us remember only how the work of Melanie Klein (1882–1960) marked an era close to Freud's death, providing, in the wake of the conceptualization of the *Death instincts,* a theory of *aggression* that placed this drive in a central position in the developmental dynamics of the human mind (Klein, 1932). Klein identified, in the preoedipal and preverbal stages of development, the central moments for the future functioning of the mind, that is the developmental phases in which the importance of the dynamics of the aggressive drive is paramount. This Kleinian and post-Kleinian revolution in considering the aggressive drive from a developmental point of view has allowed, at the same time, a developmental conceptualization of the psychotic states of the mind connected to these very early stages of mental development and therefore the possibility of elaborating hypotheses of cure. *Aggression* has, therefore, been identified as a drive with its developmental and interactive dynamic, implicitly recognizing it as being the manifestation of a biological substrate, without, however, following it with an interest in deepening the knowledge that the natural sciences were supplying about it. One of the consequences of this conceptualization was the progressive sclerosis of the developmental hypothesis, which led to a rigid pathogenic ideology that saw in the relational events of early childhood the causes of mental disorders, looking for the causes of serious discomfort in a problem of *aggression* placed in a mythical initial period of mental life. Currently, this approach is combined with researches that highlight the peculiar contribution of the later developmental moments (see, e.g., Fonagy, 2005, p. 214) and the importance of current interpersonal relationships (Lewis, 1998).

In recent decades, research on the etiopathogenesis of psychopathology has directed its attention to the motivational system of *attachment*, which has shown a high correlation between insecure and disorganized attachments and subsequent mental disorders, in particular, personality disorders (Fonagy, 2001). The massive effort given to research on attachment in recent decades has allowed psychoanalysis to benefit from basic empirical research, but has simultaneously overshadowed the problem of *aggression*. The latter has become a secondary problem regarding the regulation of emotions, which is implicitly considered to be a function of the dynamics of attachment. As a consequence, a sort of theoretical vacuum has been created, in which the blanket of attachment theory has been extended to explain the onset of psychopathology (Cowan and Cowan, 2007), especially in adolescence.

The discovery of the attachment motivational system has shown that the human species, similar to the other mammalian species, are born with biologically innate system that regulates the interactions between parents and offspring. But, there is another biologically innate system, whose function is to regulate interactions among the adults in the mammalian groups, including human species, called *Inter-male aggression* or *Agonistic behavior* (Scott and Fredericson, 1951). This type of *aggression* becomes mature with puberty and replaces the attachment system in the primacy of the regulation of the emotional states in the subject (Stevens and Price 1996), even if the attachment system will stay in function for all the life, for example, in the romantic love or in the adult health difficult moments. The research area that substantiates this theory is, as we will see, widely interdisciplinary and allows us to reframe the broad observations of clinical psychoanalysis on psychopathology with basic research data.

Aggression as a Regulator of Relationships

Briefly we will outline the theoretical scientific area of reference for a deepening of the problem of *aggression*. Evolutionism, identifying the possibility of reconstructing generative lines among different animal species including the human ones (LeDoux, 1996), is responsible for the comparative study of somatic, neurophysiological, behavioral, and emotional functioning (Lorenz, 1963; Panksepp and Biven, 2012). A neurotologist that contributed to a significant increase in the behavior comparative studies was Paul MacLean (MacLean, 1990a,b), universally known for having unified what he himself called in 1952 the *limbic system* (Roxo et al., 2011), the heart of the mammal's and human's emotional system. Paul MacLean developed an evolutionary model of the human nervous system of great heuristic significance which was greatly but not completely shared by the scientific community (Cory, 2002; Panksepp and Northoff, 2009). He identified three brain areas from an anatomical, functional, and phylogenetical perspective, that are connected with evolutionarily related species. The oldest phylogenetical part of the *triune brain* is located in the deepest part of the human brain called the *striatal system* and the *brainstem*, that MacLean calls *Complex R* or *reptilian brain* (MacLean, 1990a,b). Reptiles are characterized by the prevalence of this neuroanatomical structure, which show typical behaviors related to intraspecific communication: *territorial marking, challenge behavior, courtship,*

and submission behavior. MacLean identifies these behaviors as *Paleomentation* (MacLean, 1990a,b, p. 12) to indicate the origins of mental and communicative activity. In fact, the four types of behavior have their meaning only among individuals of the same species, including human species, as we will consider. MacLean identifies, therefore, in the phylogenetically oldest part of the brain, the *R complex*, the oldest structures of the regulation of intra-species *aggression*, which is the *territorial agonism*, from which the agonism for the formation of rank hierarchies will subsequently evolve.

Over the neuronal organization of the *reptilian brain*, a structure called the *limbic system* was evolving and characterized by the presence of *cingulum gyrus, amygdala, hippocampus, parts of the hypothalamus, area of the septum, and nucleus accumbens (part of the striatum)*. The evolution of the limbic system (MacLean, 1985, 1990a,b) allows the offspring to recognize their caregiver. In this way, the individualized recognition of the conspecific (Gherardi et al., 2010) has become an acquisition of mammals and bird species, evolution at the base of the ability to form social networks in which the individual recognizes the other and knows he is recognized by the conspecific. This individual recognition is central, as we will see below, for the formation of dominance hierarchies that structures the group. The *limbic system* characterizes the passing from a herd formed by anonymous individuals, like fish, to mammals in which each social network involves the memory in each participant of the hierarchy in which he/she is inserted.

The R-complex and the *limbic system* form what is currently called *subcortical-cortical midline structures* (SCMS) (Northoff and Panksepp, 2008; Panksepp and Northoff, 2009; Alcaro et al., 2017), homologous structure in mammals and in human species, and considered "the foundation for epigenetic emergence… of selfhood across different individuals within a species" (Panksepp and Northoff, 2009, p. 193).

Finally, a third organization has been increasingly evolving in the course of phylogenesis, consisting of the *neocortex* (MacLean, 1990a,b), of which particular interest is the *cortical midline structures* (CMS) that have intimate functional relationships with the lower structures of the *subcortical-cortical midline structures* (SCMS) (Northoff and Panksepp, 2008; Panksepp and Northoff, 2009) in the development of the selfhood.

Motivational/Emotional Systems

Affective Neuroscience, a term coined by Panksepp (1998), the ideal continuator of MacLean's work (Panksepp and Northoff, 2009), has in these last twenty years highlighted the presence of multiple motivational/emotional systems which, not only regulate the adaptation of species—including human species—to the environment, but also to the social environment (Liotti and Gilbert, 2011). There is now the knowledge of the neuronal circuits, the neuromediators, and the hormone components involved in these systems (Panksepp, 1998). The motivational/emotional systems identified and on which there is scientific consensus are SEEKING (capitalization is a convention established by Panksepp for labeling neurologically based emotional primes), LUST, RAGE, FEAR, maternal CARE, separation-distress PANIC/GRIEF, and physical PLAY (Panksepp, 1998; Solms and Turnbull, 2002; Panksepp and Biven, 2012). These systems can be divided into two large groups. Those with positive emotional value/reward, that is, SEEKING, LUST, maternal CARE, and physical PLAY, characterized by the release of endogenous opioids and activation of the dopaminergic system. Those with negative emotional valence/punishment, that is, RAGE, FEAR, and separation-distress PANIC/GRIEF, characterized by the activation of the stress axis *Hypothalamus-Pituitary-Adrenal Gland.* The motivational/emotional systems described above are believed to be the organizational structure of the human personality (Davis and Panksepp, 2018), and for this reason, a psychological test was carried out for the evaluation of individual personality differences, based on the research indicated above, called *ANPS-Affective Neuroscience Personality Scales* (Davis et al., 2003; Davis and, Panksepp, 2011) validated for the Italian population for both adolescence and adult age (Giacolini et al., 2017).

Alongside the systems described above, there is an eighth system, deriving from the integration of the RAGE and the SEEKING systems and therefore considered nonprimary, called the *Dominance motivational system* (Malatynska et al., 2005; Johnson et al., 2012; Van der Westhuizen and Solms, 2015). The *Dominance* system is in complementary interaction with the *Submissive behavior* (Allan and Gilbert, 1997; Malatynska et al., 2005; De Boer et al., 2016), which is a manifestation of the FEAR emotional system, (Panksepp, 1998, p. 208). Panksepp quotes "It makes good evolutionary sense for FEAR and RAGE circuit to be intimately related, for one of the functions of anger is to provoke fear in competitors, and one of the functions of fear is to reduce the impact of angry behaviors from threatening opponent" (Panksepp, 1998, p. 208). Then, we can speak synthetically of *Dominance and Submissive motivational system*, which regard the same behaviors and has the same functions of *Inter-male aggression* or *Agonistic behavior* (Scott and Fredericson, 1951), and which have the function of regulating access to food and sexual resources among sexually mature conspecifics, including human species. This system matures with the sexual development of puberty, which in particular determines the proliferation of testosterone receptors in the section that goes from *the medial amygdala* to the *lateral hypothalamus* (Derntl et al., 2009).

So, the *Dominance and Submissive system* is characterized by the complementarity of two systems. The *Dominance behaviors* depends on the RAGE system (hence implicated testosterone) and also the SEEKING system (therefore implicated the dopaminergic system; Panksepp, 1998), whereas the *Submissive behavior* depends on the FEAR system (including the stress axis and corticosteroids). The *Submissive behaviors* and emotions are described as Social defeat, which generate persistent stress (Tidey and Miczek, 1997).

RAGE, Aggression, and FEAR

The RAGE system is formed by three types of aggressiveness (Panksepp, 1998; Panksepp and Zellner, 2004): the *predatory aggression*, the *defensive rage*, and finally the *inter-male aggression*.

Predatory aggression does not imply activation of the *autonomic nervous system*, and in fact, it is called a *quiet-biting attack*. This brain system is confluent with another prime emotional system, the mesolimbic dopamine circuit the SEEKING system of Panksepp (1998), which runs from the *ventral tegmental area* through *the lateral hypothalamus* to *the nucleus accumbens* and other *forebrain zones*.

It is interesting what neurobiology discovered about *predatory aggression*, namely that the stimulation of the center of the system that triggers the behavior of predation in felines, the *dorsolateral hypothalamus*, which activates in a noncarnivorous species looking for food or foraging (Panksepp, 1998; Panksepp and Zellner, 2004; Siegel and Victoroff, 2009). Predatory/assertive aggression is subjectively pleasurable (elicit high levels of self-stimulation in animal experiments), and in humans, it could be seen not only in the hunting behavior but also in some pathological behaviors like serial killers, in which there is a positive feeling and a lack of autonomic activation in violence against a victim.

Of particular interest is *defensive rage,* the second type of *aggression* of RAGE system. *Defensive rage,* in contrast to *predatory aggression*, is characterized by a massive activation of the autonomic nervous system, whose effect is the rapid increase in energy availability to allow a rapid strengthening of muscle energy. The defensive aggressiveness is, in fact, activated by situations in which the individual suffers a strong coercion by external agents, but also powerful frustrations of their own motivational purpose (Panksepp, 1998; Panksepp and Zellner, 2004; Siegel and Victoroff, 2009).

The third type o*f aggression* of RAGE system is *inter-male aggression* and is aimed at comparing two contenders in order to establish a priority of access to both food and sexual resources (Bjorkqvist, 2001; Rohde, 2001; Allen and Badcock, 2003). The neural pathways involved in this type of *aggressio*n run from *medial amygdala*, through the *preoptic, anterior hypothalamus area*, until the *periaqueductal gray (PAG*; Panksepp, 1998; Panksepp and Biven, 2012). The arousability of this system is controlled by *testosterone* receptors, of which this circuit is very rich.

The intra-species aggression system works in a complementary way with the FEAR motivational/emotional system. The two systems are functionally connected and form *Dominance* (Van der Westhuizen and Solms, 2015) and *Submissive motivational system* (Stevens and Price, 1996; McGuire and Troisi, 1998; Gilbert, 2000) or *Agonistic behavior* (Scott and Fredericson, 1951; Manning and Dawkins, 2012). Let us consider the FEAR system, this along with the RAGE system, which is responsible for the defense and physical integrity of the individual (Panksepp, 1998; Panksepp and Biven, 2012). Unlike the defensive RAGE system, the FEAR system can manifest itself through two behaviors. The first is activated when the object is far away and avoidable, and in this situation, the animal shows an escape behavior. The other behavior manifests itself when the frightening stimulus is not avoidable and is characterized by immobility, by freezing. The FEAR system is the expression of a neuronal circuit composed of the *lateral and central nuclei of the amygdala* and *the anterior and medial hypothalamus* down to the *periaqueductal gray* (LeDoux, 1996; Panksepp, 1998; Weisfeld, 2002).

The two ancient systems of FEAR and defensive RAGE are closely interconnected at the level of the hypothalamus and the periaqueductal gray, interconnectedness that is maintained at the level of the *amygdala* (Panksepp and Biven, 2012), where they give rise to well-organized distinct circuits (see below). The two circuits thus become functionally interconnected in intra-species *aggression*, therefore becoming complementary. In this way, the behavioral expressions of a*ggression* have acquired the social function of determining in the adversary an emotional state of fear, and the behavioral manifestations of fear have acquired the social function of reducing the activation of the emotional system of anger in the adversary that threatens, pacifying the contender (Price and Sloman, 1987; Gilbert, 1992).

The complementarity of RAGE and FEAR systems is an important stage of phylogeny, made possible by the evolution of the *limbic system*, of which the *amygdala* is one of the parts (Behrendt, 2011). Species that have this extremely rudimentary structure (*amygdala)*, like the most ancient reptiles, do not have the ability to have social life; therefore, the regulation of access to food and sexual resources takes place through a rudimentary *territorial agonism* (Behrendt, 2012). The characteristic of this competitive system is that the competition between two members of the same species ends with one fleeing from the territory on which the other will dominate (Behrendt, 2012).

The evolution of the *limbic system* allowed the individualized recognition of conspecifics among mammal groups. This evolutionary acquisition allowed the two contenders to share the same territory, without one having to flee, but continuing to cooperate for the common defense from predators and to hunt: *Territorial agonism* has turned into a *ritual agonism*. The behaviors of fear manifested by the contender have become the signal of recognition of the superiority of the adversary, the *submissive behavior*, in order to put an end to hostilities. For this purpose, the FEAR system has coopted behavior from other behavioral and emotional systems, for example, the loser shows his willingness to offer himself as a sexual object to the winner as a *submissive behavior* with which to pacify the adversary (Eibl-Eibesfeldt, 1984). The pacification phase is preceded by a real confrontation phase, in which the two adversaries evaluate each other's power. This can happen both at a distance, showing your body, inflating it, placing it in poses that enhance its power to the opponent's eyes, or through a real test of strength at a close range. The fundamental point is that between mammals and birds, in which the ritual agonistic system has evolved, the elimination of the opponent is not foreseen (Lorenz, 1963). The defeated, therefore, manifests his own recognition of the greater power of the adversary and this gives rise to the structuring of what is called *Dominance rank*. The dominance hierarchy implies that high-ranking animals have preferred access to food and mate.

The *Dominance* hierarchy has therefore become the central regulator of the relations between adult individuals in the group of mammals. This structure, to be such and to maintain itself in time, implies that there is a continuous exchange of signs among the members of the group, aimed at maintaining the structural organization of the group. The *submissive behaviors*, described above, thus become part of what are called *yielding subroutines* (Gilbert, 1992; Sloman, 2002) through which the lower-ranking individual constantly signals the recognition of the others superiority. *Yielding subroutines* are based on an active-alert state of high stress characterized by a high concentration of *cortisol*, *low serotonin*, and *testosterone* (Sapolsky, 1983, 1986). Vice versa in the dominant individuals, the presence of *cortisol* is lower, and the concentration of *serotonin* and *testosterone* is higher; therefore, they appear more relaxed but at the same time making losers aware of their dominance through periodic threatening behaviors. These types of behaviors are called *dominance subroutines* (Gilbert, 1992; Allan and Gilbert, 1997).

In the human species, the *Dominant and Submissive motivational/emotional system* is homologous to the one described above. The human emotions homologous to *submissive behaviors* are linked to the impossibility of achieving the goal of domination, that is, Social defeat, which highlights either its own inferiority toward an opponent or the impossibility to achieve a pre-established social purpose (Bjorkqvist, 2001; Rohde, 2001; Allen and Badcock, 2003). The human emotions belonging to the *submissive behaviors* are *fear of judgment, shame, humiliation, sadness from defeat*, and *envy*. The human emotions homologous to dominance behaviors related to the ability to achieve the goal of domination are *anger, triumph, pride, contempt*, and *superiority* (Gardner, 1982; Johnson and Carver, 2012). Evolutionary psychologists and psychiatrists emphasize a further development of the *Agonistic behavior* that is present in primates and especially in the human species. It would consist in the substitution and/or integration of the agonist behavior based on the comparison of the body strength with an agonism based on the ability to create alliances and affiliations, called *hedonic competition* (Chance, 1967; Gilbert, 1992; Price, 1992; Stevens and Price, 1996). The *hedonic competition*, through which the relationships of dominance and rank are structured, is undoubtedly the one most present in human interactions and at the basis of the evaluation of one's own self-esteem. Individuals with greater relational resources or greater intellectual resources are able to attract the attention of other subjects and then they would obtain a more dominant position in the group. It is to note that progressive corticalization of the human species would have been the effect of pressure to solve the problem of group living and therefore of dominance rank (Humphrey, 1976).

The Correlation Between Psychoanalytic Aggression and Affective Neuroscience

Freud, even before explicitly defining aggression as one of the components of the *instinct of self-preservation* or *Ego instincts* (Freud, 1910, 1915a), described the instinct of *cruelty* as intimately connected with the instinct of *appropriation.* Freud quotes "The cruel component of the sexual instinct develops in childhood even more independently of the sexual activities that are attached to erotogenic zones. Cruelty in general comes easily to the childish nature, since the obstacle that brings the instinct for mastery to a halt at another person's pain—namely a capacity for pity—is developed relatively late. The fundamental psychological analysis of this instinct has, as we know, not yet been satisfactorily achieved. It may be assumed that the impulse of cruelty arises from the instinct for mastery and appears at a period of sexual life at which the genitals have not yet taken over their later role" (Freud, 1905, p. 193). Freud describes *cruelty* as an instinct that arises in childhood, from the instinct for *Mastery* (*Bemächtigungstrieb*), that is, from the desire of the subject to take possession and dominate the object, that being the other person. During the first phase of ontogenetic development, *pity* has not yet developed, without which, the sufferance of others cannot be perceived, therefore, cruelty prevails and like in *territorial agonism*, the dominant opponent cannot recognize the submission signals of the defeated contender and so is unable to restrain himself.

In Freud's exposition on *cruelty* (Freud, 1905, p. 193), we can find aspects of the motivational/emotional RAGE system described above, namely the *inter-mail aggression* (*Dominance/Submission motivational/emotional system*) in its primordial form of *territorial agonism*, where the motivational drive for the complete *mastery* of a territory is in force. Another component of the RAGE system is also visible in the instinct of *mastery* and *cruelty*, namely *predatory aggression*. *Predatory aggression* is an appetitive behavior for exploring and mastering prey. *Predatory aggression* springs from the same source of SEEKING behavior (dopaminergic system) and both are subjectively pleasurable and elicit high levels of self-stimulation (Panksepp and Zellner, 2004). Freud again in *The Three Essays on Sexual Theory* puts *impulse of cruelty* to the *instinct of scopophilia* side by side. Freud quotes "sexual development and the development of the instinct of scopophilia and cruelty are subject to mutual influences…" (Freud, 1905, p. 193 footnote 1). Freud seems to suggest that *instinct of scopophilia* (pleasure from looking) is intimately connected to the *impulse of cruelty* and then to the instinct of *mastery*. The SEEKING system has the tools in the sense organs through which the exploratory drive can take place. In the human species, the sight has undoubtedly replaced the importance that the smell has for most of the mammals (Hughes et al., 2014) both in seeking and in the sexuality. But in all the mammals looking and gazing are also means of competitive engagement (Chance, 1967, Baron-Choen, 1995) but also the vehicle to display *submissive behavior* avoiding direct eye contact with the dominant contender (Eibl-Eibesfeldt, 1984). The sense of sight is connected with *envy* (from Latin *invidia*, from *invidere* "regard maliciously, grudge," and from *in-* "into" and *videre* "to see"), which expresses the maliciously intention of taking possession of what a conspecific possesses, as Klein masterly described in the psychoanalytic field *Envy and gratitude* (Klein, 1957). *Envy* is an emotional expression of the subject frustrated in his desire to possess a matter owned by another subject, that is, "the aspirations of the SEEKING system are thwarted…" (Panksepp and Biven, 2012, p. 149); see also the equivalence between SEEKING system and Freud concept of *libido* in Solms and Turnbull, 2002). *SEEKING* system frustrated arouses the *affective attack*, the third component of the RAGE system (see above). The mind of a child or of a psychotic is particularly vulnerable to *envy* in the presence of those who own and enjoy desirable riches (for example, material goods but also intelligence, friendship, etc.). And so *envy* becomes the source of a devastating rage that wants to annihilate those who hold such resources and in turn causes the individual to become paranoid, expecting to receive similar annihilating attacks. This is the mental state described by Klein as a schizo-paranoid position (Klein, 1957). The substitution of the concept of *stage* with *position*, which implies the possibility throughout the mental life of possible oscillations between the two *schizo-paranoid* and *depressive* positions (Bion, 1963), is undoubtedly one of Klein's most interesting conceptualizations. The *schizo-paranoid* versus *depressive positions* are two ways in which the subject's psyche manages the problem of *aggression* (see above) and which can be compared to the oscillations between two types of *social competition*. The *schizo-paranoid position* can be seen as an expression of the archaic, territorial Agonism, in which rage prevails characterized by an aggression aimed at making the other contender disappear from

his own sight, from his own "territory," in which there is no limitation to the desire of *mastery* and *cruelty*. The *depressive position* can be seen as an expression of the second type of social competition aimed at the formation of *Dominance hierarchy*, in which the drive to *mastery*, *cruelty*, and *dominance* without limits is inhibited from the *submissive behaviors* of the adversary defeated. This modulates and restrains the winner's intention to annihilate and send away from his own sight the opponent forming a *Dominance hierarchy* in which both the winner and the defeated cohabit together, and so making it possible for the two contenders to stay close on the same territory and to cooperate together, living in the same group (see the *motivation to cooperate* in Tomasello and Gonzalez-Cabrera, 2017).

Freud sought to find the roots of aggression almost since the beginning of his construction of psychoanalytic theory, giving rise to observations and theoretical elaborations that have then been resumed and amplified by his successors. Above we have considered the work of Klein, now we want to consider the work of Hans Kohut (1913–1981), who took up the theory of aggression that what mentioned in Freud's theory of Narcissism.

In Freud's (1914) *Introduction to the Narcissism*, he traces the primordial roots of aggression in hate that is stimulated in the subject by the perception of objects external to the narcissistic ego and the reaction of displeasure caused by them (see above pg 5). The hate so considered belongs to the *self-preservation instincts* or *Ego instincts*, "Hate… always remains in an intimate relation with the self-preservation instinct" (Freud, 1914, p. 139). Kohut studied the narcissistic ego reaction to external stimuli and reached the conclusion that *hate* and the *aggression* are effects of the psychological defense against the *narcissistic wound* and *narcissistic blow* and not connected to an instinctual functioning. Kohut quotes "In essence then, I believe that man's destructivenss as a psychological phenomenon is secondary… Aggression, furthermore, as a psychological phenomenon, is not elemental. Like the inorganic building blocks of the organic molecule, it is, from the beginning, a constituent of the child's assertiveness, and under normal circumstances it remains alloyed to the assertiveness of the adult's mature self" (Kohut, 1977, p. 116). The roots of aggression are in the insufficiently empathic relationship among caregivers and child: "destructiveness… arises originally as a result of the failure of the self-object environment to meet the child's need for optimal… emphatic responses" (Kohut, 1977, p. 116). As a consequence, the subject who has suffered a *narcissistic wound* is vulnerable to social competition in which, instead showing an assertive aggression, he will exhibit a *Chronic Narcissistic Rage* (Kohut, 1972). So the *Chronic Narcissistic Rage* derives from a CARE system (Panksepp, 1998) not sufficiently adapted to the child's *Attachment* needs, determining a chronically activation of SADNESS system (Panksepp, 1998), which triggers the *defensive attack* of RAGE system (Panksepp, 1998). The social competition is experienced as fear of deadly oppression with acute sense of inferiority, which actives *shame and narcissistic rage* (Kohut, 1972). The activation of two latter prevents the subject from recognizing his own real defeat, and therefore the possibility of implementing a submission/pacification behavior that is functional to stop the attack of the antagonist dominant, with the consequent attack by the latter in a continuous vicious cycle. Hence, the narcissistic and borderline personality disorders, but also the manic mood disorders (see below).

We have considered how both Freud and his successors place the roots of aggression in childhood. The aggression in childhood has also been confirmed through research carried out in PLAY system (MacLean, 1985; Panksepp, 1998; Panksepp and Biven, 2012). In the ontogeny of mammals, PLAY system has the function of training the individual to regulate social and competitive interaction with the other conspecifics (Panksepp, 2008). MacLean highlights that the play has the function "to promote harmony in the nest" (MacLean, 1985), and also Panksepp highlights how PLAY system evokes positive feelings, despite being a form of training for dominance/submissive interactions (Panksepp et al., 1985; Panksepp, 2008). PLAY system is characterized by role reversals, that is, the winning contender does not remain the dominance figure indefinitely, and allows the weaker defeated antagonist to exchange roles periodically (Panksepp and Biven, 2012). With sexual maturity and testosterone production, this role reversal tends to decrease within competitive interactions and at the same time, testosterone causes the individual to become more suspicious toward his/her conspecifics (Siegel, 2005). In adolescence, as we will see below, the tendency toward peer play becomes more of an explicit social competition to gain dominance. Physical contact is one of the motivations for both animal and human species during the play (P-Biven), highlighting the fact that play is closely connected to the attachment system. PLAY system trains young offspring for social competitions in which they learn to remain included in relationships so as to learn social rules, also preparing them from an early age (Mascaro and Csibra, 2012) to face social competition (Panksepp et al., 1985; Hawley, 1999; Hawley, 2007).

Aggression, Fear, and Psychopathology: From Attachment to Dominance

The theory of motivational/emotional systems, based on a phylogenetic view of the ontogenetic development of the human brain, implies, therefore, that the human species shares with the other mammals the innate systems for regulating inter-individual relations.

The GRIEF/SADNESS and CARE motivational/emotional systems (Bowlby, 1969; Panksepp, 1998) are those that regulate the relationship between the new born and the caregivers, but they are also those that allow an adult to ask help from other adults. Furthermore, in human species, the GRIEF/SADNESS and CARE motivational/emotional systems become integrated with the LUST system to create the *romantic love* (Hazan and Shaver, 1987; Simpson, 1990) and so the lasting couples for the care of the offspring (Eibl-Eibesfeldt, 1984). Finally, there are *Dominance and Submissive motivational/emotional system*, which has been widely discussed.

The attachment system (or GRIEF/SADNESS in the Panksepp theory, 1998) has become in recent decades, as mentioned in the introduction, one of the main factors in which to look for the etiopathogenesis of mental suffering. Bowlby's work traced the lines of this "belief" (Cowan and Cowan, 2007), while the research data in this field have gradually highlighted the weakness of the attachment construct (Cowan and Cowan, 2007).

Bowlby and subsequent researchers have shown that attachment is not a simple response to external stimuli but a well-organized

behavioral system (see, e.g., Hofer, 2014), so in conditions of threat a puppy as well as a child develops a stable strategy with the same objective: seeking comfort toward an adult who can function as a *secure base*. This *secure base* would be a factor of resilience toward subsequent stressors or traumas (Sroufe and Siegel, 2011). The research on attachment has thus highlighted the instinctual basis of this behavioral system on which the good functioning of the personality is based, and the investigation on interactions between genes, social environmental factors, and individual history has now shown the overcoming of the old counterpoint between *nature vs. nurture* (Suomi, 2000). At the same time, research has begun to show the weakness of the assumption that the attachment developed in childhood was only connected to one caregiver, that is the mother, but instead there is a specific *attachment working model* for each caregiver with which the child has had significant relations (Fox et al., 1991; Sagi et al., 1995; Asendorpf and Wilpers, 2000). Instead it seems to be more sustainable that there are more *attachment working models* that have developed for different attachment figures in a continuous dimension of security rather than categorial ones (Alexandrov et al., 2005). Equally, weak is the way in which attachment remains stable as a working model for life (Grossmann et al., 2002; Zhang and Labouvie-Vief, 2004; Sroufe, 2005). Finally, notwithstanding Bowlby (1979) recognized that the attachment system undergoes a modification during development, from parental regulation through dyadic regulation to self-regulation. This developmental dynamic has been little studied and in particular in the transition from childhood to adolescence and adulthood, the scholars have preferred to take the attachment system with an unchanging "package" in time once formed (Cowan and Cowan, 2007).

The attachment system has thus remained an isolated etiopathogenetic factor in the time of development, not considered in the interaction with sexual growth. On the contrary, sexual maturity determines an intense readjustment in the dynamics of motivational/emotional systems that regulate relationships. Sexual development leads to maturity, as indicated above, *Dominance and Submissive motivational system* that is completely different from attachment and more phylogenetically archaic than that, with a specific relational "grammar." Neurobiology and developmental endocrinology indicate that puberty gives rise to a real new course both in the functioning of the organism of young individuals and in their behaviors (Tottenham and Galván, 2016).

In every species of mammals, the onset of puberty (Sisk and Foster, 2004; Schneider, 2013) causes behavioral changes by the maturation of the sexual organs in individuals. Studies in animals have now amply demonstrated the correlation between the levels of androgenic hormones and the levels of *aggression* in males (Beeman, 1947; Simpson, 2001). In the human species, the influence of the puberty development and androgen hormones on aggressive behavior is undoubtedly much more complex to study. Meta-analysis studies on research-related works on the link between hormones and *aggression* have shown a positive correlation between levels of the androgens and the aggressiveness present in male subjects (Archer, 1994; Book et al., 2001). An important contribution was given by Mazur and Booth (1998) who, revising a vast literature, introduced the distinction between aggression and dominance in men. Testosterone levels correlate positively with the dynamics of dominance, of which aggression is only an expression. Research on animals has shown that even in females, *aggression* correlates with the levels of the androgens (Van de Poll et al., 1988) and also in the human species (Dabbs et al., 1988).

Puberty and sexual maturation determine changes in neurophysiology and therefore in adaptive behaviors, by a complex interaction between gonadal hormones, dopaminergic system, and stress axis (Sinclair et al., 2014). In puberty, the maturation of androgen hormones increases dopamine synthesis and stimulates social *aggression* (Schulz et al., 2006; Wahlstrom et al., 2010). At the same time, the androgen hormones promote the increase of number glucocorticoid receptors in dopaminergic system, both in prefrontal cortex PFC, in hippocampus and in striatum (Schulz et al., 2006; Sinclair et al., 2014). These data give reason for behavioral changes in male adolescence. Testosterone also increases the sensitivity of the amygdala to social threatening stimuli (Derntl et al., 2009; Bos et al., 2012). So, in adolescence, there is an increased sensitivity of the FEAR system toward social stimuli. In the adolescence, the positive correlation among gonadal maturation, the increase of testosterone production, and the pushing to dominance behavior on the one hand and on the other an increased sensitivity of the FEAR motivational system for social stressors (Steinberg, 2007; Steinberg, 2008) led to the discovery of the *ratio* between testosterone and cortisol (Terburg et al., 2009; Van der Westhuizen and Solms, 2015) that correlates significantly with the dominance behavior.

Summarizing, first, the theory of social competition, based on *Dominance and Submissive motivational/emotional system*, circumscribes and qualifies a theory of *aggression* that contains within it, in a complementary and functional way, an equally circumscribed, and qualified theory of social fear also named Social defeat (Hollis and Kabbaj, 2014). In animal models, *Social defeat* generates persistent emotional stress without habituation (Tidey and Miczek, 1997; Moxon, 2009; Hollis and Kabbaj, 2014). The experience of *Social defeat* causes tachycardia and hyperthermia, elevated blood pressure, increased adrenocorticotropic hormone (ACTH), and corticosterone levels (Tornatzky and Miczek, 1993). The repeated exposure to *Social defeat* caused decreased locomotor and exploratory activity, reduced *aggression* and reduced sexual behavior, and increased *submissive behavior* and anxiety (Meerlo et al., 1996; Tidey and Miczek, 1997; Ruis et al., 1999; Crawford et al., 2013; Hollis and Kabbaj, 2014).

Second, the *Dominance and Submissive motivational system* is expressed through innate emotional models, which in subjects determine the activation of complementary and automatic responses.

Finally, *Dominance and Submissive motivational system* has its particular activation in the development stage of puberty, functionally connected to the sexual hormones and brain maturation.

All the peculiarities of the *Dominance and Submissive motivational system* in animal models can be found in *homologous* way in the human species, both in the "physiological" psycho-social dynamic of social competition and in their extreme forms in psychopathology (Johnson et al., 2012).

As mentioned above, the interactions related to social competition are present from the first year of life (Sheridan and Williams, 2006), but before puberty, the emotional homeostasis

disrupted by Social defeat was continually reestablished by the *Attachment motivational system*, which allowed the child to find a *safe haven* again for relational perturbations in the bond with caregiver. Instead, the adolescent perceives the impossibility to experiment the previous solution to manage the *Social defeat* to which the sexual maturation of the *Dominance and Submissive motivational systems* exposes him or her. This could explain one of the main reasons for which the psychopathology appears and stabilizes in the adolescence stage.

It is within this new *biological value systems* (consequence of pubertal sexual maturation, Edelman, 1992) located in the *brain stem, basal ganglia, and limbic system* (MacLean, 1990a,b; Panksepp, 1998; Edelman et al., 2011) that the adolescent can begin to perceive *nameless dread* (Bion, 1962a). The adolescent can begin to evolve an increasingly strong conviction to be unable to gain a place within the human group and to form and maintain emotional ties, that now are mediated by his capacity to obtain a position in the rank hierarchies (school, peers, sport, etc.) in which the group is organized outside the primary family group. It is at this point in life that anguish can become *nameless dread* (Bion, 1962a) or *catastrophic dread* (Bion, 1970) because of the massive and automatic subcortical activation of emotions connected to the expression of the *Dominance and Submissive motivational system* making the subject *spectator* of his/her own states of relational fear or impulsivity and euphoric state that until a short time before, in infancy, had not been experienced. When social interactions activate the *Agonistic behavior*, the subject can perceive himself as "destined to victory" or "destined to defeat" (Sloman, 2002). The developmental history of the subject determined by an inseparable mix of genetic endowments and experiences connected to the *Dominant and Submissive system* since the first year of life will determine how in adolescence and then in adult life the subject will react to the stressors of social competition. If the activation of the emotions connected to the *Agonistic behavior* exceed the subjective tolerance threshold, giving rise to excessive stress, activate either behaviors connected *to* the involuntary defeat strategy or involuntary dominant strategy (Price, 2002; Sloman, 2002). The first is the backdrop of depression. The depressed subject feels himself a failure and loser (Gilbert, 1992), whereas a manic person would feel successful and victorious (Johnson and Carver, 2012), without recognizing his/her true mental state unsuitable for facing the real situation and therefore self-inflicting relational frustrations and therefore mental pain. The borderline personality disorder is a combination of the two involuntary strategic (Kupferberg et al., 2016; Stone, 2013). A person with borderline personality disorder shows an extreme susceptibility to social competition, feels easily criticized, scared of failure and shame, with the simultaneous activation of both the involuntary defeat strategy and involuntary dominant strategy, switching rapidly from deescalation (depressed position) to escalation (aggressive and manic behavior), and vice versa (Williams, 2017).

CONCLUSION

Psychoanalysis has, in its theoretical essence, the fundamentals of evolutionary thought, which have been almost completely covered and hidden by the *psychological drift* that has prevailed in the psychoanalytic field. For this, following the indications of Bowlby (1969), it seems very useful for psychoanalysis to return to focus on the instincts or motivational/emotional systems that organize the human mental and relational life, since their study can give psychodynamic research that scientific foundation which is currently one of the most its onerous problems. The motivational systems through which relationships are organized in childhood and later in adolescence and adulthood, are primarily the GRIEF/SADNESS and CARE systems and then, with maturation of LUST system, the *Dominance* and *Submissive system*, with very peculiar emotional characteristics and manifestations. The *Agonistic behavior* has the characteristics, as described above, of covering most of the human phenomenology connected to the concept of *aggression*. The aggressiveness of the *Dominance* and *Submissive motivational system* is strongly "ritualized," closely and structurally connected to the complementary ritualized fear emotional behaviors.

Lorenz (1963) states that the process of individualization, or the ability of an individual to recognize one's own conspecific, has evolved as a function of intraspecious aggressiveness, which has successfully fulfilled three central functions for the survival of the species: first, to distribute the individuals of the same species on a territory in a functional way to the resources (territorial aggressiveness), second, to select the most suitable individuals for the perpetuation of the species (sexual selection), and finally, to favor the care and defense of the offspring (Lorenz, 1963). There are, however, also animal species in which there is no intraspecious *aggression.* These species have a gregarious instinct, which allows more individuals to keep close to each other, like the large shoal of fish, which Lorenz calls "anonymous ranks," without there being the ability to recognize the neighbor and distinguish him from another. This capacity would have started, however, starting from the territorial aggressiveness, connected functionally to the identification of the adversary as belonging to the same species and to the same genus and therefore the ability to recognize the various aspects related to the evaluation of the competitive resources of the other. The evolution, then, of the *territorial agonism* in *agonism for the dominance of rank* among more individuals copresent in the same territory, has been functionally connected to a more continuous recognition of the other, identified in the dominant or submissive relational position within the group to which they belong. In the course of phylogeny, therefore, the ability to recognize one's own conspecific has been increasingly selected in order to establish a correct distance between them.

The recognition of the same species activates in the conspecific agonistic *aggression* (Lorenz, 1963), and this happens because the individual makes himself clearly visible in the eyes of the other. Regarding the previous sentence, Lorenz's descriptions of animals that are defeated in the competitive area, quickly fade their colors before which they were extremely intense. That which has been described by the great ethologist could be more than a suggestive metaphor, usable to understand both the emotional state and the care of the suffering human mind. The evolutionary and developmental processes called individuation or subjectivation (De Monticelli, 2008), see the subject engaged in the hard struggle to gain visibility and recognition within the group to which he belongs. This is often related to a state of deep fear, which makes this personal

developmental process extremely painful or impossible and therefore could provoke anxiety, mood, and personality disorders. The conceptualization of *aggression* as *intraspecies aggression* could give coherence to mental states, behaviors, and emotions that characterize the various nosographic pictures and can constitute a theoretical-clinical model of great heuristic force.

Even during childhood, hierarchies of peer dominance are formed (Havely, 2007), in which children can feel the emotions connected to being dominant or submissive. But, as considered above, at this age, the immaturity of the sexual system and the priority of the attachment system in the hierarchy of motivational/emotional systems mitigate the presence of emotions connected to the *Dominance* and *Submissive motivational system*. PLAY system has a central position in the development of *Dominance* and *Submissive motivational system* and, in connection with the attachment system, mitigate the emotions of social competition among peers, making it possible to exchange the positions of winner and loser during the competitive interactions.

As seen in this article, the link between childhood and aggression has been a key factor throughout the history of psychoanalysis. The asymmetric relationship between children and their parents exposes the former to the danger of being annihilated by the action of latter causing the aggressive emotions in the offspring, as explained initially in Freud's theories concerning Oedipus and castration complex. Authors such as Hans Kohut (Kohut, 1972), Donald Winnicott, or Wilfred Bion (each one having had different opinions) stated that the nonempathic relationship (Winnicott, 1960; Kohut, 1972) or insufficient *Reverie* (Bion, 1962b) with parents was the cause of offspring vulnerability toward self-control of aggression in social competition. Psychoanalyst John Bowlby associated this vulnerability with the failure of the instinctual CARE system thus impeding a *secure* attachment (see, e.g., Bowlby, 1944). So, psychoanalysts could have been misled by the theory that the roots of pathogenic aggression took hold during childhood. The problem of aggression/fear according to the model of *Dominance and Submissive motivational/emotional system*, that has its specific activation in adolescence, first of all indicates the need to reposition the etiopathogenic conflict from the inter-family dimension to the relationship subject-world outside the family. This allows, secondarily, a greater contextualization of the genesis of mental illness, being able to identify which environmental aspects "collude" etiopathogenetically (Gilbert et al., 2007) with the change in the subject from the primacy of the attachment motivational system to the agonistic one. Finally, the model presented here could indicate the need to reconsider some points of the clinical theory in psychoanalysis, for example, that of *transference* or that of *insight,* for which some psychoanalysts have already been engaged for some time (see, e.g., Gabbard and Westen, 2003; Pally, 2007; Allen et al., 2008), indicating ways that are more compatible with epistemology as proposed in this work.

AUTHOR CONTRIBUTIONS

TG is the main author—development of hypotheses and concepts. US is the coauthor—critical discussion of literature and concepts.

REFERENCES

Alcaro, A., Carta, S., and Panksepp, J. (2017). The affective core of the self: a neuro-archetypical perspective on the foundations of human (and animal) subjectivity. *Front. Psychol.* 8:1424. doi: 10.3389/fpsyg.2017.01424

Alexandrov, E. O., Cowan, P. A., and Cowan, C. P. (2005). Couple attachment and the quality of marital relationships: method and concept in the validation of the new couple attachment interview and coding system. *Attach Hum. Dev.* 7, 123–152. doi: 10.1080/14616730500155170

Allan, S., and Gilbert, P. (1997). Submissive behaviour and psychopathology. *Br. J. Clin. Psychol.* 36, 467–488. doi: 10.1111/j.2044-8260.1997.tb01255.x

Allen, J. G., Fonagy, P., and Bateman, A. W. (2008). *Mentalizing in clinical practice*. Washington, DC: American Psychiatric Pub.

Allen, N. B., and Badcock, P. B. (2003). The social risk hypothesis of depressed mood: evolutionary, psychosocial, and neurobiological perspectives. *Psychol. Bull.* 129, 887–913. doi: 10.1037/0033-2909.129.6.887

Anzieu, D. (1975). *L'auto-analyse de Freud et la découverte de la psychanalyse [L'autoanalisi di Freud e la scoperta della psicoanalisi]*, 2, Paris/Rome.

Archer, J. (1994). Testosterone and aggression. *J. Offender Rehabil.* 21, 3–25.

Archer, J. (2009). The nature of human aggression. *Int. J. Law Psychiatry,* 32, 202–208. doi: 10.1016/j.ijlp.2009.04.001

Asendorpf, J. B., and Wilpers, S. (2000). Attachment security and available support: closely linked relationship qualities. *J. Soc. Pers. Relat.* 17, 115–138. doi: 10.1177/0265407500171006

Baron-Cohen, S. (1995). *Mindblindness: an essay on autism and theory of mind*. Cambridge, MA: MIT Press. doi: 10.1111/j.1469-7610.1997.tb01599.x

Beeman, E. M. (1947). The effect of male hormone on aggressive behaviour on mice. *Physiol. Zool.* 20, 373–405. doi: 10.1086/physzool.20.4.30151969

Behrendt, R. P. (2011). *Neuroanatomy of social behaviour: an evolutionary and psychoanalytic perspective*. London: Karnac Books Ltd.

Behrendt, R. P. (2012). *The evolved structure of human social behaviour and personality: psychoanalytic insights*. Routledge. doi: 10.1007/s00772-018-0436-2

Bjorkqvist, K. (2001). Social defeat as a stressor in humans. *Physiol. Behav.* 73, 435–442. doi: 10.1016/S0031-9384(01)00490-5

Bion, W. R. (1962a). *Learning from experience.* Oxford, Jason Aronson, Inc.

Bion, W. R. (1962b). "A theory of thinking" in *Second thoughts*. London: Karnac Books Ltd, 1984.

Bion, W. R. (1963). *Elements of psycho-analysis.* London: Karnac Books Ltd, 1984.

Bion, W. R. (1970). *Attention and interpretation: a scientific approach to insight in psycho-analysis and groups*. Abingdon: Routledge.

Book, A. S., Starzyk, K. B., and Quinsey, V. L. (2001). The relationship between testosterone and aggresion: a meta-analysis. *Aggress. Violent Behav.* 6, 579–599. doi: 10.1016/S1359-1789(00)00032-X

Bos, P. A., Hermans, E. J., Ramsey, N. F., and van Honk, J. (2012). The neural mechanisms by which testosterone acts on interpersonal trust. *Neuroimage* 61, 730–737. doi: 10.1016/j.neuroimage.2012.04.002

Bowlby, J. (1944). "Forty-four juvenile thieves: Their characters and home-life." *The International Journal for Psycho-Analysis*, 25, 19–53, 170–128.

Bowlby, J. (1969). *Attachment and loss.* (Vol. 1) London, UK: The Hogarth Press.

Bowlby, J. (1979). *The making and breaking of affectional bonds*. London: Tavistock.

Campbell, D. (1975). "Reintroducing Konrad Lorenz to psychology" in *Konrad Lorenz: the man and his ideas*. ed. Evans, R. I. (New York: Harcourt Brace Jovanovich), 88–118.

Chance, M. R. A. (1967). Attention structure as the basis of primate rank orders. *Man*, 2, 503–518. doi: 10.2307/2799336

Cory, G. A. (2002). "Reappraising MacLean's triune brain concept" in *The evolutionary neuroethology of Paul MacLean. Convergences and Frontiers*. eds. Cory, G. A., and Gardner, R. (Westport, CT: Praeger Publishers).

Cowan, P. A., and Cowan, C. P. (2007). Attachment theory: seven unresolved issues and questions for future research. *Res. Hum. Dev.* 4, 181–201. doi: 10.1080/15427600701663007

Crawford, L. K., Rahman, S. F., and Beck, S. G. (2013). Social stress alters inhibitory synaptic input to distinct subpopulations of raphe serotonin neurons. *ACS Chem. Neurosci.* 4, 200–209. doi: 10.1021/cn300238j

Dabbs, J. M., Ruback, J. M., Frady, R. L., and Hopper, C. H. (1988). Saliva testosterone and criminal violence among women. *Personal. Individ. Differ.* 9, 269–275. doi: 10.1016/0191-8869(88)90088-8

Darwin, C. (1859). *On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life*. 1st Edn. London: John Murray.

Darwin, C. (1871). *The descent of man, and selection in relation to sex*. London: John Murray.

Davis, K. L., Panksepp, J., and Normansell, L. (2003). The affective neuroscience personality scales: normative data and implications. *Neuropsychoanalysis* 5, 57–69. doi: 10.1080/15294145.2003.10773410

Davis, K. L., and Panksepp, J. (2011). The brain's emotional foundations of human personality and the affective neuroscience personality scales. *Neurosci. Biobehav. Rev.* 35, 1946–1958. doi: 10.1016/j.neubiorev.2011.04.004

Davis, K. L., and Panksepp, J. (2018). *The emotional foundations of personality: a neurobiological and evolutionary*. W. W. Norton & Company Publication.

De Boer, S. F., Buwalda, B., and Koolhaas, J. M. (2016). "Aggressive behavior and social stress" in *Stress: concepts, cognition, emotion, and behavior*. ed. Fink, G. 293–303.

De Monticelli, R. (2008). Subjectivity and essential individuality: a dialogue with Peter van Inwagen and Lynn Baker. *Phenomenol. Cogn. Sci.* 7, 225–242. doi: 10.1007/s11097-007-9047-1

Derntl, B., Windeschberger, C., Robinson, S., Kryspin-Exner, I., Gur, R., Moser, E., et al. (2009). Amygdala activity to fear and anger in healthy young males is associated with testosterone. *Psychoneuroendocrinology* 34, 687–693. doi: 10.1016/j.psyneuen.2008.11.007

Edelman, G. M. (1992). *Bright air, brilliant fire: on the matter of the mind*. New York: Basic books. doi: 10.1073/pnas.89.24.11651

Edelman, G. M., Gally, J. A., and Baars, B. J. (2011). Biology of consciousness. *Front. Psychol.* 2:4. doi: 10.3389/fpsyg.2011.00004

Eibl-Eibesfeldt, I. (1984). *Die Biologie des menschlichen Verhaltens. Grundriß der Humanethologie*. München. *Human ethology*. New York: Aldine de Gruyter; 1989. *Etologia umana. Le basi biologiche e culturali del comportamento*, *Bollati Boringhieri, Torino*; 2001.

Flinn, M. V., Ponzi, D., and Muehlenbein, M. P. (2012). Hormonal mechanisms for regulation of aggression in human coalitions. *Hum. Nat.* 23, 68–88. doi: 10.1007/s12110-012-9135-y

Fonagy, P. (2001). *Attachment theory and psychoanalysis.* London: Karnac Book Ltd, 2004.

Fonagy, P. (2005). "La teoria evolutiva psicoanalitica". In: Person, E. S., Cooper, A. M., Gabbard, G. O. *Psicoanalisi*, Milano, Raffaello Cortina, 2006. [Person, E. S., Cooper, A. M., Gabbard, G. O. *Textbook of Psychoanalysis*, Washington DC and London, UK: Psychiatic Publishing Inc.]. doi: 10.1080/14616730500269278

Fox, N. A., Kimmerly, N. L., and Schafer, W. D. (1991). Attachment to mother/attachment to father: a meta-analysis. *Child Dev.* 62, 210–225.

Freud, S. 1950 [1895]. *Project for a scientific psychology*. Strachey, J. (1966). S. E. V. I (1886–1899). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1905). *Three essays on sexuality*. Strachey, J. (1953). S. E. V. VII (1901–1905). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1910). *The psycho-analytic view of psychogenic disturbance of vision*. Strachey, J. (1957). S. E. V. XI (1910). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1911). *Formulations on the two principles of mental functioning*. Strachey, J. (1958). S. E. V. XII (1911–1913). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1912–13). *Totem and Taboo*. Strachey, J. (1955). S. E. V. XIII (1913–1914). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1913). *The disposition to obsessional neurosis, a contribution to the problem of the choice of neurosis*. Strachey, J. (1958). S. E. V. XII (1911–1913). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1914). *On Narcissism: an introduction*. Strachey, J. (1957). S. E. V. XIV (1914–1916). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1915a). *Instincts and their Vicissitudes*. S. E. V. XIV (1914–1916). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1915b). *The unconscious*. S. E. V. XIV (1914–1916). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1916). *Introductory lectures on psychoanalysis*. S. E., V. XV (1915–1916). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1919). *'A Child is Being Beaten' A contribution to the study of the origin of sexual perversions*. Strachey, J. (1955). S. E. V. XVII (1917–1919). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1920). *Beyond the pleasure principle*. S. E. V. XVIII (1920–1922). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1923). *The Ego and the Id*. S. E. V. XIX (1923–1925). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1927). *The future of an illusion*. S. E. V. XXI (1927–1931). London: The Hogarth Press and the Institute of Psychoanalysis.

Freud, S. (1939). *Moses and Monotheism*. S. E. V. XXIII (1937–1939). London: The Hogarth Press and the Institute of Psychoanalysis.

Gabbard, G. O., and Westen, D. (2003). Rethinking therapeutic action. *Int. J. Psychoanal.* 84, 823–841. doi: 10.1516/N4T0-4D5G-NNPLH7N

Gardner, R. (1982). Mechanisms in manic-depressive disorder: an evolutionary model. *Arch. Gen. Psychiatry* 39, 1436–1441. doi: 10.1001/archpsyc.1982.04290120066013

Gherardi, F., Cenni, F., Parisi, G., and Aquiloni, L. (2010). Visual recognition of conspecifics in the American lobster, *Homarus americanus*. *Anim. Behav.* 80, 713–719. doi: 10.1016/j.anbehav.2010.07.008

Giacolini, T., Ardizzone, I., Davis, K. L., Ferrara, M., Piccioni, L., Terrinoni, A., et al. (2017). Brain emotional systems: the italian version of the ANPS-affective neuroscience personality scales 2.4 (reliability and validity). *Clin. Neuropsychiatry* 14, 263–274. doi: 10.1080/17405629.2013.807242

Gilbert, P. (1992). "Depression" in *The evolution of powerlessness*. (Hove, UK: Psychology Press).

Gilbert, P. (2000). "Social mentalities" in *Genes on the couch*. eds. Gilbert, P., and Baley, K. (Hove, UK: Brunner-Routledge).

Gilbert, P., Broomhead, C., Irons, C., McEvan, K., Bellew, R., Mills, A., et al. (2007). Development of a striving to avoid inferiority scale, *Br. J. Soc. Psychol.* 46, 633–648. doi: 10.1348/014466606X157789

Grossmann, K., Grossmann, K. E., Fremmer-Bombik, E., Kindler, H., Scheuerer-Englisch, H., and Zimmermann, P. (2002). The uniqueness of the child–father attachment relationship: fathers' sensitive and challenging play as a pivotal variable in a 16-year longitudinal study. *Soc. Dev.* 11:3. doi: 10.1111/1467-9507.00202

Hawley, P. H. (1999). The ontogenesis of social dominance: a strategy-based evolutionary perspective. *Dev. Rev.* 19, 97–132. doi: 10.1006/drev.1998.0470

Hawley, P. H. (2007). "Social dominance in childhood and adolescence: why social competence and aggression may go hand in hand" in *Aggression and adaptation: the bright side to bad behavior*. eds. Hawley, P. H., Todd, D. L., and Rodkin, P. C. (Hillsdale, NJ: Lawrence Erlbaum and Associates), 1–29.

Hazan, C., and Shaver, P. (1987). Romantic love conceptualized as an attachment process. *J. Pers. Soc. Psychol.* 52, 511–524. doi: 10.1037/0022-3514.52.3.511

Hofer, M. A. (2014). The emerging synthesis of development and evolution: a new biology for psychoanalysis. *Neuropsychoanalysis* 16, 3–22. doi: 10.1080/15294145.2014.901022

Hollis, F., and Kabbaj, M. (2014). Social defeat as an animal model for depression. *ILAR J.* 55. doi: 10.1093/ilar/ilu002

Hughes, G. M., Teeling, E. C., and Higgins, D. G. (2014). Loss of olfactory receptor function in hominin evolution. *PLoS One* 9:e84714. doi: 10.1371/journal.pone.0084714

Humphrey, N. K. (1976). "The social function of intellect" in *Growing points in ethology*. eds. Bateson, P. P. G., and Hinde, R. A. (Oxford, England: Cambridge University Press). doi: 10.1016/0010-7824(76)90105-0

Johnson, S. L., Leedom, L. J., and Muhtadie, L. (2012). The dominance behavioral system and psychopathology: evidence from self-report, observational, and biological studies. *Psychol. Bull.* 138, 692–743. doi: 10.1037/a0027503

Johnson, S. L., and Carver, C. S. (2012). The dominance behavioral system and manic temperament: motivation for dominance, self-perceptions of power, and socially dominant behaviors. *J. Affect. Disord.* 142, 275–282. doi: 10.1016/j.jad.2012.05.015

Jones, E. (1953/1977). *The life and works of Sigmund Freud [Vita ed opere di Freud]*, Vol. 1. New York/Milano, Basic Books, Inc/Il Saggiatore.

Klein, M. (1932). *The psycho-analysis of children*. New York: Grow Press, Inc., 1960.

Klein, M. (1957). *Envy and gratitude: a study of unconscious sources London*. Tavistock Publications, Ltd, London.

Kohut, H. (1972). Thoughts on narcissism and narcissistic rage. *Psychoanal. Study Child* 27, 360–400.

Kohut, H. (1977). *The restoration of the self*. New York: International Universities Press.

Kupferberg, A., Hager, O. M., Fischbacher, U., Brändle, L. S., Haynes, M., and Haslercor, G. (2016). Testing the social competition hypothesis of depression

using a simple economic game. *BJPsych. Open* 2, 163–169. doi: 10.1192/bjpo.bp.115.001362

Laplanche, J., and Pontalis, J. B. (1967). *Vocabulaire de la psychanalyse*, Paris, Puf.

LeDoux, J. (1996). *The emotional brain: the mysterious underpinnings of emotional life*. New York: Simon and Schuster. doi: 10.1016/S0301-5629(98)00101-X

Lewis, J. M. (1998). For better or worse: interpersonal relationships and individual outcome, *Am. J. Psychiatr.* 155, 582–589. doi: 10.1176/ajp.155.5.582

Liotti, L., and Gilbert, P. (2011). Mentalizing, motivation, and social mentalities: theoretical considerations and implications for psychotherapy. *Psychol. Psychother. Theory Res. Pract.* 84, 9–25. doi: 10.1348/147608310X520094

Lorenz, K. (1963). *Das sogenannte Böse zur Naturgeschichte der Aggression [So-called evil, Toward a Natural History of Aggression]*. Original edition: Borotha-Schoeler G; 1963. It. *L'aggressività*. Milano: Verlag/Il saggiatore; 1969.

Lorenz, K. (1977). *Behind the mirror: a search for a natural history of human knowledge*. Ronald Taylor, London: Methuen.

Lorenz, K. (1981). *The foundations of ethology*. Lorenz, K. Z., and Kickert, R. W. New York: Springer-Verlag. doi: 10.1055/s-2008-1056499. (Originally published as Vergleichende Verhaltensforschung, 1978).

MacLean, P. D. (1985). Brain evolution relating to family, play, and the separation call. *Arch. Gen. Psychiatry* 42, 405–417. doi: 10.1001/archpsyc.1985.01790270095011

MacLean, P. D. (1990a). "The limbic system in historical perspective" in *The triune brain in evolution. Role in paleocerebral function*. (New York: Plenum Press).

MacLean, P. D. (1990b). *The triune brain in evolution. Role in paleocerebral function*. New York: Plenum Press.

Malatynska, E., and Knapp, R. J. (2005). Dominant–submissive behavior as models of mania and depression. *Neurosci. Biobehav. Rev.* 29, 715–737. doi: 10.1016/j.neubiorev.2005.03.014

Malatynska, E., Rapp, R., Harrawood, D., and Tunnicliff, G. (2005). Submissive behavior in mice as a test for antidepressant drug activity. *Pharmacol. Biochem. Behav.* 82, 306–313. doi: 10.1016/j.pbb.2005.08.020

Manning, A., and Dawkins, S. M. (2012). *An introduction to animal behaviour*. Glasgow: Cambridge University Press.

Mascaro, O., and Csibra, G. (2012). Representation of stable social dominance relations by human infants. *Proc. Natl. Acad. Sci.* 109. doi: 10.1073/pnas.1113194109

Mazur, A., and Booth, A. (1998). Testosterone and dominance in men. *Behav. Brain Sci.* 21, 353–397.

McGuire, M. T., and Troisi, A. (1998). *Darwinian psychiatry*, New York, Oxford University Press.

Meerlo, P., De Boer, S. F., Koolhaas, J. M., Daan, S., and Van den Hoofdakker, R. H. (1996). Changes in daily rhythms of body temperature and activity after a single social defeat in rats. *Physiol. Behav.* 59, 735–739.

Moxon, S. (2009). Dominance as adaptive stressing and ranking of males, serving to allocate reproduction by differential self-suppressed fertility: towards a fully biological understanding of social systems. *Med. Hypotheses* 73, 5–14. doi: 10.1016/j.mehy.2009.02.011

Northoff, G., and Panksepp, J. (2008). The trans-species concept of self and the subcortical-cortical midline system. *Trends Cognit. Sci.* 12, 259–264. doi: 10.1016/j.tics.2008.04.007

Pally, R. (2007). The predicting brain. Unconscious repetition, conscious reflection and therapeutic change. *Int. J. Psychoanal.* 88, 861–81.

Panksepp, J., Jalowiec, J., DeEskinazi, F. G., and Bishop, P. (1985). Opiates and play dominance in juvenile rats. *Behav. Neurosci.* 99, 441–453. doi: 10.1037/0735-7044.99.3.441

Panksepp, J. (1998). *Affective neuroscience. The foundations of human and animal emotions*. New York: Oxford University Press.

Panksepp, J., and Zellner, M. R. (2004). Towards a neurobiologically based unified theory of aggression. *Rev. Int. Psychol. Soc.* 17, 37–62. doi: 10.1016/j.brainres.2004.07.076

Panksepp, J. (2008). Play, ADHD, and the construction of the social brain: should the first class each day be recess?. *Am. J. Play* 1, 55–79.

Panksepp, J., and Northoff, G. (2009). The trans-species core SELF: the emergence of active cultural and neuro-ecological agents through self-related processing within subcortical-cortical midline networks. *Conscious. Cogn.* 18, 193–215. doi: 10.1016/j.concog.2008.03.002

Panksepp, J., and Biven, L. (2012). *The archaeology of mind*. New York: W. W. Norton & Company. doi: 10.1016/j.tics.2011.11.005

Price, J. S. (1992). The agonic and hedonic modes: definition, usage, and the promotion of mental health. *World Futures: J. Gen. Evol.* 35, 87–113.

Price, J. (2002). The triune brain, escalation, de-escalation strategies, and mood disorders in *The evolutionary neuroethology of Paul MacLean. Convergences and frontiers*. eds. Cory, G. A., and Gardner, R. (Westport, CT: Praeger Publishers), 107–117. doi: 10.1124/mi.2.6.392

Price, J. S., and Sloman, L. (1987). Depression as yielding behaviour: an animal model based on Schjelderup-Ebb's pecking order. *Evol. Hum. Behav.* 8, 85–98.

Rohde, P. (2001). The relevance of hierarchies, territories, defeat for depression in humans—hypotheses and clinical predictions. *J. Affect. Disord.* 65, 221–230. doi: 10.1016/S0165-0327(00)00219-6

Roxo, M. R., Franceschini, P. R., Zubaran, C., Kleber, F. D., and Sander, J. W. (2011). The limbic system conception and its historical evolution. *Sci. World J.* 11, 2427–2440. doi: 10.1100/2011/157150

Ruis, M. A. W., Te Brake, J. H. A., Buwalda, B. D. S. F., De Boer, S. F., Meerlo, P., Korte, S. M., et al. (1999). Housing familiar male wildtype rats together reduces the long-term adverse behavioural and physiological effects of social defeat. *Psychoneuroendocrinology* 24, 285–300.

Sagi, A., Van IJzendoorn, M. H., Aviezer, O., Donnell, F., Koren-Karie, N., Joels, T., et al. (1995). Attachments in a multiple-caregiver and multiple-infant environment: the case of the Israeli kibbutzim. *Monogr. Soc. Res. Child Dev.* 60, 71–91.

Sapolsky, R. M. (1983). Individual differences in cortisol secretory patterns in the wild baboon: role of negative feedback sensitivity. *Endocrinology* 113, 2263–2267. doi: 10.1210/endo-113-6-2263

Sapolsky, R. M. (1986). Stress-induced elevation of testosterone concentrations in high ranking baboons: role of catecholamines. *Endocrinology* 118, 1630–1635. doi: 10.1210/endo-118-4-1630

Schneider, M. (2013). Adolescence as a vulnerable period to alter rodent behavior. *Cell Tissue Res.* 354, 99–106. doi: 10.1007/s00441-013-1581-2

Schulz, K. M., Menard, T. A., Smith, D. A., Albers, H. E., and Sisk, C. L. (2006). Testicular hormone exposure during adolescence organizes flank-marking behavior and vasopressin receptor binding in the lateral septum. *Horm. Behav.* 50, 477–483. doi: 10.1016/j.yhbeh.2006.06.006

Scott, J. P., and Fredericson, E. (1951). The causes of fighting in mice and rats. *Physiol. Zool.* 24, 273–309. doi: 10.1086/physzool.24.4.30152137

Sheridan, S., and Williams, P. (2006). Constructive competition in preschool. *J. Early Child. Res.* 4, 291–310. doi: 10.1177/1476718X06067581

Siegel, A. (2005). *The neurobiology of aggression and rage*. Boca Raton, FL: CRC Press. doi: 10.1016/j.talanta.2005.03.028

Siegel, A., and Victoroff, J. (2009). Understanding human aggression: new insights from neuroscience. *Int. J. Law Psychiatry* 32, 209–215. doi: 10.1016/j.ijlp.2009.06.001

Simpson, J. A. (1990). Influence of attachment styles on romantic relationships. *J. Pers. Soc. Psychol.* 59, 971–980. doi: 10.1037/0022-3514.59.5.971

Simpson, K. (2001). The role of testosterone in aggression. *McGill J. Med.* 6, 32–40.

Sinclair, D., Purves-Tyson, T. D., Allen, K. M., and Weickert, C. S. (2014). Impacts of stress and sex hormones on dopamine neurotransmission in the adolescent brain. *Psychopharmacology* 231, 1581–1599. doi: 10.1007/s00213-013-3415-z

Sisk, C. L., and Foster, D. L. (2004). The neural basis of puberty and adolescence. *Nat. Neurosci.* 7, 1040–1047. doi: 10.1038/nn1326

Sloman, L. (2002). "Involuntary defeat strategy as backdrop for depression" in *The evolutionary neuroethology*. eds. Cory, G. A. Jr., and Gardner, R. (Paul MacLean: Praeger, U.S.A.). doi: 10.1097/00002820-200212000-00005

Solms, M., and Turnbull, O. (2002). *The brain and the inner world: an introduction to the neuroscience of subjective experience*. London: Karnac Books.

Sroufe, L. A. (2005). Attachment and development: a prospective, longitudinal study from birth to adulthood. *Attach Hum. Dev.* 7, 349–367. doi: 10.1080/14616730500365928

Sroufe, L. A., and Siegel, D. (2011). The verdict is in. *Psychother. Networker* 35, 35–39.

Steinberg, L. (2007). Risk-taking in adolescence: new perspectives from brain and behavioral science. *Curr. Dir. Psychol. Sci.* 16, 55–59.

Steinberg, L. (2008). A social neuroscience perspective on adolescent risk-taking. *Dev. Rev.* 28, 78–106. doi: 10.1016/j.dr.2007.08.002

Stevens, A., and Price, J. (1996). *Evolutionary psychiatry. A new beginning*. London, Routledge. doi: 10.1016/S0092-8674(00)81808-5

Stone, M. H. (2013). A new look at borderline personality disorder and related disorders: hyper-reactivity in the limbic system and lower centers. *Psychodyn. Psychiatry* 41, 437–466. doi: 10.1521/pdps.2013.41.3.437

Sulloway, F. J. (1979). *Freud, biologist of the mind: beyond the psychoanalytic legend*. New York: Basic Books.

Suomi, S. J. (2000). "A biobehavioral perspective on developmental psychopathology" in *Handbook of developmental psychopathology*. (Boston, MA: Springer), 237–256.

Terburg, D., Morgan, B., and van Honk, J. (2009). The testosterone-cortisol ration: a hormonal marker for proneness to social aggression. *Int. J. Law Psychiatry* 32, 216–223. doi: 10.1016/j.ijlp.2009.04.008

Tidey, J. W., and Miczek, K. A. (1997). Acquisition of cocaine self-administration after social stress:role of accumbens dopamine. *Psychopharmacology* 130, 203–212. doi: 10.1007/s002130050230

Tomasello, M., and Gonzalez-Cabrera, I. (2017). The role of ontogeny in the evolution of human cooperation. *Hum. Nat.* 28, 274–288. doi: 10.1007/s12110-017-9291-1

Tornatzky, W., and Miczek, K. A. (1993). Long-term impairment of autonomic circadian rhythms after brief intermittent social stress. *Physiol. Behav.* 53, 983–993. doi: 10.1016/0031-9384(93)90278-N

Tottenham, N., and Galván, A. (2016). Stress and the adolescent brain: amygdala-prefrontal cortex circuitry and ventral striatum as developmental targets. *Neurosci. Biobehav. Rev.* 70, 217–227. doi: 10.1016/j.neubiorev.2016.07.030

Tinbergen, N. (1951). *The study of instinct*. Oxford: Clarendon Press.

Van de Poll, N. E., Taminiau, M. S., Endert, E., and Louwerse, A. L. (1988). Gonadal steroid influence upon sexual and aggressive behavior of female rats. *Int. J. Neurosci.* 41, 271–286.

Van der Westhuizen, D., and Solms, M. (2015). Social dominance and the affective neuroscience personality scales. *Conscious. Cogn.* 33, 90–111. doi: 10.1016/j.concog.2014.12.005

Wahlstrom, D., White, T., and Luciana, M. (2010). Neurobehavioral evidence for changes in dopamine system activity during adolescence. *Neurosci. Biobehav. Rev.* 34, 631–648. doi: 10.1016/j.neubiorev.2009.12.007

Weisfeld, G. E. (2002). "Neural and functional aspects of pride and shame" in *The evolutionary neuroethology of Paul MacLean: convergences and frontiers*, 193–214.

Williams, R. (2017). Anger as a basic emotion and its role in personality building and pathological growth: the neuroscientific, developmental and clinical perspectives. *Front. Psychol.* 8:1950. doi: 10.3389/fpsyg.2017.01950

Winnicott, D. W. (1960). The theory of the parent-infant relationship. *Int. J. Psychoanal.* 41, 585–595.

Zhang, F., and Labouvie-Vief, G. (2004). Stability and fluctuation in adult attachment style over a 6-year period. *Attach Hum. Dev.* 6, 419–437. doi: 10.1080/1461673042000303127

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Human Neuroscience

REVIEW
published: 23 January 2019
doi: 10.3389/fnhum.2018.00522

The "Instinct" of Imagination. A Neuro-Ethological Approach to the Evolution of the Reflective Mind and Its Application to Psychotherapy

Antonio Alcaro[1]* *and Stefano Carta*[2]

[1]*Department of Psychology, Sapienza University of Rome, Rome, Italy,* [2]*Department of Pedagogy, Psychology, and Philosophy, Università degli Studi di Cagliari, Cagliari, Italy*

Recent neuro-psychoanalytic literature has emphasized the view that our subjective identity rests on ancient subcortical neuro-psychic processes expressing unthinking forms of experience, which are "affectively intense without being known" (Solms and Panksepp, 2012). Devoid of internal representations, the emotional states of our "core-Self" (Panksepp, 1998b) are entirely "projected" towards the external world and tend to be discharged through instinctual action-patterns. However, due to the close connections between the subcortical and the cortical midline brain, the emotional drives may also find a way to be reflected within an intrinsic self-referential processing, evident when the organism is not actively engaged with the external world. Thanks to such endogenous functioning, the core-Self emotional dispositions are not overtly executed, but they are organized within coherent dynamic mental structures, called "feeling-toned complexes" by C. G. Jung and "unconscious phantasies" by Melanie Klein. The intrinsic self-referential dynamism of the "brainmind" originated from REM sleep arousal and then evolved in the resting-state activity of a complex of cortico-limbic midline brain structures (CMS), also called Default Mode Network (DMN). From our neuro-ethological perspective, it is sustained by an "introverted" SEEKING activity leading to the subjective exploration of internally constructed virtual scenarios. This "mind wandering" function, implicated in dreaming, fantasy processing, remembering and thinking, is the essence of the imaginative function and constitutes the first form of reflection, where intentions and drives gain a primordial form of conscious (but not self-conscious) representation. During postnatal development, this original ("archetypal") imaginative function is slowly attuned in a relational "transitional" space and may be expressed first in non-verbal and eventually in abstract-verbal social communicative patterns. Our view has noticeable implications for psychotherapy. Instead of trying to directly modify interpersonal, extrinsic relationships (a top-down approach), dysfunctional emotional-relational patterns may be modified by a process in which the patient is helped to let-go of the perceived feeling-objects in favor of an immersion, *via* the actual feeling, from the superficial level of perception towards a void feeling-state, empty of images. Only starting from this "anoetic" feeling-state, the deep imaginal creative and re-structuring self-referential activity may be reactivated by a process of spontaneous imagination.

Keywords: default mode network, self, affective, dream (images), mentalization, emotion, consciousness, noetic

OPEN ACCESS

Edited by:
Anatolia Salone,
Università degli Studi G. d'Annunzio Chieti e Pescara, Italy

Reviewed by:
Claudio Colace,
Azienda Sanitaria Locale di Viterbo, Italy
Marina Farinelli,
"Villa Bellombra" Rehabilitation Hospital, Italy

***Correspondence:**
Antonio Alcaro
antonioalcaro@yahoo.it

Received: *31 August 2018*
Accepted: *11 December 2018*
Published: *23 January 2019*

Citation:
Alcaro A and Carta S (2019) The "Instinct" of Imagination. A Neuro-Ethological Approach to the Evolution of the Reflective Mind and Its Application to Psychotherapy. Front. Hum. Neurosci. 12:522. doi: 10.3389/fnhum.2018.00522

INTRODUCTION

Most scholars today consider subjectivity (personal experience) the result of an individual historical process and, therefore, as an acquisition of human development. In particular, the emergence of a mental life and of a sense of "self" have been associated with emotional and cognitive skills that permit to the child to reflect upon his/her experience (Damasio, 2010). Such essential function, called "mentalization" or "reflective function," is usually considered a product of the attachment relationship (Stern, 1985; Schore, 1994; Fonagy and Target, 1997; Fonagy et al., 2002). Cognitive psychologists, psychoanalysts and neuroscientists are in agreement that the child *learns* to have a subjective mental life and to recognize it as his own by internalizing experiences and aspects of the attachment relationship, which are dependent on the self-reflective capacity of the caregiver (Bowlby, 1969/1982; Bretherton and Munholland, 1999).

While recognizing the importance of such theories, we think that strict developmental views fail to consider that newborns are provided by an innate potential endogenous mental activity where the intersubjective environment is subjectively experienced and represented. Indeed, neurodevelopmental studies have shown that human embryos already possess an intrinsic brain dynamism typical of REM sleep, that appears before non-REM sleep and active waking and that is largely preponderant in the last trimester of pregnancy (Birnholz, 1981). Interestingly, REM sleep leads to the endogenous activation of a complex of subcortical midline structures (SCMS) and cortical midline brain structures (CMS) involved in highly emotional self-referential processing. Moreover, recent neurometabolic studies showed that CMS show high levels of metabolic activity not only during REM-sleep, but also in resting wakefulness, when the organism is not engaged with the environment (Raichle, 2015).

The endogenous self-referential processing of the CMS has been related to an intrinsic virtual-models generator function, through which the organism forms an inferential knowledge about the structure of (its) reality (Hobson and Friston, 2012). During REM sleep, this inferential process may be subjectively experienced in the form of perceptual-like images that we call dreams, and that express a primordial form of consciousness, or proto-consciousness (Hobson, 2009). During resting wakefulness, it may be subjectively experienced as an internal flux of imagines and thoughts (Carhart-Harris and Friston, 2010; Schacter et al., 2012; Agnati et al., 2013; Fox et al., 2013) that clearly resembles what William James described as the "stream of consciousness":

> *"As we take [. . .] a general view of the wonderful stream of our consciousness, what strikes us first is this different pace of its parts. Like a bird's life, it seems to be made of an alternation of flights and perchings [. . .] The resting-places [. . .] can be held before the mind for an indefinite time [. . .] The places of flight . . . obtain between the matters contemplated in the periods of comparative rest" (James, 1890).*

Therefore, following such neuroscientific paths and in accordance with Jung's Analytical Psychology (Jung, 1937), we believe that the so-called "reflective function" is grafted in an embryonic form of mental activity, that lays on the "off-line," resting-state activity of the brain. Flowing from this instinct for reflection, the intrinsic emotional dispositions of the living organism are maintained in a "potential state" and rather than expressing itself in actions (motor or physiological) they fit back upon themselves and eventually establish a subjective psychic dimension (Jung, 1937; Shamdasani, 2003). Such essential self-referential function, evident in dreaming, remembering, thinking and fantasy processing, generates images as the first phenomenological building blocks of our nature as wholly psychic animals. Indeed, as suggested by Jung, "everything of which we are conscious is an image, and that image is psyche . . . [which] is a world in which the ego is contained" (Jung, 1967, p.75).

Therefore, within this contribute we present a neuro-ethological viewpoint (MacLean, 1990; Panksepp, 1998b; Panksepp and Biven, 2012) that integrates human and animal evidences showing how the "imaginative function" have evolved in terrestrial vertebrates and which kind of brain processes are related to it. In the final part of the manuscript, we discuss some implication of our perspective for clinical psychology and psychotherapy.

THE DMN RESTING-STATE ACTIVITY AND SELF-REFERENTIAL PROCESSING

In 1997, Shulman et al. (1997) published a meta-analytic study showing brain areas with increased blood flow during passive viewing of a stimulus array relative to that during active tasks. The brain areas showing high metabolism at rest belong to a complex of CMS that are tightly connected form an anatomic and functional point of view and have been defined as the Default Mode Network (DMN; Raichle et al., 2001; Raichle and Snyder, 2007). As shown by Rahicle "the brain's DMN consists of discrete, bilateral and symmetrical cortical areas, in the medial and lateral parietal, medial prefrontal, and medial and lateral temporal cortices of the human, nonhuman primate, cat, and rodent brains" (Raichle, 2015, p. 433).

It has been showed that the DMN is characterized by high intrinsic activity during resting states with visual fixating or with eye closed that decreases when subjects engage in goal-directed tasks (Gusnard et al., 2001; Raichle et al., 2001; Greicius et al., 2003). As a consequence, the DMN has been linked to internally-oriented mental processes (Mason et al., 2007) and its functioning is considered in contrast to the dorsal attention network (DAN), that is recruited when attention is directed towards the external world[1] (Corbetta et al., 2008). Moreover, the DMN resting-state activity is particularly evident during REM sleep, an evolutionary old state of the brain characterized by intense neurophysiological arousal accompanied by the

[1] Attention usually shift back and forth between the external and the internal world, and this correspond to parallel shift between the DAN and the DMN. In addition it has been identified a right-lateralized ventral attention network (VAN) which is activated by salient stimuli and re-direct activity from internal-oriented DMN activity towards the DAN (Corbetta et al., 2008).

organism's isolation from the external world (Nir and Tononi, 2010).

Since the great majority of brain metabolism is directed to aliment the DMN resting-state activity, such disproportionate energy consumption not employed in active engagement with the environment has led to an analogy with the dark energy of cosmology. As Zhang and Raichle (Zhang and Raichle, 2010, p. 15) write:

> *"Like our cosmos, the brain also has its own 'dark energy.' Indeed, 'visible' elements of brain activity—neuronal responses to environmentally driven demands—account for less than 5% of the brain's energy budget, leaving the majority devoted to intrinsic neuronal signaling" (Zhang and Raichle, 2010, p. 15).*

Therefore, an open question among researchers is to ascertain which psychological functions are related to such intrinsic functioning of the brain. In the attempt to answer to this question, an increasing body of human studies has shown that the DMN are crucial for self-specific processing, that is the elaboration of stimuli and activities related to the self[2] (Northoff, 2011, 2013, 2016). For example, functional brain imaging studies show that DMN is strongly engaged when personal relevant stimuli, such as person's name, are presented compared with non-self-related ones, like another person's name (Qin and Northoff, 2011). Most surprisingly, DMN activity does not change if we compare self-related activity and resting-state activity (D'Argembeau et al., 2005). This "rest–self overlap" (Northoff, 2016) strongly suggests that resting-state activity is in some way related to the processing of self-relevant information.

Studies of the self-referential DMN activity have radically changed our understanding of the brain. Until the 1990's, research in cognitive psychology and neuroscience was dominated by a task-centric view of mental functioning and emphasized the view of the "brainmind" as an organ reacting to enteroceptive and/or exteroceptive stimuli. However, the massive presence of endogenous activity implies a tendency to form self-organized dynamic patterns (Northoff, 2013, 2014a,b, 2015a,b, 2016, 2018; Northoff and Stanghellini, 2016; but see also Brown, 2002; Llinás, 2002). This also implies that the "brainmind" does not merely react to stimuli, but that it integrates them within its endogenous "intrinsic" functioning (Northoff et al., 2010a; Northoff and Stanghellini, 2016; Northoff, 2018).

Under a Jungian light, the endogenous mental activity (the Self) is formed by potential psychic organizers that give to outer objects their emotional and cognitive value/meaning. Such organizers derive from archetypal schemas that possess a general validity for interpreting the perceived stimuli, which will progressively match with outer experiences and perceptions in order to form personalized complexes (see next paragraph). After Jung, also Melanie Klein's unconscious phantasies (Klein, 1921, 1952/2018; Isaacs, 1948), or Winnicott (1967) "conceived objects," expressed the idea of endogenous psychological structures that match with perceived objects, and that are eventually stored under the form of memories belonging to coherent episodes and narratives[3].

THE AFFECTIVE-EMOTIONAL GROUND OF THE DMN SELF-REFERENTIAL ACTIVITY

Recent neuroscientific evidences show that the degree of self-relatedness depends on the functioning of a core ventral portion of the DMN (D'Argembeau et al., 2005), which is specifically involved in carrying the emotional-affective ground within internally-oriented mental activity (Christoff et al., 2016). In other words, the ventral portion of the DMN "constrains" the imaginative activity within specific orbits of meaning centered on characteristic emotional feelings or moods.

The ventral-core part of the CMS includes the ventromedial prefrontal cortex (VMPFC), the medial orbitofrontal cortex (MOFC), and the sub- and pregenual part of the anterior cingulate cortex (PACC). These regions are densely connected with subcortical regions (brain stem, midbrain, and basal forebrain), as well as with the amygdala, the basal ganglia (striatum and nucleus accumbens), and all primary exteroceptive sensory modalities (Northoff et al., 2006; Christoff et al., 2016). In particular, the affective-emotional grounding exerted by the ventral portion of the DMN depends on the strict connections with a complex of SCMS (Northoff et al., 2006) involved in basic visceral-homeostatic regulation as well as in the emergence of instinctual drives and basic emotional dispositions (Panksepp, 1998a,b, 2005, 2010, 2011; Damasio, 1999; Denton, 2006; Alcaro et al., 2017).

In consideration of their essential functions, the SCMS have been called the "core-Self" (Panksepp, 1998b), or "proto-Self" (Damasio, 1999). They have been implicated in the emergence of a primary form of affective consciousness, characterized by moods, somato-visceral states and basic emotional feelings, which constitute the first form of self-orientation in the world (Panksepp, 1998b; Damasio, 1999; Merker, 2007; Solms and Panksepp, 2012; Alcaro and Panksepp, 2014; Alcaro et al., 2017). Such primordial form of "anoetic" awareness has been defined as "the rudimentary state of autonomic awareness [. . .], with a fundamental form of first-person "self-experience" which relies on affective experiential states and raw sensory and

[2]But what does "Self" mean? Although the "Self" may be viewed as the product of a self-conscious representation, it is also possible to define the Self on the bases of certain minimal essential characteristics that do not presuppose "autonoetic knowledge": the feeling of agency, the ownership of feelings from the body, the experiencing the self as a unit, the labeling of stimuli as self-referential, etc.. As suggested by Weiler and coll., this "minimal self is the most basic level of the self and refers to the consciousness of oneself as an immediate subject of experience that is temporally and spatially confined to the immediate present (Clare et al., 2011); this self does not require language nor working memory but only a short-term memory (Damasio, 1998). It has a relationship with time processing in the sense that perceptions and actions should be continually sensed by someone; disruptions in this system (and therefore in the "minimal self") are commonly seen in schizophrenic patients (Martin et al., 2014; Weiler et al., 2016, p. 246).

[3]With "matching," we are referring to Sander's (2007) analysis of human interactions within a complex dynamic system theory point of view, and to Winnicott's elegant paradigm of the object presenting (Winnicott, 1964, 1965).

perceptual mental existences" (Vandekerckhove and Panksepp, 2009, p. 1).

By anchoring its activity within specific affective routs, the ventral portion of the DMN unfolds an essential settling function for the emergence of a stable sense of self and of external reality. Interestingly, clinical observations demonstrated that patients with lesions in ventral portion of the DMN present a deeply disorganized, psychotic-like mental activity (Solms and Solms, 2000) and remain unable to develop a coherent model of their own self (Damasio, 1999; Schore, 2003, 2009). In our opinion, this may be viewed as the consequence of the disconnection between the DMN and the SCMS. In such case, the imaginative function loses its core-Self affective ground, essential for its coherence, integration, stability, and self-relatedness.

On the other hand, when the power of affect is excessively high, the focus of mental activity may be strongly restricted. This gives rise to rumination, where fixed thoughts or imagines are compulsively produced and dominate the mental field. This phenomenon is particularly evident in depression, a pathological mental state characterized by hyperemotional ruminative thoughts and by increased resting-state activity in the cortical-subcortical midline brain structures (Alcaro et al., 2010; Northoff et al., 2011).

Surprisingly, the absolute relevance of affective processes for self-relatedness was grasped long time ago by C. G. Jung, who wrote that:

> *"Every psychic process has a value quality attached to it, namely its feeling-tone. This indicates the degree to which the subject is affected by the process or how much it means to him (in so far as the process reaches consciousness at all). It is through the 'affect' that the subject becomes involved and so comes to feel the whole weight of reality" (Jung, 1959: para. 61).*

According to Jung, affects not only carry an intrinsic subjective quality, but also an essential integrative property. Indeed, he thought that mental life is organized around specific dynamic structures, called "feeling-toned complexes," that gather together different mental contents on the base of a common affective state (see also Wilkinson, 2006). Each complex is unified by the same affect, which defines its core of meaning, and organizes experience, perception, phantasy and thought around a central theme. For example, a particular complex of inferiority may be made by a constellation of memories, thoughts and phantasies related to the lack of self-worth, a doubt and uncertainty about oneself, and feelings of not measuring up to standards.

The Jungian theory of the feeling-toned complexes is an elaboration of the work of Pierre Janet on the autonomous fixed ideas. According to Janet (1889), fixed ideas are mental images or thoughts that have a high emotional charge and take on exaggerated proportions, so they may not be normally integrated within the ego-consciousness and become isolated from the habitual personality, creating dissociated states of the mind (Monahan, 2009). However, in contrast to the original theory of Janet, Jung sustained that the dissociative aspect of complexes is usually reversible, so they may be much or more integrated according to the momentary situation. Only in severe mental pathologies, such as psychoses, certain complexes are permanently dissociated from the conscious ego and the personality become fragmented. Such disconnection exposes the subject to the powerful and not-modulated activity of "his" complexes, and the subject is anancastically forced to react to his endogenous affective, archaic images, almost devoid of voluntary agency and proper working memory.

THE ESSENCE OF THE IMAGINATIVE FUNCTION: MIND WANDERING AS INTROVERTED SEEKING

The highly affective self-referential resting-state DMN activity may act in a total unconscious way, influencing the individual attitude towards its environment and the subjective (affective) meaning given to external experiences. Such unconscious processing has been described by clinical psychologists by the concept of "implicit unrepressed unconscious" (Fonagy et al., 2002), or of "internal working models" (Bowlby, 1969/1982; Stern, 1985). However, the self-referential processing of the brain may also become accessible to subjective awareness by a process of active imagination that enlightens the intrinsic dispositions of the Self and its prediction models (Alcaro and Panksepp, 2014). The emerging conscious representations refer to objects that have not actually been perceived by the exteroceptive senses, but that are subjectively built in order to express and represent the intrinsic dispositions of the living organism (instincts, drives, habits, emotions) and their connection with ongoing predictive operative working models (see **Appendix 1** for a definition of images and image schema).

When self-referential processing accedes to subjective awareness, our mental field is populated by perceptual-like exteroceptive images with predominant (but not exclusive) visuo-spatial features. The product of this reflective instinct is a pouring out of images (and thoughts) that, like jets of clear water from the rocks of a mountain's stream, are born in a borderland between the unconscious and the conscious, between the body and the mind, and whose substratum is that of raw emotions.

In accordance with such idea, contemporary neuroscientists start to look at DMN resting-state activity in relation to the spontaneous and free-floating flux of conscious images and thoughts implicated in remembering past events, anticipating future events or simply in simulating fantastic or virtual scenarios (Carhart-Harris and Friston, 2010; Schacter et al., 2012; Agnati et al., 2013; Fox et al., 2013; Christoff et al., 2016). Some of them refers to such spontaneous imaginative function with the term "mind wandering" (Mason et al., 2007; Fox et al., 2013; Christoff et al., 2016), defined as the tendency of moving "higher and tighter without fixed course or certain aim" (Simpson, 1989). More specifically, mind wandering is a mental exploration characterized by spontaneity, internal orientation, high propensity to explore, positive affects, freedom from constraints, creativity and

high entropy[4] (Carhart-Harris et al., 2014; Christoff et al., 2016).

Mind wandering has been specifically related to the activity of the medio-temporal-lobe (MTL), a set of brain areas centered on the hippocampus and the parahippocampal complex that constitute the oldest component of the DMN and whose antecedents have been found in the medial cortex of reptiles (Reiter et al., 2017). The MTL is implicated in navigating through the world (both physically and mentally) and in the formation of complex and abstract representations necessary for spatio-temporal orientation, declarative memory, contextual learning, creative thinking and social behaviors (Reiter et al., 2017).

It has then been proposed that the MTL deserves a "self-projective" function, through which the individual travels across a virtual dimension, imaging what has happened, what may happen or what could never happen. Due to such self-projective function, the MTL is implicated in forming new contextual associations, remembering past episodic events, or imaging virtual, novel and potential future scenarios (Buckner and Carroll, 2007; Buckner et al., 2008; Buckner, 2010; Maguire and Hassabis, 2011).

In our neuro-ethological perspective, the self-projective exploratory function mediated by the MTL is supported by the expression of a basic emotional drive, called the SEEKING disposition, whose neural substrates are centered on the ascending mesolimbic dopaminergic system and its forebrain projection areas (Alcaro et al., 2007; Alcaro and Panksepp, 2011, 2014). The SEEKING system is an intrinsic psycho-behavioral function of the brain that evolved to induce organisms to explore and to search for all varieties of life-supporting stimuli (Ikemoto and Panksepp, 1999; Alcaro et al., 2007; Alcaro and Panksepp, 2011). Its activation "changes the individual's attitude towards the environment, promoting an energized appetitive disposition, which unconditionally promotes exploration and foraging for resources, and creates expectancy states that allow animals to anticipate the presence of future rewards" (Alcaro and Panksepp, 2011, p. 1805).

Interestingly, animal studies have shown that the exploratory SEEKING activity is accompanied by the emergence of certain oscillatory rhythms in some forebrain areas belonging to the DMN (for a review, see Alcaro and Panksepp, 2011). More specifically, orienting and exploratory movements are associated with theta oscillations in the hippocampal complex, coupled with gamma oscillations within the ventro-medial frontal cortex and basal ganglia circuits (for a review, see Alcaro and Panksepp, 2011). These neurodynamic patterns seem related to the tendency to move, explore and approach specific sources of stimulation and to the internal attitude to be open and trusty towards novel and unpredictable experiences (Alcaro and Panksepp, 2011).

Moreover, it is also presumable that the same SEEKING neurodynamic patterns are activated also when the exploratory movements are directed towards imaginal objects or thoughts. In accordance with such a view, studies of patients with brain lesions have confirmed that the ventro-medial quadrant of the frontal lobe, that is rich in projections from the SEEKING system, is necessary for dream generation and mind wandering (Solms, 1997, 2000). Moreover, the dopaminergic-SEEKING system is thought to contribute to creativity, in particular divergent thinking, cognitive flexibility, innovative insights, and associative thinking (Flaherty, 2005; Chermahini and Hommel, 2010; Takeuchi et al., 2010; Zabelina et al., 2016; Boot et al., 2017).

As suggested in a previous article, the exploratory SEEKING drive may also have an introverted direction that "permits the channeling of SEEKING not only towards external objects of perception, but also towards internalized mental representations of subjective environments" (Alcaro and Panksepp, 2011, p. 1809). This phenomenon is evident when the categories of stimuli and configurations represented within the MTL do not refer to an external space, but instead to the internally oriented psychological world.

As already indicated in the previous paragraph, the self-referential DMN resting-state activity is usually constrained within specific orbits or "basins of attraction" (Carhart-Harris et al., 2014; Christoff et al., 2016). In particular, some researcher refers to "automatic constraints" to indicate the involuntary influence exerted by feeling-toned complexes elaborated within the ventral portion of the DMN and the SCMS[5] (Christoff et al., 2016). The expression of the automatic emotional constraints may be registered and represented within the MTL, which condenses the operative procedural functioning of the DMN into abstract configurations (image schema). When such configurations become the objects of mind wandering, the unconscious self-referential process elaborated within the DMN is enlightened and transformed into a noetic conscious flux of mental representations (Alcaro and Panksepp, 2014). As shown in the next paragraph, such function is maximally evident during REM sleep dreaming.

DREAMING AS THE ARCHETYPAL FORM OF MIND WANDERING

It has been widely underlined that REM sleep's dreaming constitute the purest and most archaic phenomenal expression of all the possible forms of mind-wandering (Christoff et al., 2016). This claim is perfectly in line with the psychoanalytic assumption that dreams are the "royal road to the unconscious," since they reveal clearly the functioning of our ancestral and primary-process mental activity (Freud, 1900; Jung, 1967).

Interestingly, recent experimental evidences demonstrated that also reptiles show neurophysiological and behavioral correlates of the REM phase during sleep (Shein-Idelson et al., 2010). This evidence suggests the possibility that that dreaming may be not an exclusive characteristic of humans,

[4]"Entropy" measures the unpredictability of the system, its degree of "apparent" randomness and distance from a recognizable order (Ben-Naim, 2008).

[5]It should be mentioned that it has also been recognized the presence of another source of constraints, different from automatic constraints. Deliberate constraints consist of cognitive evaluations and judgments that are explicitly directed towards a goal and that may be overtly represented within the ego consciousness. These deliberate constraints seem to be related to the activity of the dorsal subcomponent of the DMN, which include the dorsomedial prefrontal cortex, the lateral temporal cortex and the inferior frontal gyrus (Christoff et al., 2016).

but instead an instinctual function of the vertebrate brain. Interestingly, during the REM phase, endothermic animals lose their thermoregulatory capacity, so the body is left without its usual metabolic controls, while the brain instead becomes metabolically hyperactive especially in certain MTL regions (Cerri et al., 2017). The "regression" to a metabolic pattern similar to the ectothermic state supports the view than dreams represent an evolutionary archaic mode of functioning of the brainmind (Panksepp, 1998b) and express a primary form of consciousness, or protoconsciousness (Hobson, 2009). Such view also fit with the fact that the brainstem nuclei controlling the REM phase are evolutionary oldest that those controlling slow wave sleep and active wakefulness (Panksepp, 1998b). Moreover, neurodevelopmental studies show that REM sleep appears before non-REM sleep and active waking in the human embryos, and that REM sleep is largely preponderant in the last trimester of pregnancy, decreasing progressively after birth (Birnholz, 1981).

The idea that REM-sleep dreaming represents an archaic and unconstrained form of mind wandering is supported by the evidences showing that the REM-phase is characterized by:

1. a robust ("bursting") activation of the SEEKING-mesolimbic dopamine system (Hartman et al., 1980; Gottesman, 1999; Dahan et al., 2007; Perogamvros and Schwartz, 2012, 2015), which may have something in common with that observed in florid schizophrenia (dominated by positive symptoms such as hallucinations, delusions, hyper-vigilant states, etc.; Solms, 1997);
2. a maximum neurometabolic activity in the MTL, the oldest part of the DMN that endotherms share with reptiles (Christoff et al., 2016);
3. a major independence of MTL activity from the influence exerted by other DMN areas (Carhart-Harris et al., 2014);
4. a deactivation of cortical areas that exert deliberate control over mental functioning and that are involved in self-monitoring, such as the orbitofrontal cortex, the posterior cingulate cortex, the precuneus, the dorsolateral prefrontal cortex, and the inferior parietal cortex (Nir and Tononi, 2010; Christoff et al., 2016);
5. a profound inhibition of the primary perceptual and motor areas.

In relation to the neurophysiological peculiarities of REM-sleep, REM-type dreaming expresses several phenomenological differences with waking consciousness (for a review, see Nir and Tononi, 2010). First of all, dreams are often characterized by increased emotional arousal and affective involvement (Schredl, 2010). Such increased emotionality in REM sleep is related to hyper-activation of the highly emotional limbic brain (for a review, see Nir and Tononi, 2010) and, in particular, of the SCMS, where all the main basic emotional systems are located (Panksepp, 1998a,b; Alcaro et al., 2017). Interestingly, also animals dream highly emotional experiences, since cats with lesions in neural areas responsible for muscle atony during REM, show complex emotional behaviors of attack, defense and exploration (Sastre and Jouvet, 1979). Similarly, highly emotional behaviors are also frequent in subjects with REM sleep behavior disorder, who act out their dreams (Oudiette et al., 2009). Moreover, experimental evidences in humans demonstrated that after the 13th week of gestation and during the neonatal period smiles and other emotional expressions are more frequent, stable, and enduring during REM sleep than during other behavioral states (Dondi et al., 2007; Messinger and Fogel, 2007).

Interestingly from an affective neuro-ethological viewpoint, only certain emotional dispositions are overexpressed in dreams, such as surprise, anger, fear, euphoric expectancy (SEEKING), or sexual desire, while, sadness, guilt or depressed affects are rare (Fosse et al., 2001; Smith et al., 2004; Nir and Tononi, 2010). Moreover, children preschool dream reports are often characterized by an explicit fulfillment of a wish (Colace, 2010, 2013). This fact confirms the original psychoanalytic view that dreams often constitute a hallucinatory expression of an unfulfilled desire, as well as our neuro-ethological view that imagination and dreaming are the expression of an introverted SEEKING drive. However, we think that this evidence does not necessarily confirm the Freudian assumption that dreams serve to discharge an excitatory somatic overload (drive-reduction theory; see next paragraph).

In adults, dreams are also characterized by reduced attention and voluntary control, delusional ideation, disorientation, impaired working memory, and lack of usual logical and linear spatio-temporal relations (Nir and Tononi, 2010). In an old but efficacious psychodynamic language, we can say that dreaming consciousness is characterized by an "abbaissament du niveau mental," a collapse of the psychological tension that usually integrates mental contents and organizes them in a rational structure (Janet, 1889).

However, the studies on the ontogenesis of dreaming have shown that children preschool dreams (3–5 years) are frequently simple and without bizarreness (Colace et al., 1993; Colace, 2010, 2012). These evidences indicate that bizarreness is not an intrinsic property of neurophysiological events in the REM phase of sleep. In our opinion, the increase in dream bizarreness during development may be related to the increasing complexity of the individual brainmind and not just to the attempt to bypass repression, as suggested by Sigmund Freud. Indeed, the more the noetic memory system becomes ramified and differentiated, the more the dream will manifestly show those highly complex synthetic formations, which we call images, and which Freud though were a product of a condensation process. By doing so, the dream functions as a producer of virtual scenes that express the coherent and symbolic meaning of our inner world, which does not follow the rules of the external reality (Wilkinson, 2006; Alcaro and Panksepp, 2014). As suggested by Jung, "dreams do not deceive, they do not lie, they do not distort or disguise, but naively announce what they are and what they mean. [. . .] they are invariably seeking to express something that the ego does not know and does not understand" (Jung, 1946, para. 189).

ON THE FUNCTION OF DREAMS

In the attempt to ascertain the adaptive function deserved by the evolution of dreaming, the majority of research and theories focused on its role in the consolidation of memories (for a review, see Diekelmann and Born, 2010). These theories start with the

phenomenological observation that dreams often incorporate experiences that the subject had during the day or within the days before Foulkes and Rechtschaffen (1964), Foulkes (1985) and Foulkes et al. (1989). It has also been demonstrated that the amount of time spent in the REM phase during the night following a training session has a positive influence on the person performance in the following days (Grieser et al., 1972; Barker, 1977). On the other hand, the selective deprivation of the REM phase has a negative influence on performance on the days following the training (Chernick, 1972). Further experimental studies in humans and animals showed that during the REM phase one witnesses a reactivation of the very same neurons and neural circuits that were particularly active during wakefulness (Pavlides and Winson, 1989; Maquet et al., 2000). Moreover, REM sleep is able to strengthening memory consolidation by activating the expression of genes linked to synaptic plasticity (Ribeiro and Nicolelis, 2004; Rossi, 2004).

It has been suggested that dreams are involved in the reactivation of cerebral circuits stimulated during wakefulness in a way that reinforces the new connections (Stickgold, 1998; Stickgold et al., 2000). Withdrawing oneself from the outside work, the organism sinks within a psychobiological "off-line" state that allows it to enter in contact with the recently acquired experiences, re-elaborating and integrating them with those already existing (Gais et al., 2000; Maquet, 2001; Mednick et al., 2003).

Although supported by an abundance of data, mnestic consolidation theories of dream's function are not able to explain why dreams are not limited to repeating already-lived experiences, but instead they re-elaborate them in new and creative ways. A careful look into the contents of dreams reveals that they combine information acquired the day before with past memories as well with expectations and phantasies (see next paragraph). As suggested by Ribeiro and Nicolelis (2004) dreams "are hyper-associative strings of fragmented memories that simulates past events and future expectations" (p. 12).

The most influential simulation theory of dream's function was proposed by the psychologist and philosopher Revonsuo. He sustained that dreams allow an off-line simulation of threatening events and promote the development and maintenance of threat-avoidance skills during wakefulness (for a recent review, see Valli and Revonsuo, 2009). It was further showed that such anticipatory off-line training of the brainmind was not exclusively directed toward avoiding aversive experience, but also approaching appetitive situations and conditions (for a review, see Perogamvros and Schwartz, 2012).

THE PRIMARY AND THE SECONDARY PROCESS OF THINKING

The spontaneous and free-floating flux of imagines that characterizes dreaming and mind wandering has been recognized in psychoanalysis long time ago. Sigmund Freud referred to it as the "primary process of thinking," described as the instinctual, visual and unstructured mental processing typical in children, in dreams, and in those with psychoses. Whereas for Freud the primary process is involved only the discharge activity of psychosomatic drives, for Jung it actually constituted a specific way of "thinking." According to Jung, such processes carry not only an unknowable somatic aspect (Freud's drives), nor just a fundamental affective content, but also a cognitive activity which may be potentially extremely developed, albeit functioning in its specific imagistic, metaphorical, condensed way.

In accordance with Jungian view, recent neuro-dynamic models suggest that dreaming and mind wandering are inferential predictive processes of the brain, where virtual realities are created in order to optimize organism's expectations and performances within the external reality (Hobson and Friston, 2012; Moutoussis et al., 2014). Indeed, experimental data showed that REM sleep enhance cognitive flexibility (Walker et al., 2002), decision making (Pace-Schott et al., 2012), moral reasoning (Killgore et al., 2007), insight (Wagner et al., 2004), and creativity (Home, 1988; Cai et al., 2009; Schacter et al., 2012).

It seems then very plausible that the primary process of thinking permits a "psychic rehearsal of possibilities" (Ribeiro and Nicolelis, 2004) that unfolds a prospective adaptive function, helping to anticipate possible future events or to find solutions to unresolved problems or conflicts. Such idea was anticipated that C. G. Jung, who was in overt conflict with the Freud in assuming that dreams are "an anticipation in the unconscious of future conscious achievements, something like a preliminary exercise or sketch, or a plan roughed out in advance. Its symbolic content sometimes outlines the solution of a conflict. . ." (Jung, 1947/1954, p. 493).

In waking modern adults, the primary process is usually abandoned in favor of a more mature, linear, constrained and "rational" way of thinking, that we may call, after Freud, the "secondary process of thinking" and that is related to the emergence of a stable sense of self and of the external reality. Freud and Jung argued that the primary process of thinking is dominant in all unconscious ways of functioning, in human infancy and in the "savage" (sic!) man. However, healthy adults of our modern society it generally shows a new and more mature form of cognition, characterized by the ability to form metacognition and to self-reflection (Shimamura, 2000; Fleming et al., 2012).

It is very hard to describe what makes this fundamental evolutionary passage possible, and any attempt in such direction is beyond the scope of this contribution (see Carhart-Harris and Friston, 2010; Northoff et al., 2010b). However, following a neuro-psychoanalytic path, we may consider that in humans the attachment relationship becomes the instrument for an additional and fundamental evolutionary step in subjective mental life. This step has been described with the concept of "object cathexis" (Northoff, 2011), that is to say with the development from a spontaneous imaginative activity centered on affects to an imaginative activity centered on the representation of internal objects isomorphic to the external ones perceived[6]. This process is directly linked to the permanence and stabilization of object's representations and self-representation,

[6]However, a failure in the postnatal attachment relationship may lead to a block of social communication and to variety of pathological outcomes as a consequence

and permits the passage from the primary to the secondary process of thinking (Carhart-Harris and Friston, 2010; Northoff, 2011).

However, the primary process does not disappear, but it continues to live in the underworld in the form of unconscious fantasies that influence our mental processes, our moral evaluations, our behavior and, pervasively, our conscious activity. Moreover, the primary process of thinking may be consciously accessible in non-ordinary states of consciousness, such as dreaming, free-association, meditation, divergent thinking/creativity, sensory deprivation, near death experiences, psychedelic states, magical thinking, religious experiences, the onset-phase of psychosis and the dreamy-state of temporal lobe epilepsy (Carhart-Harris and Friston, 2010; Carhart-Harris et al., 2014).

The archaic mind-wandering function does not disappear in humans, but unfolds an essential *dispositional* re-equilibrating" function that permits to maintain the organism's neuro-psychic identity and stability. Jung called it the "compensatory" function (Jung, 1935a, 1956). A quite similar hypothesis has been proposed by Jouvet (1975), who considered dreams a form of neurogenetic re-elaboration where new experiences are assimilated in accordance with the organism's instinctual psychobiological nature. According to Jouvet, dreams constitute a form of neuro-genetic programming, where lived experience of contact with the external reality is assimilated and re-organized beginning with one's own psychobiological identity. In our view, such process of continual re-programming theorized by Jouvet and Jung has a primarily affective origin. In fact, while during active wakefulness emotional dispositions are strongly tied to the conditions of the external environment, during imagination and dreaming they can be expressed more freely, influencing our mental activity in a manner that is direct and all-embracing (Hopkins, 2016).

THE NEURO-EVOLUTION OF THE IMAGINATIVE FUNCTION

The evolution of the imaginative function follows a path that may be divided in three stages:

1. REM-sleep dreaming that is present in reptiles and constitutes the first form of mental imaging.
2. Mind-wandering that is present in endotherms and constitutes the amplification of a dreamlike imaginative function in the resting wakefulness.
3. Constrained secondary-process imagination that is present in humans and is characterized the by a stable sense of the Self and of the external (physical and social) reality.

Reptiles and the Dreaming Brain

The evolution of terrestrial vertebrates is characterized by increasing complexity and plasticity in their neuro-psycho-behavioral organization and by the emergence of a new form of "noetic" consciousness that superimposes the core-Self anoetic awareness (Fabbro et al., 2015). Noetic knowledge refers to experiences that "arise when refined attentional capacities permit a clear distinction and categorization of specific features of the environment which, with enough neo-cortex, allows animals to think ahead. Indeed, when specific aspects of events become the focus of attention, explicit object-related reflective awareness comes into the fore while semantic (conceptual) memory helps to analyze and categorize the situation (Tulving, 1985). This is the form of consciousness that Edelman called "primary consciousness, " and that he related to the activity of re-entrant thalamo-cortical brain circuitries (Edelman, 1989). Indirect evidence suggest that noetic consciousness is present across mammals, birds, and perhaps also in reptiles (Edelman et al., 2005), and that human babies, born very immature, start to manifest it after the 3rd month of development" (Alcaro et al., 2017, p.10).

As suggested by Jung and Jouvet (see previous paragraph), the evolution of noetic knowledge may threaten the maintenance of an integrated and coherent psychobiological identity (the Self). Therefore, the focused attention processes used by terrestrial vertebrates when they are dealing with the external environment may be compensated by the return to a "primary-process" unconstrained arousal that turns things upside-down. In such a way, the impact of the external reality on the organism is assisted by an inverse movement, through which the organism re-organizes its experience using an instinctual code.

Interestingly, recent evidences showed that, together with their novel noetic abilities, reptiles exhibit neurophysiological correlates of the REM sleep (Shein-Idelson et al., 2010), suggesting that a primordial form of dreaming evolved early in terrestrial vertebrates, well before the evolution of endothermic species (mammals and birds). Such kind of mental nomadism may be related to the off-line expression of a SEEKING-self-projective drive within the medial cortex, which constitute the reptilian antecedent of the MTL of mammals (Reiter et al., 2017). In producing an enormous amount of mental images and representations, dream imagination "help to solidify the many unconscious habits that are the very foundation of our personality. In the final accounting, dreams may construct the powerful subconscious or preconscious affective psychological patterns that make us. . .the people that we are. They may help construct the many emotional myths and beliefs around which our lives revolve" (Panksepp, 1998b, p. 142). In this essential mythopoietic process, dreams are the first ring of the reflective function, permitting that the "Self comes into mind" (Damasio, 2010).

Endotherms and the Amplification of the Imaginative Function

In contrast to cold-bloodied terrestrial vertebrates[7], mammals and birds present metabolic modifications that facilitate oxygen

of the dissociation between core emotional feelings, internal autonomous imagery, and action through verbal and non-verbal expression.

[7]It has been shown that cold-bloodied terrestrial vertebrates show lower respiratory rates than endothermic vertebrates, and present a predominant anerobic metabolism (Bennett and Dawson, 1976; Bennett, 1991). Such low metabolic potentials of ectoterms reduce their ability for spatial exploration. Although they are able of bursts of intense exercise, they rapidly fatigue as a result of lactic acid accumulation.

uptake, transport and delivery[8] (for a review, see Hillenius and Ruben, 2004). Due to elevated rates of cellular oxygen consumption, mammals and birds are able to sustain higher levels of activity for extended periods of time, with considerable ecological advantages. Such stamina enables these animals to forage over large territories, and/or to perform extensive seasonal migrations in pursuit of favorable resource conditions (Hillenius and Ruben, 2004).

The increased cardio-pulmonary capacity not only affects behavioral activity, but also potentiates *resting metabolic rates*, that in mammals and birds are 10–15 times greater than in reptiles (Bennett, 1973; Schmidt-Nielsen, 1984). The increased resting metabolic rate allows for increase body heat and for regulating it in an autonomous mode, independent of the external physical environment (Hillenius and Ruben, 2004). Therefore, endothermic species can use the excess metabolic capacity to increase internal order, homeostasis and their living subjective autonomy (Torday and Miller, 2018).

The increase in metabolism does not influence only body heat, but effects also the level of resting-state brain activity. Although ectoterms show a consistent reduction of brain metabolism when they are not engaged within specific actions, mammals and birds periodically show brain metabolism during sleep and resting wakefulness that reaches and even exceeds the levels typical of periods of active engagement (Mantini et al., 2011; Lu et al., 2012; Raichle, 2015). Therefore, in endotherms, the endogenous self-referential inferential processing is not restricted, as in reptiles, to brief off-line REM-like arousal states, but occupies wide portions of sleep and resting wakefulness. In such a way, they are able of greater exploration (SEEKING) not only directed towards the external world, but also towards the mental internally-generated world. Such important amplification is related to the evolution of some ventral and dorsal midline cortical brain structures (Raichle, 2015).

In our neuro-ethological view, the imagination of endotherms is closely related to the evolution of complex socio-affective relational patterns that may be modified by experience and constantly re-programmed within resting-state DMN activity. In accordance with such hypothesis, the neuroanatomy of their social emotional systems (PLAY, CARE and PANIC/SADNESS) extends to cortico-limbic midline areas belonging to the DMN[9] (Panksepp and Biven, 2012). It seems also plausible that in the early infancy, the attachment process, sustained by basic emotional drives, is open to modulations exerted by the imaginative function.

As a consequence of their amplified imaginative function, endothermic species show complex social, cognitive and affective capacity, such as creative thinking, the ability to fake, some form of a "theory of mind," etc. (Griffin, 1985; Crystal, 2012; Roberts, 2012). In particular, the inferential and innovative aspect of the resting-state imaginative activity influences the communication skills by enriching them with a repertoire of potentially unlimited signals, signs and symbols[10]. An illuminating example in this regard is that of bird singing in migrating birds such as the *Sylvia atricapilla* (Portmann, 1986), in which repetition and creative spontaneity are combined, giving birth to a unique and unrepeatable language.

Interestingly, recent evidences show that birdsong sleep is characterized by periods of neural activity implicated in song-replay (Derégnaucourt et al., 2005), that unfold an important function in the vocal learning of songbirds (Shank and Margoliash, 2009; Margoliash, 2010). Although the contribute played by different sleep stages in such a process has not been determined yet, experimental data show that the plasticity of vocal songs is incremented by certain oscillatory bursts of neural activity that in mammals accompanies REM sleep and the activation of the SEEKING brain system (Yanagihara and Hessler, 2012).

Humans and the Evolution of Verbal Thinking

Originally, the imaginative function was essentially an "off-line" process that takes place in REM sleep (reptiles). With the evolution of endotherms, the DMN resting-state patterns is attuned in a "transitional space" where internally generated fantasies and external communicative actions overlap. In the human species, such transitional space realizes its vast potential due to the evolution of linguistic communication, a tremendous jump that separated our species from other animals and that is the base of all forms of human civilization.

With the acquisition of language, the flux of visuo-spatial representations may acquire the structure of audio-verbal thoughts. In such a way, during human development, the collective and transpersonal dimension may be interiorized within individual psyche, permitting the kind of cultural revolution that is linked to and completes biological development.

It has been supposed that the evolution of language permitted the development of "autonoetic consciousness" (Fabbro et al., 2015), defined as the capacity to represent themselves across

[8]For example, endotherms show increased pulmonary capacity, ventilation rate increased blood volume and blood oxygen carrying capacities, fully segregated pulmonary and systemic circulations and expanded cardiac output, as well as increased mitochondrial density and enzymatic activities.

[9]It has been noted that three elements of behavior mark the transition from reptiles to early mammals (and birds): nursing, play, and the separation call (MacLean, 1985). Further studies in affective neuroscience have localized specific subcortical brain circuits responsible for such social behaviors and their characteristic emotional feelings: the CARE/nurturing love system, the PLAY/joy system and SEPARATION distress/panic-sadness system (Panksepp, 1998a; Colonnello et al., 2011; Panksepp and Biven, 2012; Panksepp and Panksepp, 2013). All three systems use vocal and non-vocal channels that initially develop during attachment and then are used in all other types of social interactions.

[10]Neuro-evolutionary studies performed by Stephen Porges have shown that emotional expression and communication (facial expression, sucking, swallowing, breathing, crying, vocalization, etc.) are controlled by cranial nerves and muscles that evolved from the primitive gill arches that extract oxygen from water. Moreover, they depend on the efficient functioning of the ventral vagal complex (VVC), a parasympathetic system that evolved in high vertebrates to regulate the internal state of the body in a flexible and rapid way (see Porges, 2011 for a compendium). Together this suggests a means of tuning the psycho-physiological regulatory function to socio-emotional communicative processes, as well as of registering the intersubjective social environment on the internal affective world of the individual (see Trevarthen and Aitken, 2001, for a review).

space and time, and to build a stable and conscious psychological identity, that we may call the "ego." For example, Sigmund Freud underlined how verbal thinking is the main form of self-conscious perception of internal mental activity. The importance of verbal language and specialized linguistic brain areas for self-consciousness has today been confirmed by influential neuroscientific theories (Edelman, 1992).

However, the psychological analysis of patients with cerebral lesions shows that damages to the right hemisphere induce deeper personality diseases and deficit in self-consciousness than equivalent lesions to the left hemisphere, where language areas are located (Kaplan-Solms and Solms, 2000). For example, not only right-damaged patients tend to completely neglect their diseases (anosognosia), but they often present severe psychiatric symptoms, such as profound melancholia, paranoid ideation or a complete collapse of the ego functions as observed in florid psychotic states. Kaplan-Solms and Solms (2000) concluded that the right cortico-limbic network is implicated in "object catexis," the process through which mind wandering is constrained by experience-dependent operative models of attachment organized within the right brain (Schore, 1994). This kind of containment is necessary to the passage from the primary to the secondary process of thinking, and then for a stabilization of ego and objects representations (Carhart-Harris and Friston, 2010; Northoff, 2011).

A way to integrate the linguistic and non-linguistic theories of autonoetic consciousness is to suppose that verbal thinking permits the passage to the secondary process and amplifies its functioning only when the subject is able to distinguish the internal from the external world. This differentiation presupposes the mentalization of the experience of being separated from the desired/loved object (Klein, 1921; Bowlby, 1969/1982). In our neuro-ethological perspective, it means the possibility of a complete expression of the PANIC/SADNESS SEPARATION DISTRESS emotional complex within the conscious self-referential imaginative activity. Only in such case, verbal thinking and mental imaging may be properly attributed to an internal psychological space, which is different from the external social world of others[11].

We are aware that this is a very important theme, which needs a deeper and wider analysis, especially in consideration of the process of "object catexis" (Northoff, 2011). It is then our proposal to dedicate to such argument an entire article that will complete a trilogy about the neuro-evolutionary architecture of human mind. Such trilogy started with the article about the affective core of the self (Alcaro et al., 2017), continued with this article on the primary-process imaginative function and will finish with a work on "object catexis" and the secondary process of thinking.

[11] We are aware that this is a very important theme, which needs a deeper and wider analysis, especially in consideration of the process of "object catexis" (Northoff, 2011). It is then our proposal to dedicate to such argument an entire article that will complete a trilogy about the neuro-evolutionary architecture of human mind. Such trilogy started with the article about the affective core of the self (Alcaro et al., 2017), continued with this article on the primary-process imaginative function and will finish with a work on "object catexis" and the secondary process of thinking.

PSYCHODYNAMIC CONSIDERATIONS AND PSYCHOTHERAPEUTIC APPLICATIONS

In the following pages, we will try to sketch our idea of the psychotherapeutic process (which fundamentally refers to the paradigm of Analytical Psychology) on the basis of the considerations that we have presented in the previous pages. In order to do so, we must once again recall our view of the mindbrain as a dispositional organic whole, which is activated "bottom up" and "inside out." This means that the origin and the foundation of the mindbrain's activity is activated from anoetic anobjectual affective states through a noetic endogenous imaginal production (image schemas), towards a autonoetic-verbal domain. All this is coherent with Jung's idea that the primary level of mental processes is fundamentally *affective*. This first pre-formed affective motivational layer (the readiness to respond) acquires a complete psychological shape when is connected to—represented by—adequate "images," that actually act as gestalt-patterning structures (Bucci, 1997). As we said, this connection between affects and images is a fundamental evolutionary gain (in endothermic animals) and is the precondition for a healthy mental development in ontogenesis. Indeed, without the adequate imaginal containment, the affective states of the Self have a diffuse and undifferentiated presence and are therefore projected directly onto the external perceptual world. In such a way, these indistinct emotional states and the objects of the perceived external world overlap. In other words, the individual is not able to "reflect on experience" and to distinguish the internal and the external.

If, as Jung maintained, the unconscious is formed by complexes of representations, which give shape and express fundamental affective dispositions, then producing appropriate images means to re-structure the integrative function in order to interpret and then respond to stimuli (i.e., to experience) in accordance to the nature of the "core-Self." Jung described this imaginative process in his *Red Book* (Jung, 2012) or in his essay on the so-called "transcendent function" (Jung, 1916/1957). This process is experienced by artists (Carta, 2017b), who are able to first (receptively) *find* and then (actively) *give* an imaginal shape to their feeling states.

For Jung, the two fundamental ways to access the unconscious formations—what he called "complexes"—were dreams and the emergent imagery activated through "active imagination," both of which possess a noetic form of consciousness. Both dreams and active imagination may eventually be followed by an autonoetic process through which the emergent noetic images may be analyzed and verbally shared in an autonoetic (self-reflectively conscious) state.

As we said, the noetic activity is the core of "active imagination" (Jung, 1916/1957, 2012), a process analogous to D.W. Winnicott's concept of *non-integration*—i.e., of a relaxed/empty state of mind in which the ego may come into contact with endogenous impulses of the "True Self" (Winnicott, 1964, 1965). It is also similar to Bollas' concept

of the *unthought known* (Bollas, 1987), which refers to an archaic objectless affective activation that, in some "regressed" patients, appears like a form of diffuse mood. Active imagination has also been described at length by Khan (1983) as a state in which the mind "lies fallow," i.e., retires from activity in the outside world in order to restore its connection with the Self. Such a state is connected with the capacity to be alone, i.e., to withstand a hollow resting state open to the reception of inner stimuli (images). This state may be also connected to the crucial moments of *alert inactivity* (Wolff, 1966), during which the newborn probably rehearses and explores through images new associative links in order to give emotional stability and cognitive coherence to his experiences.

From all we have said up to this point, we are now in the position to sketch some fundamental principles for a psychotherapeutic approach, which are based on the process through which the dispositional brainmind forms its *endogenous images*[12] (hence not necessarily perceptions, nor memories of perceptual biographical events). This implies the departing from experiences/representations of outer/perceived objects towards a state from which endogenous, conceived images may arise. Therefore, in a way anti-behavioristically, we will not work on directly coping with "outer" facts, but we will *primarily* look for "inner images," therefore restructuring the mindbrain capability to spontaneously form images. In a way: to learn how to properly *dream* in the waking state within the analytical situation.

We stress the word "primarily," because it is obvious that the relationship between the inner and the outer environment—the brain-mind and the outer world—is a circular one. What we are trying to say may be expressed by comparing, in a somehow stretched manner, the main orientation of behavioral psychotherapy (BT), and of a noticeable part of cognitive-behavioral psychotherapy (CBT), with our model. It seems to us that, *within the circular process between disposition and situation*—between the brainmind and the environment—BT and CBT focus their attention on the outer object (on the situation). For instance, in order to cope with a phobic response, BT or CBT may systematically intervene on the way the subject deals with the perceived object by trying to better respond and adapt him to the situation. If the phobic object is a mouse, or an elevator, the psychotherapist will focus on them.

Our aim is apparently the same—to provide a more harmonic adaptation to the environment. Nevertheless, we would not consider the perceived object, which has become so salient for the phobic patient, as the true object that the patient is attracted to, but as a "fetish" that contains, or refers to, another, unconscious self-referential process that the subject is not yet able to imagine for a number of reasons. Such unconscious process is activated by an anoetic affect, which is projected onto the outer object (the phobic, fetish) *in search for an imaginal* shape[13]. In a "normal" situation, outer objects may provide a good-enough imaginal shape to the subject's anoetic objectless affects, so that we may normally not be aware of the fact that, in truth, every meaningful (affectively salient) relationship represents the emergence of an inner, endogenous, potential affective image. As Winnicott explains, the shape that the outer object lends to the endogenous affect *should* be "just" good enough, in order to promote and maintain the activity of the SEEKING system at a productive level, and hence foster creative adaptation[14]. Therefore, our work will not be directed towards the outer—perceived—object, but towards the autonomous image that we expect will raise from the patient's unconscious *via* the anxious, phobic feeling tone that the fetish contains. Once again, the process is actually circular, but our approach does not aim at adapting the subject to his situation, but to help him to dispositionally interpret it as something that is at the same time "found and created" (Winnicott, 1967)—i.e., transform facts into meanings. In order to do so, we must help the patient to look at his objects as projected images which have a symptomatic, and not a symbolic, character, as they are not yet able to express the patient's dispositional affective nature within his environment. In other words, such object-relations express an inability not just to adapt, but to adapt in a personalized (creative) way to the world, because, as Heidegger would say, humans do not live in an environment, but into a *world*.

More generally, we usually do not interpret anxiety as a non-specific response to an environmental menace, but as the failure by the brainmind to form "good images," i.e., images that, following Jung's model, may give an imaginal noetic shape to affects that organize the Self into complexes and, eventually, into an autonoetic, verbal activity. Thus, we think that the psychotherapeutic efforts to directly deal to the outer object-world, especially through higher cognitive functions, actually point to a secondary level—a level of reaction/adaptation. On the contrary, our model aims to focus on a primary level that deals with the failure of the brainmind to form good images, i.e., to properly organize its own bottom-up activity, from basic raw affects to self-reflective consciousness, through spontaneous endogenous noetic image-formation process.

In our perspective, the spontaneous formation of feeling-toned conscious images is therapeutic *per se*, since it creates the conditions where rejected affects (this rejection may

[12]Of course, such images may acquire, through projection, the likeness of outer objects. This is clear in fetishism and phobias, in which the objective, perceived, outer object acquires a value-meaning from the projection of an endogenous, still unconscious affect-image image. Therefore, also in such cases we think that the "active principle" that produces a phobia or a fetish is to be found "inside" the object, which acts as a carrier. Hence, the best approach should not be from the outside towards the inside of the mind, or from perception to cognition and emotion, but "inside out"—the other way around.

[13]If we turn our view from the outer object, to the brain, we may refer to Panksepp's (1998b) view of the role of the amygdala regarding FEAR. He maintains that the amygdala is not the origin of the FEAR affect, but that it is an associative site in which the original raw affects (the unconditioned stimulus) arising from lower regions of the brain, especially the PAG, are redirected within the brain and associated with conditioned stimuli.

[14]Without this character of non-perfect adaptation of the inner endogenous image to the environment, our specie would be extinct, as humans need plasticity in order to compensate their neotenic biological endowment.

reach the level of what Lacan (1958) called "forclusion") may gain access to the imaginative field and then may be eventually perceived by self-awareness. This is possible by the creation of a condition for a possible regression towards a state of relaxation, or non-integration, that favors spontaneous imagination. Such a regressive condition has to do with the "regressive" shift from autonoetic (verbal) consciousness towards noetic, pre-reflective awareness. Jung (1946) theorized in length on this condition, but also Freud had this in mind when he wrote about a regressed state of the patient laying on the couch, in which the patient can associate "freely" while the analyst maintains a free-floating attentive state. Both these two authors make it clear a fundamental condition for psychotherapy: not only the patient, but *also the psychotherapist must maintain a noetic level of consciousness*.

Being fundamentally affective, the patient's and the analyst's endogenous images will be representations of their inter-affective, analytical field: their psychological *place of meeting* (see Stern, 1985; Sander, 2007) often described as *transference*. The creation of this transferential field is made possible by the analyst's disposition to affectively/imaginatively tune in with the patient. In doing so, the analyst must be open to any signal that belongs to what Jung, on the basis of his theory of (psychosomatic) complexes, called somatic transference. Within this state not only verbal meanings are important. What is actually central are expressions which are based on *implicit* meanings, and which may be conveyed by non-verbal expressions, or by specific *actions*[15]. By this the therapeutic relationship may gradually turn into a sophisticated form of reciprocal *active imagination*, in which the analytical couple forms a relational network formed by the combination of their conscious and unconscious processes (for a description of this situation, in which the analytical relationship is also a co-imaginative process, see Jung, 1935b[16]).

It is crucial that, within the transferential field, the analyst sinks into a double mental state in which he is at the same time self-reflective and in contact with his inner noetic (dreamlike) activity. The therapist must be able to master a *double* state of consciousness—a noetic form of imagination monitored by an autonoetic activity—a hybrid state necessary in order for to perform what Bion (1985) called *rêverie*[17]. This implies that he will be tuned with the patient's psychological formal activation level, so that the images that rise in the therapist's mind, inter-affectively tuned with the patient may actually be (also) the latter one'. One of us has discussed this situation, and called it "ecstatic" (Carta, 2017a). It will happen that, in this state, images will flow through the analyst mind, too. They should be taken into close and critical account, as they may be aspects of the patient's anoetic (purely bodily/affective) states that are projected into the analyst, or that the analyst just feels. The same may be true for elements of the analyst's somatic transference.

Thanks to the double-state of its mental activity (noetic and autonoetic), the therapist is in the position to verbally reflect on these images in an autonoetic conscious state. For a patient this means to be able to express the noetic emergent images and to negotiate them with the analyst—an exceedingly important function, indeed. If the image is the reflection of the affective state upon itself, the autonoetic word is the self-reflection of the image. Nevertheless, during the imaginative noetic phase the verbal nature of the cure must be suspended. First, let the images flow, and then talk from them about them.

We would like to stress that the transformation from image to word is gradual. In fact, before words may fully express self-reflectivity and a mature object relatedness (with no confusion nor split between self and object), the quality of the language is deeply metaphorical. In fact, metaphors are the verbal formations closest to images, as they tend to condense two terms into a hybrid third one, which, like images, will be understood through a synthetic apprehension, *en masse*. At this stage of the process, non-metaphorical, intellectual, analytical words may feel irrelevant, abstract or, worse, dissociating due to their intellectual/ intellectualizing nature. In our experience, metaphorical language is by far the most frequent form of language that flows between patient and analyst. It is a non-yet fully conscious (autonoetic) language, but it is the direct verbal immediate product of the transformation of affective contents expressed or expressible through images (dreamable).

In sum, the function of the psychotherapist and the therapeutic process may be recapitulated as such:

1. **Description**. The psychotherapist helps the patient to describe his situation. He will not try to intervene on the patient's representation of his extroverted objects, but will help him/her to focus on the feelings and on any association that may arise from this representation. If, for instance, the patient will refer to his/her phobia of flying, at this stage the psychotherapist will not suggest any interventions or any

[15]In this case, such actions are the opposite of acting outs, as they not only do not substitute meanings and block change, but actually convey an implicit, condensed complexual meaning that seems to be finding its bottom-up way from affects, through the noetic action, into a autonoetic, self-reflective process.

[16]If, as Jung says, in the wakeful state we are the subject of all objects, and, [...] in complete reversal of my ordinary consciousness," in the unconscious I am the object of all subjects (Jung, 1959, para. 46; or in dreams, as in the dream every image possesses an autonomous subjectivity), in the noetic state of mind like that that supports active imagination, the affective images may autonomously flow into the analytical space, while the egos of analyst and patient still participate with their own specific subjectivity. In fact, within the individual, private imagining process the ego may imagine to interact or to talk to these images in a brainmind state that we think is based on the activity of the Default Mode Network Network (DMN). The same may happen in a relational space, in which the other is at the same time perceived and conceived. This "imagining the other" has obvious transferential connotations. Nevertheless, far from being always blind and narcissistically wish-fulfilling, it may actually grasp, through unconscious perception (intuition) elements of truth that are still unapproachable by autonoetic consciousness.

[17]An important distinction between our position and Bion's rêverie, is that the contents of the latter are not just what he called "beta elements" (raw sense-data and of "inchoate elements," Bion, 1967) but may be, due the imaginal nature of the noetic processes, also affective images, which corresponds to what Bion called "alpha elements."

possible modification, as the image of flying may not actually be the best image connected to the original affect, but just a second associative carrier for the affect itself. We think that from this stage, the language spoken is already deeply metaphorical. Intellectualizing, theorizing, or sharp analyses are now counterproductive. The psychotherapist must *already be in a double state of consciousness*.

2. **Focalization. Patient sinking into the resting state**. At this point, the psychotherapist helps the patient to depart from his/her involvement with extroverted images/objects, and focus on his feelings. In fact, in order to let the endogenous image raise it is imperative that the patient attentively focuses on the feeling-tone, or the specific mood, which is the *prima materia* out of which the images are formed. Such a focus must also be directed towards bodily feelings, tensions, movements of any kind, while a correct breathing is secured[18]. While the patient sinks into the resting state and begins to imagine, he should not speak. Verbal activation and speech may actually interfere with the process of imagination.
3. **Containment**. The psychotherapist must contain the patient as he/she experiences contact with endogenous images. This means to be able to *go where the patient is*, which we believe to be the cornerstone of psychotherapy. This process implies a mature and sustained empathy, and the ability to somehow see *who the patient is, and in which emotional/imaginal environment he/she really is*. Such containing function is important also because the patient's enteroceptive and proprioceptive experience may be somehow modified during the emergence of his/her feeling-toned endogenous images. His body schema and his body image (Dolto, 1984), hence his/her feeling of his/her subjectivity me be perceived as if he/she is, for instance, a certain kind of child.
4. **Negotiation**. The psychotherapist must help the patient to interact and negotiate with his/her endogenous images. During this stage the patient will still limit his/her verbal interactions to just briefly report, should this be needed, what is happening between him/her and his/her images.
5. **Elaboration**. At this stage, the patient may share his/her experience with the endogenous feeling-toned images and the interactions he/she had with them. During such phase, endogenous images will be matched with the patient's "real," objectual life experiences that he/she reported during phase (1) and with associations with further objectual life experiences and with past memories. Here, the psychotherapist experience in mastering his own dual state of consciousness will be his/her fundamental tool to go back and forth between these two realities, and transfer the emotional-cognitive-relational meaning of the autonomous images into the patient's life. At this stage, the language used may become less metaphorical, more analytical and, somehow, abstract, as it may autonoetically express and shed light on the relationship, the links-between.

Before presenting a very brief example of this process, we are in the position to clarify that its bottom-up nature does not actually describe it in a fair way. In fact, the psychotherapeutic process we are describing *begins* at the "bottom"—affects and somatic activation—*via* images, through metaphors, towards autonoetic cognitive contents, but in its ongoing nature it actually describes a cycle, in which we find its necessary place for the up-down flow from cognitions towards affects, as in phase (5). Yet, we want to point out again that this last (autonoetic, verbal) phase may actually not occur, and that the re-integration between the affective/motivational/intentional layer and the patient's experience with his relational reality may take place *implicitly*. In fact, we think that this cycle is constantly happening implicitly at every moment of one's life. Our description within a psychotherapeutic setting is just an attempt to describe it and show how it may be "used" in a psychotherapeutic relationship.

A CLINICAL SKETCH

What follows is a very condensed clinical sketch. Our purpose is not to discuss a clinical case (as this sketch is not even a clinical vignette), but to show a possible way to apply what we have been discussing so far in the clinical domain.

The patient is an unmarried, 40-year-old, man. He is going through a period of pervasive distimic mood, in which he is gripped by feelings of usefulness, desperation and passivity. He is stuck in his relational world (both with his relationship to his girlfriend, which he cannot transform into a stable commitment which could transform him into a father, but also with his colleagues) and in his professional/creative area, as he does not feel able to be intelligent and productive. During the previous session, he was feeling in a kind of swamp (this is an image). He described, once again, what had happened between the sessions, in relation to this depressive feeling (DESCRIPTION).

At the end of the hour, he suddenly remembered an old dream. The therapist told him that they could go back to that dream in their next session, which is the one we are describing now.

P. I searched among my writings for a description of the dream that came up at the end of the last session, but I could not find it. Nevertheless, I remember the facade of a small Baroque style church that is set in light-colored rock. I enter through the door and am inside a large cavern, it seems like a uterus, dark and full of blood. I am entranced by this image. There is a naked woman, crucified on two large, rough tree trunks that have only been thinned of their branches, which hang up high near one of the walls. Above me a witch flies round and round and I am tied to a large trunk that is laid on the ground, on one side by my feet

[18]There is no space here to underline how the somatic level, is crucial in order to lay the ground for the whole therapeutic process. Breathing, for instance, is a fundamental aspect of such a sinking towards the resting state from which images may rise from the patients's feelings, or the mood the patient feels (Zelano et al., 2016; Piarulli et al., 2018).

and the other by my arms which are stretched over my head. I am naked and the witch swoops towards me in a nosedive while the crucified woman thrashes about weeping and crying out in pain.

This dream is from many years ago and it makes me think of how much time has passed and how these themes are still so much alive in me. What has changed, in your opinion in these years?

T. I think in some things you have changed and in others less so. You still do not devote yourself to engage in your being in the world and you do not commit thoroughly to your relationship with others, especially in the case of your girlfriend.

There are a few minutes of silence.

P. In the past few days I have felt very tired. I have trouble getting up in the morning and I have no energy. Saturday I have to give a seminar and the thought of it crushes me. These days I feel very tired. It is difficult to get up in the morning. I have no energy. Saturday I have to hold a seminar, and this thought crushes me. (Here, the phase of DESCRIPTION seems complete).

T. What image do you have of this?

P. There is no image. I am just afraid to remain speechless, to make a mistake, to get stuck, to find myself in a deadlock.

T. What feelings come up when you speak about it?

P. I do not feel anything, I just feel very tired.

T. You should try to stay with this feeling tired, and try to let image emerge. (FOCALIZATION).

A. few minutes pass as the P. sits with his eyes closed. He knows he should not talk while he imagines.

P. I pictured a swamp with mangrove trees, I see the bottom of the swamp of dark-gray mud under a half meter of clear water as if it is a lateral cross-section. I see myself, naked, sinking into the very dense mud, I am tired, exhausted, I see my feet that as they are moving, sink. I tried to get out, I attempt to walk in the low water of this endless forest. Perhaps, though, this imagining of getting out corresponds to not wanting to stay in this emotional situation. (FOCALIZATION).

T. You interrupted you experience of imagining. Can you resume it? (CONTAINMENT).

Several minutes pass.

P. I imagined myself to be in the deep sea (phrase also means "in trouble"), floating naked and trying to hold on. I felt lost, desperate, and that I will soon be dead. I have looked all around me without seeing absolutely anything. The sea has become dark and grown rough. I am forced to float straight up. I was always more exhausted and desperate.

T. You did not do anything at all to say yourself. . .

The P. comes to a standstill. He says "What could I have done? There was nothing that could be done." Nonetheless the non-verbal cues by which he expressed himself, sounded to the T. as a defense. It sounded like an intellectual defense, a distancing into the autonoetic layer of the noetic imaginative process linked to affects.

T. Are you sure there was absolutely nothing that could be done?

The affective-relational atmosphere generated by the strong therapeutic alliance, founded on solid trust, makes it possible for the patient to take the question seriously and it lets him to reconnect with the image. (CONTAINMENT).

P. Well, I looked around but I did not see people or other. . .

T. But you did not call for help, for example, perhaps someone or something would have heard you. Who knows what might have happened?

Minutes of silence pass, while the P. intertwines his hands and looks around, and T. for a moment feels deeply sleepy. (CONTAINMENT. The T's sleepiness is a sign of his projective identification with the patient's unconscious, dissociated affects).

After several minutes of silence which make the relational field intensely concentrated, something moves in P., his face relaxes and his body assumes a more open position. T. feels that P. has understood something.

P. In this moment, some imagines came to mind of a film I saw several nights ago. The film is called "The Grey" and tells the story of an airplane that crashes in Alaska. The protagonist Liam Neeson guides some of the survivors towards possible safety from hypothermia and wolves. They start off with eight people but perhaps only he is able to save himself. In the most critical moments, the protagonist is able to access images and memories: he images that he is lying on a bed with his beloved and she says to him "Don't be afraid" and he remembers being in his father's study and reading a poem that has framed and hanging on the wall, that he recites like this "Once more into the fray, Into the last good fight I'll ever know, Live or die on this day, Live or die on this day." After the images of this film, I saw the image of my girlfriend's mother, who is dying and is passive and angry at the world for what has happened to her, and then my mother who was angry with everyone for her unhappiness.

T. You imagined your Anima-guide and a paternal figure that help you in finding a solution, a way out of a dramatic situation, how do you feel now? (NEGOTIATION).

P. I feel to have re-surfaced (he pulls himself up on the seat of the chair).

A few seconds pass.

P. The feeling of fear returned, thinking of Saturday.

T. And then?

P. I imagined a solution to deal with it.

T. Allow the image to form itself. Let it go. (CONTAINMENT).

P. I imagined to be a warrior and I remembered a dream about Kung Fu that I had last week. I was in a Japanese house with three other people. A samurai woman with long, black hair tied back and a sort of light armor was accompanied by a second person, was coming towards me and I threw an object at her with an astounding gesture that I was amazed that I had actually performed. The woman dodged it without difficulty and looked at me as one would a master or a very capable warrior. (FOCALIZATION).

Using a Jungian metaphor, the T. thinks that the P. had restored the image of a strong, determined and capable Anima in place of a wounded and passive one. (ELABORATION).

T. How do you feel now?

The P. confirms what had already clearly been expressed by his posture (now more vigorous) and my his facial expression, more awake and alert.

T. It seems that now you can decide to take an action, and you can truly do it. (ELABORATION).

P. Yes, it is really like that[19].

[19]As we already wrote, we chose to avoid every interpretive aspect of our clinical sketch, which clearly involves a complex relational network between the patient and his endogenous mother complex, which shows evident impersonal, archetypal qualities, not totally deriving from his direct experience with his mother-in-the flesh. The patient's mother complex seems responsible for the his feeling of being psychologically and energetically castrated—hence for his depression—together with his intense emotional difficulties involving his relational world.

AUTHOR CONTRIBUTIONS

AA had the original idea and developed mainly the neuro-ethological part. SC introduced important theoretical and clinical contribution, especially in relation to Jungian perspective and image formation.

REFERENCES

Agnati, L. F., Guidolin, D., Battistin, L., Pagnoni, G., and Fuxe, K. (2013). The neurobiology of imagination: possible role of interaction-dominant dynamics and default mode network. *Front. Psychol.* 4:296. doi: 10.3389/fpsyg.2013.00296

Alcaro, A., Carta, S., and Panksepp, J. (2017). The affective core of the self: a neuro-archetypical perspective on the foundations of human (and animal) subjectivity. *Front. Psychol.* 8:1424. doi: 10.3389/fpsyg.2017.01424

Alcaro, A., Huber, R., and Panksepp, J. (2007). Behavioral functions of the mesolimbic dopaminergic system: an affective neuroethological perspective. *Brain Res. Rev.* 56, 283–321. doi: 10.1016/j.brainresrev.2007.07.014

Alcaro, A., and Panksepp, J. (2011). The SEEKING mind: primal neuro-affective substrates for appetitive incentive states and their pathological dynamics in addictions and depression. *Neurosci. Biobehav. Rev.* 35, 1805–1820. doi: 10.1016/j.neubiorev.2011.03.002

Alcaro, A., and Panksepp, J. (2014). "Le radici affettive e immaginative del Sé. Un'indagine neuroetologica sulle origini della soggettività," in *La Plasticità del Sé. Una Prospettiva Neuropsicodinamica*, eds G. Nortoff, M. Farinelli, R. Chattat and F. Baldoni (Bologna: Il Mulino), 65–89.

Alcaro, A., Panksepp, J., Witczak, J., Hayes, D. J., and Northoff, G. (2010). Is subcortical-cortical midline activity in depression mediated by glutamate and GABA? A cross-species translational approach. *Neurosci. Biobehav. Rev.* 34, 592–605. doi: 10.1016/j.neubiorev.2009.11.023

Barker, R. (1977). "The effects of REM sleep on the retention of a visual task," in *Night Life: Explorations in Dreaming*, ed. R. Cartwright (Englewood Cliffs, NJ: Prentice Hall), 94–95.

Ben-Naim, A. A. (2008). *Farewell to Entropy: Statistical Thermodynamics Based on Information.* Singapore: World Scientific.

Bennett, A. F. (1973). Ventilation in two species of lizards during rest and activity. *Comp. Biochem. Physiol. A Comp. Physiol.* 46A, 653–671. doi: 10.1016/0300-9629(73)90119-9

Bennett, A. F. (1991). The evolution of activity capacity. *J. Exp. Biol.* 160, 1–23.

Bennett, A. F., and Dawson, W. R. (1976). "Metabolism," in *Biology of the Reptilia*, eds C. Gans and W. R. Dawson (London: Academic Press), 127–223.

Bion, W. W. (1967). *Second Thoughts.* London: Heinemann.

Bion, W. W. (1985). *Elements of Psychoanalysis.* London: Routledge.

Birnholz, J. C. (1981). The development of human fetal eye movement patterns. *Science* 213, 679–681. doi: 10.1126/science.7256272

Bollas, C. (1987). *The Shadow of the Object: Psychoanalysis of the Unthought Known.* London: Free Association Books.

Boot, N., Baas, M., van Gaal, S., Cools, R., and De Dreu, C. K. W. (2017). Creative cognition and dopaminergic modulation of fronto-striatal networks: integrative review and research agenda. *Neurosci. Biobehav. Rev.* 78, 13–23. doi: 10.1016/j.neubiorev.2017.04.007

Bowlby, J. (1969/1982). *Attachment and Loss: Vol. 1. Attachment.* New York, NY: Basic Books.

Bretherton, I., and Munholland, K. A. (1999). "Internal working models in attachment relationships: a con-struct revisited," in *Handbook of Attachment: Theory, Research, and Clinical Applications*, eds J. Cassidy and P. R. Shaver (New York, NY: Guilford Press), 89–111.

Bromberg, P. M. (2001). *Standing in the Spaces: Essays on Clinical Process Trauma and Dissociation.* London: Routledge.

Brown, J. W. (2002). *The Self-Embodying Mind. Process, Brain Dynamics and the Conscious Present.* New York, NY: Barrytown.

Bucci, W. (1997). *Psychoanalysis and Cognitive Science: A Multiple Code Theory.* New York, NY: The Guildford Press.

Buckner, R. L. (2010). The role of the hippocampus in prediction and imagination. *Annu. Rev. Psychol.* 61, 27–48. doi: 10.1146/annurev.psych.60.110707.163508

Buckner, R. L., Andrews-Hanna, J. R., and Schacter, D. L. (2008). The brain's default network: anatomy, function, and relevance to disease. *Ann. N Y Acad. Sci.* 1124, 1–38. doi: 10.1196/annals.1440.011

Buckner, R. L., and Carroll, D. C. (2007). Self-projection and the brain. *Trends Cogn. Sci.* 11, 49–57. doi: 10.1016/j.tics.2006.11.004

Cai, D. J., Mednick, S. A., Harrison, E. M., Kanady, J. C., and Mednick, S. C. (2009). REM, not incubation, improves creativity by priming associative networks. *Proc. Natl. Acad. Sci. U S A* 106, 10130–10134. doi: 10.1073/pnas.0900271106

Cappuccio, M., and Wheeler, M. (2012). "Ground-level intelligence: action oriented representation and the dnamic of the background," in *Knowing Without Thinking. Mind, Action, Cognition, and the Phenomenon of the Background*, ed. Z. Radman (New York, NY: Palgrave Macmillan), 13–36.

Carhart-Harris, R. L., and Friston, K. J. (2010). The default-mode, ego-functions and free-energy: a neurobiological account of Freudian ideas. *Brain* 133, 1265–1283. doi: 10.1093/brain/awq010

Carhart-Harris, R. L., Leech, R., Hellyer, P. J., Shanahan, M., Feilding, A., Tagliazucchi, E., et al. (2014). The entropic brain: a theory of conscious states informed by neuroimaging research with psychedelic drugs. *Front. Hum. Neurosci.* 8:20. doi: 10.3389/fnhum.2014.00020

Carta, S. (2017a). "Towards an ecstatic politics," in *The Citizen in the Polis*, eds S. Carta, A. Adorisio and R. Mercurio (Rome: Streetlib).

Carta, S. (2017b). Writing stories in time the unfolding of the objective biography in life and work. *Aras Connections*. Available online at: https://aras.org/sites/default/files/docs/00120Carta.pdf

Cerri, M., Luppi, M., Tupone, D., Zamboni, G., and Amici, R. (2017). REM sleep and endothermy: potential sites and mechanism of a reciprocal interference. *Front. Physiol.* 8:624. doi: 10.3389/fphys.2017.00624

Chermahini, S. A., and Hommel, B. (2010). The (b)link between creativity and dopamine: spontaneous eye blink rates predict and dissociate divergent and convergent thinking. *Cognition* 115, 458–465. doi: 10.1016/j.cognition.2010.03.007

Chernick, D. (1972). Effect of REM sleep deprivation on learning and recall by humans. *Percept. Mot. Skills* 34, 283–294. doi: 10.2466/pms.1972.34.1.283

Christoff, K., Irving, Z. C., Fox, K. C., Spreng, R. N., and Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: a dynamic framework. *Nat. Rev. Neurosci.* 17, 718–731. doi: 10.1038/nrn.2016.113

Clare, L., Marková, I. S., Roth, I., and Morris, R. G. (2011). Awareness in Alzheimer's disease and associated dementias: theoretical framework and clinical implications. *Aging Ment. Health.* 15, 936–944. doi: 10.1080/13607863.2011.583630

Colace, C. (2010). *Children's Dreams: From Freud's Observations to Modern Dream Research.* London: Karnac Books.

Colace, C. (2012). Dream bizarreness and the controversy between the neurobiological approach and the disguise censorship model: the contribution of children's dreams. *Neuropsychoanalysis* 14, 165–174. doi: 10.1080/15294145.2012.10773700

Colace, C. (2013). Are wish-fulfilment dreams of children the royal road for looking a the functions of dreams? *Neuropsychoanalysis* 15, 161–175. doi: 10.1080/15294145.2013.10799828

Colace, C., Doricchi, F., Di Loreto, E., and Violani, C. (1993). Developmental qualitative and quantitative aspects of bizarreness in dream reports of children. *Sleep Res.* 22:57.

Colonnello, V., Iacobucci, P., Fuchs, T., Newberry, R. C., and Panksepp, J. (2011). Octodon degus. A useful animal model for social-affective neuroscience research: basic description of separation distress, social attachments and play. *Neurosci. Biobehav. Rev.* 35, 1854–1863. doi: 10.1016/j.neubiorev.2011.03.014

Corbetta, M., Patel, G., and Shulman, G. L. (2008). The reorienting system of the human brain: from environment to theory of mind. *Neuron* 58, 306–324. doi: 10.1016/j.neuron.2008.04.017

Crystal, J. D. (2012). Prospective cognition in rats. *Learn Motiv.* 43, 181–191. doi: 10.1016/j.lmot.2012.05.006

D'Argembeau, A., Collette, F., Van der Linden, M., Laureys, S., Del Fiore, G., Degueldre, C., et al. (2005). Self-referential reflective activity and its relationship with rest: a PETstudy. *Neuroimage* 25, 616–624. doi: 10.1016/j.neuroimage.2004.11.048

Dahan, L., Astier, B., Vautrelle, N., Urbain, N., Kocsis, B., and Chouvet, G. (2007). Prominent burst firing of dopaminergic neurons in the ventral tegmental area during paradoxical sleep. *Neuropsychopharmacology* 32, 1232–1241. doi: 10.1038/sj.npp.1301251

Damasio, A. R. (1998). Investigating the biology of consciousness. *Philos. Trans. R Soc. Lond. B Biol. Sci.* 353, 1879–1882. doi: 10.1098/rstb.1998.0339

Damasio, A. R. (1999). *The Feeling of What Happens: Body and Emotion in the Making of Consciousness.* New York, NY: HarcourtBrace.

Damasio, A. R. (2010). *The Self Comes Into Mind. Constructing the Conscious Brain.* New York, NY: Pantheon, Hardcover.

Denton, D. A. (2006). *The Primordial Emotions: The Dawning of Consciousness.* New York, NY: Oxford University Press.

Derégnaucourt, S., Mitra, P. P., Fehér, O., Pytte, C., and Tchernichovski, O. (2005). How sleep affects the developmental learning of bird song. *Nature* 433, 710–716. doi: 10.1038/nature03275

Diekelmann, S., and Born, J. (2010). The memory function of sleep. *Nat. Rev. Neurosci.* 11, 114–126. doi: 10.1038/nrn2762

Dolto, F. (1984). *L'Image Inconsciente du Corps.* Paris: éd. du Seuil.

Dondi, M., Messinger, D., Colle, M., Tabasso, A., Simion, F., Dalla Barba, B., et al. (2007). A new perspective on neonatal smiling: differences between the judgments of expert coders and naive observers. *Infancy* 12, 235–255. doi: 10.1111/j.1532-7078.2007.tb00242.x

Edelman, G. M. (1989). *The Remembered Present: A Biological Theory of Consciousness.* New York, NY: Basic Books.

Edelman, G. M. (1992). *Bright Air, Brilliant Fire: On the Matter of the Mind.* New York, NY: Basic Books.

Edelman, D. B., Baars, B. J., and Seth, A. K. (2005). Identifying hallmarks of consciousness in non-mammalian species. *Conscious. Cogn.* 14, 169–187. doi: 10.1016/j.concog.2004.09.001

Fabbro, F., Aglioti, S. M., Bergamasco, M., Clarici, A., and Panksepp, J. (2015). Evolutionary aspects of self- and world consciousness in vertebrates. *Front. Hum. Neurosci.* 9:157. doi: 10.3389/fnhum.2015.00157

Flaherty, A. W. (2005). Frontotemporal and dopaminergic control of idea generation and creative drive. *J. Comp. Neurol.* 493, 147–153. doi: 10.1002/cne.20768

Fleming, S. M., Dolan, R. J., and Frith, C. D. (2012). Metacognition: computation, biology and function. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 367, 1280–1286. doi: 10.1098/rstb.2012.0021

Fonagy, P. (2002). Paper presented at the Anna Freud 50th anniversary conference.

Fonagy, P., Gergely, G., Jurist, E., and Target, M. (2002). *Affect Regulation, Mentalization, and the Development of the Self.* New York, NY: Other Books.

Fonagy, P., and Target, M. (1997). Attachment and reflective function: their role in self-organization. *Dev. Psychopathol.* 9, 679–700. doi: 10.1017/s0954579497001399

Fosse, R., Stickgold, R., and Hobson, J. A. (2001). The mind in REM sleep: reports of emotional experience. *Sleep* 24, 947–955. doi: 10.1093/sleep/24.8.1

Foulkes, D. (1985). *Dreaming: A Cognitive-Psychological Analysis.* Hillsdale, NJ: Lawrence Erlbaum.

Foulkes, D., Bradley, L., Cavallero, C., and Hollifield, M. (1989). Processing of memories and knowledge in REM and NREM dreams. *Percept. Mot. Skills* 68, 365–366. doi: 10.2466/pms.1989.68.2.365

Foulkes, D., and Rechtschaffen, A. (1964). Presleep determinants of dream content: effects of two films. *Percept. Mot. Skills* 19, 983–1005. doi: 10.2466/pms.1964.19.3.983

Fox, K. C., Nijeboer, S., Solomonova, E., Domhoff, G. W., and Christoff, K. (2013). Dreaming as mind wandering: evidence from functional neuroimaging and first-person content reports. *Front. Hum. Neurosci.* 7:412. doi: 10.3389/fnhum.2013.00412

Freud, S. (1900). "The interpretation of dreams," in *The Standard Edition of the Complete Psychological Works of Sigmund Freud*, ed. J. Strachey (Princeton, NJ: Princeton University Press), 15–234.

Gais, S., Plihal, W., Wagner, U., and Born, J. (2000). Early sleep triggers memory for early visual discrimination skills. *Nat. Neurosci.* 3, 1335–1339. doi: 10.1038/81881

Gottesman, C. (1999). Neurophysiological support of consciousness during waking and sleep. *Prog. Neurobiol.* 59, 469–508. doi: 10.1016/s0301-0082(99)00014-3

Greicius, M. D., Krasnow, B., Reiss, A. L., and Menon, V. (2003). Functional connectivity in the resting brain: a network analysis of the default mode hypothesis. *Proc. Natl. Acad. Sci. U S A* 100, 253–258. doi: 10.1073/pnas.0135058100

Grieser, C., Greenberg, R., and Harrison, R. (1972). The adaptive function of sleep: the differential effects of sleep and dreaming on recall. *J. Abnorm. Psychol.* 80, 280–286. doi: 10.1037/h0033641

Griffin, D. (1985). *Animal Thinking.* Cambridge MA: Harvard University Press.

Gusnard, D. A., Raichle, M. E., and Raichle, M. E. (2001). Searching for a baseline: functional imaging and the resting human brain. *Nat. Rev. Neurosci.* 2, 685–694. doi: 10.1038/35094500

Hartman, E., Russ, D., Oldfield, M., Falke, R., and Skoff, B. (1980). Dream content: effect of L-dopa. *Sleep Res.* 9:153.

Hillenius, W. J., and Ruben, J. A. (2004). The evolution of endothermy in terrestrial vertebrates: who? When? Why? *Physiol. Biochem. Zool.* 77, 1019–1042. doi: 10.1086/425185

Hobson, J. A. (2009). REM sleep and dreaming: towards a theory of protoconsciousness. *Nat. Rev. Neurosci.* 10, 803–813. doi: 10.1038/nrn2716

Hobson, J. A., and Friston, K. J. (2012). Waking and dreaming consciousness: neurobiological and functional considerations. *Prog. Neurobiol.* 98, 82–98. doi: 10.1016/j.pneurobio.2012.05.003

Home, J. A. (1988). Sleep loss and "divergent" thinking ability. *J. Sleep Res. Sleep Med.* 11, 528–536. doi: 10.1093/sleep/11.6.528

Hopkins, J. (2016). Free energy and virtual reality in neuroscience and psychoanalysis: a complexity theory of dreaming and mental disorder. *Front. Psychol.* 7:922. doi: 10.3389/fpsyg.2016.00922

Isaacs, S. (1948). "On the nature and function of phantasy," in *International Journal of Psychoanalysis. Developments in Psychoanalysis*, (Vol. 29) republished in eds M. Klein, P. Heimann, S. Isaacs and J. Riviere (London: Hogarth Press), 73–97.

Ikemoto, S., and Panksepp, J. (1999). The role of nucleus accumbens dopamine in motivated behavior: a unifying interpretation with special reference to reward-seeking. *Brain Res. Rev.* 31, 6–41. doi: 10.1016/s0165-0173(99)00023-5

James, W. (1890). *The Principles of Psychology.* New York, NY: Dover.

Janet, P. (1913). La Psycho-Analyse. *Journal de Psychologique Normal et Pathologique II*. Paris: Alcan. 1–36, 97–130.

Janet, P. (1889). *L'Automatisme Psychologique.* Paris: L'Harmattan.

Jouvet, M. (1975). "The function of dreaming: a neurophysiologist's point of view," in *Handbook of Psychobiology*, eds M. S. Gazzaniga and C. Blakemore (New York, NY: Academic Press), 499–527. doi: 10.1016/B978-0-12-278656-3.X5001-7

Jung, C. G. (1916/1957). "The transcendent function," in *The Collected Works of C.G. Jung: vol. 8*, (R.F.C. Hull Trans.) eds H. Read, M. Fordham, G. Adler and W. McGuire (Princeton, NJ: Princeton University Press), 139–158.

Jung, C. G. (1935a). "Structure and dynamics of the psyche," in *The Collected Works of C.G. Jung. vol 8. R.F.C. Hull (Trans.)*, eds H. Read, M. Fordham, G. Adler and W. McGuire (Princeton, NJ: Princeton University Press), 3–570.

Jung, C. G. (1935b). "Principles of practical psychotherapy," in *The Collected Works of C.G. Jung. vol 16. R.F.C. Hull (Trans.)*, eds H. Read, M. Fordham, G. Adler and W. McGuire (Princeton, NJ: Princeton University Press), 3–20.

Jung, C. G. (1937). "Psychological factors determining human behaviour," in *The Collected Works of C.G. Jung, vol 8. R.F.C. Hull (Trans.)*, eds H. Read, M. Fordham, G. Adler and W. McGuire (Princeton, NJ: Princeton University Press), 114–128.

Jung, C. G. (1946). "Psychology of the transference," in *The Collected Works of C.G. Jung, vol 16. R.F.C. Hull (Trans.)*, eds H. Read, M. Fordham, G. Adler and W. McGuire (Princeton, NJ: Princeton University Press), 163–321.

Jung, C. G. (1948). "General aspects of dream psychology structure and Dynamics of the Psyche," in *The Collected Works of C.G. Jung, vol 8. R.F.C. Hull (Trans.)*, eds H. Read, M. Fordham, G. Adler and W. McGuire (Princeton, NJ: Princeton University Press), 237–280.

Jung, C. G. (1956). "Symbols of transformation," in *The Collected Works of C.G. Jung, vol 5. R.F.C. Hull (Trans.)*, 2nd Edn. eds H. Read, M. Fordham, G. Adler and W. McGuire (Princeton, NJ: Princeton University Press), 3–494.

Jung, C. G. (1959). "Archetypes of the collective unconscious," in *The Collected Works of C.G. Jung, vol 5. R.F.C. Hull (Trans.)*, eds H. Read, M. Fordham, G. Adler and W. McGuire (Princeton, NJ: Princeton University Press), 3–417.

Jung, C. G. (1967). "Alchemical studies," in *The Collected Works of C.G. Jung, vol 13. R.F.C. Hull (Trans.)*, eds H. Read, M. Fordham, G. Adler and W. McGuire (Princeton: Princeton University Press), 3–380.

Jung, C. G. (2012). *Red Book*. New York, NY: W. W. Norton & Company.

Jung, C. G. (Ed.). (1947/1954). "On the nature of the psyche," in *The Collected Works of C. G. Jung, Vol. 8*, eds H. Read, M. Fordham, G. Adler and W. McGuire (Princeton, NJ: Princeton University Press), 159–236.

Kaplan-Solms, K., and Solms, M. (2000). *Clinical Studies in Neuro-Psychoanalysis: Introduction to a Depth Neuropsychology*. London: Karnac.

Khan, M. (1983). *Hidden Selves*. London: The Hogarth Press and The Institute of PsychoAnalysis.

Killgore, W. D., Killgore, D. B., Day, L. M., Li, C., Kamimori, G. H., and Balkin, T. J. (2007). The effects of 53 hours of sleep deprivation on moral judgment. *Sleep* 30, 345–352. doi: 10.1093/sleep/30.3.345

Klein, M. (1921). "The development of a child," in *Love, Guilt and Reparation and Other Works, 1921-1945*, (New York, NY: The Free Press), 1–53.

Klein, M. (1952/2018). "Observations on the behaviour of young Infants," in *Deveopments in Psychoanalysis*, ed. J. Riviere (London: Routledge), 237–270.

Knox, J. M. (2001). Memories, fantasies, archetypes: an exploration of some connections between cognitive science and analytical psychology. *J. Anal. Psychol.* 46, 613–635. doi: 10.1111/1465-5922.00270

Knox, J. M. (2004a). From archetypes to reflective function. *J. Anal. Psychol.* 49, 1–19. doi: 10.1111/j.0021-8774.2004.0437.x

Knox, J. M. (2004b). "Developmental aspects of analytical psychology: new perspectives from cognitive neuroscience and attachment theory," in *Analytical Psychology. Contemporary Perspectives in Jungian Analysis*, eds J. Cambray and L. Carter (New York, NY: Brunner-Routledge), 56–82.

Lacan, J. (1958). *D'une Question Préliminaire à Tout Traitement Possible de la Psychose*. Paris: La Psychanalyse, P.U.F. 1–50.

Llinás, R. R. (2002). *I of the Vortex: From Neurons to Self*. Cambridge, MA: MIT Press.

Lu, H., Zou, Q., Gu, H., Raichle, M. E., Stein, E. A., and Yang, Y. (2012). Rat brains also have a default mode network. *Proc. Natl. Acad. Sci. U S A* 109, 3979–3984. doi: 10.1073/pnas.1200506109

MacLean, P. D. (1985). Brain evolution relating to family, play, and the separation call. *Arch. Gen. Psychiatry* 42, 405–417. doi: 10.1001/archpsyc.1985.01790270095011

MacLean, P. D. (1990). *The Triune Brain in Evolution: Role in Paleocerebral Functions*. New York, NY: Plenum Press.

Maguire, E. A., and Hassabis, D. (2011). Role of the hippocampus in imagination and future thinking. *Proc. Natl. Acad. Sci. U S A* 108:E39. doi: 10.1073/pnas.1018876108

Mandler, J. M. (1988). How to build a baby: on the development of an accessible representational system. *Cogn. Dev.* 3, 113–136. doi: 10.1016/0885-2014(88)90015-9

Mandler, J. M. (1992). How to build a baby: II. Conceptual primitives. *Psychol. Rev.* 99, 587–604. doi: 10.1037/0033-295x.99.4.587

Mandler, J. M. (2000). Perceptual and conceptual processes in infancy. *J. Cogn. Dev.* 1, 3–36. doi: 10.1207/s15327647jcd0101n_2

Mantini, D., Gerits, A., Nelissen, K., Durand, J. B., Joly, O., Simone, L., et al. (2011). Default mode of brain function in monkeys. *J. Neurosci.* 31, 12954–12962. doi: 10.1523/JNEUROSCI.2318-11.2011

Maquet, P. (2001). The role of sleep in learning and memory. *Science* 294, 1048–1051. doi: 10.1126/science.1062856

Maquet, P., Laureys, S., Peigneux, P., Fuchs, S., Petiau, C., Phillips, C., et al. (2000). Experience-dependent changes in cerebral activation during human REM sleep. *Nat. Neurosci.* 3, 831–836. doi: 10.1038/77744

Margoliash, D. (2010). Sleep, learning, and birdsong. *ILAR J.* 51, 378–386. doi: 10.1093/ilar.51.4.378

Martin, B., Wittmann, M., Franck, N., Cermolacce, M., Berna, F., and Giersch, A. (2014). Temporal Structure of consciousness and minimal self in schizophrenia. *Front. Psychol.* 5:1175. doi: 10.3389/fpsyg.2014.01175

Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., and Macrae, C. N. (2007). Wandering minds: the default network and stimulus-independent thought. *Science* 315, 393–395. doi: 10.1126/science.1131295

Mednick, S., Nakayama, K., and Stickgold, R. (2003). Sleep-dependent learning: a nap is as good as a night. *Nat. Neurosci.* 6, 697–698. doi: 10.1038/nn1078

Merker, B. (2007). Consciousness without a cerebral cortex: a challenge for neuroscience and medicine. *Behav. Brain Sci.* 30, 63–134. doi: 10.1017/S0140525X07000891

Messinger, D., and Fogel, A. (2007). The interactive development of social smiling. *Adv. Child Dev. Behav.* 35, 327–366. doi: 10.1016/b978-0-12-009735-7.50014-1

Monahan, P. (2009). C.G. Jung: Freud's heir or Janet's? The influence upon Jung of Janet's dissociationism. *Int. J. Jungian Studies* 1, 33–49. doi: 10.1080/19409050802681876

Moutoussis, M., Fearon, P., El-Deredy, W., Dolan, R. J., and Friston, K. J. (2014). Bayesian inferences about the self (and others): a review. *Conscious. Cogn.* 25, 67–76. doi: 10.1016/j.concog.2014.01.009

Nir, Y., and Tononi, G. (2010). Dreaming and the brain: from phenomenology to neurophysiology. *Trends Cogn. Sci.* 14, 88–100. doi: 10.1016/j.tics.2009.12.001

Northoff, G. (2011). *Neuropsychoanalysis in Practice. Brain, Self and Objects*. Oxford: Oxford University Press; 2011.

Northoff, G. (2013). What the brain's intrinsic activity can tell us about consciousness? A tri-dimensional view. *Neurosci. Biobehav. Rev.* 37, 726–738. doi: 10.1016/j.neubiorev.2012.12.004

Northoff, G. (2014a). *Unlocking the Brain: Coding, Vol. 1*. Oxford: Oxford University Press.

Northoff, G. (2014b). Do cortical midline variability and low frequency fluctuations mediate William James' "Stream of Consciousness"? "Neurophenomenal Balance Hypothesis" of "Inner Time Consciousness". *Conscious. Cogn.* 30, 184–200. doi: 10.1016/j.concog.2014.09.004

Northoff, G. (2015a). Spatiotemporal psychopathology I: no rest for the brain's resting state activity in depression? Spatiotemporal psychopathology of depressive symptoms. *J. Affect. Disord.* 190, 854–866. doi: 10.1016/j.jad.2015.05.007

Northoff, G. (2015b). Spatiotemporal psychopathology II: how does a psychopathology of the brain's resting state look like? Spatiotemporal approach and the history of psychopathology. *J. Affect. Disord.* 190, 867–879. doi: 10.1016/j.jad.2015.05.008

Northoff, G. (2016). Is the self a higher-order or fundamental function of the brain? The "basis model of self-specificity" and its encoding by the brain's spontaneous activity. *Cogn. Neurosci.* 7, 203–222. doi: 10.1080/17588928.2015.1111868

Northoff, G. (2018). *The Spontaneous Brain. From the Mind-Body to the World-Brain Problem*. Cambridge, MA: The Mit Press.

Northoff, G., Duncan, N. W., and Hayes, D. J. (2010a). The brain and its resting state activity—experimental and methodological implications. *Prog. Neurobiol.* 92, 593–600. doi: 10.1016/j.pneurobio.2010.09.002

Northoff, G., Qin, P., and Nakao, T. (2010b). Rest-stimulus interaction in the brain: a review. *Trends Neurosci.* 33, 277–284. doi: 10.1016/j.tins.2010.02.006

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., and Panksepp, J. (2006). Self-referential processing in our brain—a meta-analysis of imaging studies on the self. *Neuroimage* 31, 440–457. doi: 10.1016/j.neuroimage.2005.12.002

Northoff, G., and Stanghellini, G. (2016). How to link brain and experience? Spatiotemporal psychopathology of the lived body. *Front. Hum. Neurosci.* 10:76. doi: 10.3389/fnhum.2016.00172

Northoff, G., Wiebking, C., Feinberg, T., and Panksepp, J. (2011). The 'resting-state hypothesis' of major depressive disorder-a translational subcortical-cortical framework for a system disorder. *Neurosci. Biobehav. Rev.* 35, 1929–1945. doi: 10.1016/j.neubiorev.2010.12.007

Oudiette, D., De Cock, V. C., Lavault, S., Leu, S., Vidailhet, M., and Arnulf, I. (2009). Nonviolent elaborate behaviors may also occur in REM sleep behavior disorder. *Neurology* 72, 551–557. doi: 10.1212/01.wnl.0000341936.78678.3a

Pace-Schott, E. F., Nave, G., Morgan, A., and Spencer, R. M. (2012). Sleep-dependent modulation of affectively guided decision-making. *J. Sleep Res.* 21, 30–39. doi: 10.1111/j.1365-2869.2011.00921.x

Panksepp, J. (1998a). The periconscious substrates of consciousness: affective states and the evolutionary origins of the SELF. *J. Conscious. Stu.* 5, 566–582.

Panksepp, J. (1998b). *Affective Neuroscience: The Foundations of Human and Animal Emotions.* New York, NY: Oxford University Press.

Panksepp, J. (2005). Affective consciousness: core emotional feelings in animals and humans. *Conscious. Cogn.* 14, 30–80. doi: 10.1016/j.concog.2004.10.004

Panksepp, J. (2010). Affective consciousness in animals: perspectives on dimensional and primary process emotion approaches. *Proc. Biol. Sci.* 277, 2905–2907. doi: 10.1098/rspb.2010.1017

Panksepp, J. (2011). Cross-species affective neuroscience decoding of the primal affective experiences of humans and related animals. *PLoS One* 6:e21236. doi: 10.1371/journal.pone.0021236

Panksepp, J., and Biven, L. (2012). *The Archaeology of Mind: Neuroevolutionary Origins of Human Emotion.* New York, NY: W. W. Norton and Company.

Panksepp, J., and Panksepp, J. B. (2013). Toward a cross-species understanding of empathy. *Trends Neurosci.* 36, 489–496. doi: 10.1016/j.tins.2013.04.009

Pauli, W. (2006). *Psiche e Natura.* Milano: Adelphi.

Pavlides, C., and Winson, J. (1989). Influences of hippocampal place cell firing in the awake state on the activity of these cells during subsequent sleep episodes. *J. Neurosci.* 9, 2907–2918. doi: 10.1523/jneurosci.09-08-02907.1989

Perogamvros, L., and Schwartz, S. (2012). The roles of the reward system in sleep and dreaming. *Neurosci. Biobehav. Rev.* 36, 1934–1951. doi: 10.1016/j.neubiorev.2012.05.010

Perogamvros, L., and Schwartz, S. (2015). Sleep and emotional functions. *Curr. Top. Behav. Neurosci.* 25, 411–431. doi: 10.1007/7854_2013_271

Piarulli, A., Zaccaro, A., Laurino, M., Menicucci, D., De Vito, A., Bruschini, L., et al. (2018). Ultra-slow mechanical stimulation of olfactory epithelium modulates consciousness by slowing cerebral rhythms in humans. *Sci. Rep.* 8:6581. doi: 10.1038/s41598-018-24924-9

Porges, S. W. (2011). *The Polyvagal Theory: Neurophysiological Foundations of Emotions, Attachment, Communication and Self-regulation.* New York, NY: W. W. Norton.

Portmann, A. (1986). The orientation and world relation of animals. *Spring* 53, 1–13.

Qin, P., and Northoff, G. (2011). How is our self related to midline regions and the default-mode network? *Neuroimage* 57, 1221–1233. doi: 10.1016/j.neuroimage.2011.05.028

Raichle, M. E. (2015). The brain's default mode network. *Annu. Rev. Neurosci.* 38, 433–447. doi: 10.1146/annurev-neuro-071013-014030

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., and Shulman, G. L. (2001). A default mode of brain function. *Proc. Natl. Acad. Sci. U S A* 98, 676–682. doi: 10.1073/pnas.98.2.676

Raichle, M. E., and Snyder, A. Z. (2007). A default mode of brain function: a brief history of an evolving idea. *Neuroimage* 37, 1083–1090. doi: 10.1016/j.neuroimage.2007.02.041

Reiter, S., Liaw, H. P., Yamawaki, T. M., Naumann, R. K., and Laurent, G. (2017). On the value of reptilian brains to map the evolution of the hippocampal formation. *Brain Behav. Evol.* 90, 41–52. doi: 10.1159/000478693

Ribeiro, S., and Nicolelis, M. A. L. (2004). Reverberation, storage and postsynaptic propagation of memories during sleep. *Learn. Mem.* 11, 686–696. doi: 10.1101/lm.75604

Roberts, W. A. (2012). Evidence for future cognition in animals. *Learn Motiv.* 43, 169–180. doi: 10.1016/j.lmot.2012.05.005

Rossi, E. L. (2004). Gene expression and brain plasticity in stroke rehabilitation: a personal memoir of mind-body healing dreams. *Am. J. Clin. Hypn.* 46, 215–227. doi: 10.1080/00029157.2004.10403601

Sander, L. (2007). *Sistemi Viventi. L'emergere Della Persona Attraverso L'evoluzione Della Consapevolezza.* Milano: Raffaello Cortina.

Sastre, P. J.-P., and Jouvet, M. (1979). Le comportement onirique du chat. *Physiol. Behav.* 22, 979–989. doi: 10.1016/0031-9384(79)90344-5

Saunders, P., and Skar, P. (2001). Archetypes, complexes and self-organization. *J. Anal. Psychol.* 46, 305–323. doi: 10.1111/1465-5922.00238

Schacter, D. L., Addis, D. R., Hassabis, D., Martin, V. C., Spreng, R. N., and Szpunar, K. K. (2012). The future of memory: remembering, imagining and the brain. *Neuron* 76, 677–694. doi: 10.1016/j.neuron.2012.11.001

Schmidt-Nielsen, K. (1984). *Scaling.* Cambridge: Cambridge University Press.

Schore, A. N. (1994). *Affect Regulations and the Origin of the Self.* Mahvah, NJ: Lawrence Erlbaum Associates.

Schore, A. N. (2003). *Affect Regulation and the Repair of the Self.* New York, NY: W.W. Norton.

Schore, A. N. (2009). Relational trauma and the developing right brain: an interface of psychoanalytic self psychology and neuroscience. *Ann. N Y Acad. Sci.* 1159, 189–203. doi: 10.1111/j.1749-6632.2009.04474.x

Schredl, M. (2010). Characteristics and contents of dreams. *Int. Rev. Neurobiol.* 92, 135–154. doi: 10.1016/S0074-7742(10)92007-2

Shamdasani, S. (2003). *Body and Soul, Jung and the Making of Modern Psychology: The Dream of Science, Vol. 254.* Cambridge, MA: Cambridge University Press.

Shank, S. S., and Margoliash, D. (2009). Sleep and sensorimotor integration during early vocal learning in a songbird. *Nature* 458, 73–77. doi: 10.1038/nature07615

Sheets-Johnstone, M. (2010). "Steps entailed in foregrounf the background: taking the challenge of languaging experience seriously," in *Knowing Without Thinking. Mind, Action, Cognition, and the Phenomenon of the Background*, eds Z. Radman (New York, NY: Palgrave MacMillan), 165–182.

Shein-Idelson, M., Ondracek, J. M., Liaw, H.-P., Reiter, S., and Laurent, G. (2010). Slow waves, sharp waves, ripples, and REM in sleeping dragons. *Science* 352, 590–595. doi: 10.1126/science.aaf3621

Shimamura, A. P. (2000). Toward a cognitive neuroscience of metacognition. *Conscious. Cogn.* 9, 313–323; discussion 324–326. doi: 10.1006/ccog.2000.0450

Shulman, G. L., Fiez, J. A., Corbetta, M., Buckner, R. L., Miezin, F. M., Raichle, M. E., et al. (1997). Common blood flow changes across visual tasks: II. decreases in cerebral cortex. *J. Cogn. Neurosci.* 9, 648–663. doi: 10.1162/jocn.1997.9.5.648

Simpson, J. A. (1989). *The Oxford English Dictionary.* Oxford, NY: Clarendon Press.

Smith, M. R., Antrobus, J. S., Gordon, E., Tucker, M. A., Hirota, Y., Wamsley, E. J., et al. (2004). Motivation and affect in REM sleep and the mentation reporting process. *Conscious. Cogn.* 13, 501–511. doi: 10.1016/j.concog.2004.03.002

Solms, M. (1997). *The Neuropsychology of Dreams.* Mahwah, NJ: Erlbaum.

Solms, M. (2000). Dreaming and REM sleep are controlled by different brain mechanisms. *Behav. Brain Sci.* 23, 843–850. doi: 10.1017/s0140525x00003988

Solms, M., and Panksepp, J. (2012). The "id" knows more than the "ego" admits: neuropsychoanalytic and primal consciousness perspectives on the interface between affective and cognitive neuroscience. *Brain Sci.* 2, 147–175. doi: 10.3390/brainsci2020147

Solms, K. K., and Solms, M. (2000). *Clinical Studies in Neuro-Psychoanalisis.* Madison: International University Press, Inc.

Stern, D. (1985). *The Interpersonal World of the Infant: A View From Psychoanalysis and Developmental Psychology.* New York, NY: Basic Book.

Stickgold, R. (1998). Sleep: off-line memory processing. *Trends Cogn. Sci.* 2, 484–492. doi: 10.1016/s1364-6613(98)01258-3

Stickgold, P., James, L., and Hobson, J. A. (2000). Visual discrimination requires sleep after learning. *Nat. Neurosci.* 3, 1237–1238. doi: 10.1038/81756

Takeuchi, H., Taki, Y., Sassa, Y., Hashizume, H., Sekiguchi, A., Fukushima, A., et al. (2010). Regional gray matter volume of dopaminergic system associate with creativity: evidence from voxel-based morphometry. *Neuroimage* 51, 578–585. doi: 10.1016/j.neuroimage.2010.02.078

Torday, J. S., and Miller, W. B. Jr. (2018). A systems approach to physiologic evolution: from micelles to consciousness. *J. Cell. Physiol.* 233, 162–167. doi: 10.1002/jcp.25820

Trevarthen, C., and Aitken, K. J. (2001). Infant intersubjectivity: research, theory and clinical applications. *J. Child Psychol. Psychiatry* 42, 3–48. doi: 10.1111/1469-7610.00701

Tulving, E. (1985). Memory and consciousness. *Can. Psychol.* 26, 1–12. doi: 10.1037/h0080017

Valli, K., and Revonsuo, A. (2009). The threat simulation theory in light of recent empirical evidence: a review. *Am. J. Psychol.* 122, 17–38.

Vandekerckhove, M., and Panksepp, J. (2009). The flow of anoetic to noetic and autonoetic consciousness: a vision of unknowing (anoetic) and knowing (noetic) consciousness in the remembrance of things past and imagined futures. *Conscious. Cogn.* 18, 1018–1028. doi: 10.1016/j.concog.2009.08.002

Von Franz, M. L. (1974). *Number and Time: Reflections Leading Toward a Unification of Depth Psychology and Physics.* Chicago: Northwestern Univ Pr.

Von Franz, J. M. (1998). *Dreams: A Study of the Dreams of Jung, Descartes, Socrates and Other Historical Figures.* London-Boston: Shambala.

Wagner, U., Gais, S., Haider, H., Verleger, R., and Born, J. (2004). Sleep inspires insight. *Nature* 427, 352–355. doi: 10.1038/nature02223

Walker, M. P., Liston, C., Hobson, J. A., and Stickgold, R. (2002). Cognitive flexibility across the sleep-wake cycle: REM-sleep enhancement of anagram problem solving. *Cogn. Brain Res.* 14, 317–324. doi: 10.1016/s0926-6410(02)00134-9

Weiler, M., Northoff, G., Damasceno, B. P., and Balthazar, M. L. F. (2016). Self, cortical midline structures and the resting state: implications for Alzheimer's disease. *Neurosci. Biobehav. Rev.* 68, 245–255. doi: 10.1016/j.neubiorev.2016.05.028

Wilkinson, M. (2006). The dreaming mind-brain: a Jungian perspective. *J. Anal. Psychol.* 51, 43–59. doi: 10.1111/j.0021-8774.2006.00571.x

Winnicott, D. W. (1964). "The concept of the false self," in *Home is Where We Start From: Essays by a Psychoanalyst*, eds C. Winnicott, R. Shepherd and M. Davis (Harmondsworth: Penguin), 65–70.

Winnicott, D. W. (1965). "Ego distortion in terms of true and false self [1960]," in *The Maturational Processes and the Facilitating Environment: Studies in the Theory of Emotional Development*, eds D. W. Winnicott (London: Hogarth), 140–152.

Winnicott, D. W. (1967). *Playing and Reality*. London: Routledge.

Wolff, P. H. (1966). The causes, controls and organization of behavior in the neonate. *Psychol. Issues* 5, 1–105.

Yanagihara, S., and Hessler, N. A. (2012). Phasic basal ganglia activity associated with high-γ oscillation during sleep in a songbird. *J. Neurophysiol.* 107, 424–432. doi: 10.1152/jn.00790.2011

Zabelina, D. L., Colzato, L., Beeman, M., and Hommel, B. (2016). Dopamine and the creative mind: individual differences in creativity are predicted by interactions between dopamine genes DAT and COMT. *PLoS One* 11:e0146768. doi: 10.1371/journal.pone.0146768

Zelano, C., Jiang, H., Zhou, G., Arora, N., Schuele, S., Rosenow, J., et al. (2016). Nasal respiration entrains human limbic oscillations and modulates cognitive function. *J. Neurosci.* 6, 12448–12467. doi: 10.1523/jneurosci.2586-16.2016

Zhang, D., and Raichle, M. E. (2010). Disease and the brain's dark energy. *Nat. Rev. Neurol.* 6, 15–28. doi: 10.1038/nrneurol.2009.198

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

APPENDIX 1. THE FORMATION OF IMAGE SCHEMA

In cognitive psychology and neuroscience, images are the (re)presentational emergences of structural configurations, which are analogous to what are called *schemas* (Sheets-Johnstone, 2010; Cappuccio and Wheeler, 2012), or *maps*[20] (Damasio, 1999, 2010), and, which a more engrossing and transversal meaning, Jung called *complexes*.

According to Mandler (1988, 1992, 2000), *image schemas* emerge from the comparison between stimuli and are the base of abstract concept formation. Mandler refers to *perceptual analysis* as the fundamental procedure through which, *using* external perceptions acquired by what she calls *perceptual recognition*, the brainmind expresses, at a mental level, the innermost symbolic sense of its life. For Mandler, perceptual recognition is a sensorimotor activity, which takes place automatically and does not require any conceptual framework. On the other side, perceptual analysis is an active process of comparison between stimuli, and is the earliest evidence of a contemplative attitude (Knox, 2004a) and constitutes the basis of abstract concept formation.

Along with Knox (2001, 2004a,b), we consider the mechanism of perceptual analysis as described by Mandler a persuasive model that may explain how mental images are formed. One fundamental point is that schematic images are not produced by "perceptual recognition." In fact, it is the active, innate process of perceptual analysis that *uses* perceptual recognition *in order to form re-presentations of the intrinsic dispositions of the living organism (instincts, drives, emotions)*. In this sense, image-schemas may be equated with Jung's archetypes-as-such, and their patterned representational content may be referred to what Jung described as the "self reflection of the instinct upon itself" (Jung, 1948, p. 257).

Here, we disagree with Fonagy (2002), for whom the early psychic structures are produced through (not modified by) early pre-verbal infant experience before the emergence of consciousness. Therefore, due to this situational tilt or self-environment interaction, for Fonagy any psychological imagery can be experienced as if it is innate, when it actually is not. Our dispositional tilt also contrasts with the views shared by Knox (2004a), Saunders and Skar (2001) or Merchant, who, reversing Jung's psychogenetic theory, see archetypal imagery as an emergent phenomenon arising out of mind/brain structures (the image schemas) which have been laid down in early infant life as a result of the infant's developmental experience (mostly interpreted through attachment theory), so that, while the complexes occur first, the "archetypes" would be a label arising from further categorization of these archaic experiences.

Consistent with the Jungian perspective, we must strongly emphasize that the isomorphism between the image-schemas and the object world to which the former refer does not mean that the self-produced mental images resemble those of the outside. Our starting point for our dispositional tilt is given by our extraordinary capacity, based on the "knowableness" of natural numbers on the part of the human species, to "know" the "external reality." In fact, the reflective isomorphism that we are referring to is based on the radically "transitional" (Winnicottian) nature of natural numbers, which are simultaneously invented by the mind and found in the outside world. Therefore, the image-schemas we are referring to represent the "means" (rooted in the perceptive structures, for example visual, but not only), to reach, through a process of abstract refining, their ultimate mathematical root (Jung, 1935a; Von Franz, 1974). This relationship between the endogenous "knowability" of the object world by the brain/mind and mathematical (scientific) knowledge [as in some revealing dreams, like the famous dream by Descartes (Von Franz, 1998)] is the base of the Hintergrudphysik of Pauli (2006).

In general, we disagree with the line of thought deriving from attachment theory, as it interprets psychogenetic development through what we call a situational tilt. In fact, the emerging dispositional scaffolding process that we mentioned earlier, which from perceptual-motor data will metaphorize lofty concepts, is not primarily patterned by early interactions, but actually *uses* meaningful interactions to give shape to primary, endogenous affects into complex emotions. The key to this dispositional process is that perceptual analysis (which, as we have seen in the previous pages, is an active endogenous pattern-forming activity involving the DMS) is primarily activated not by exteroperceptions, but by the SEEKING emotional system originally activated in connection with enteroceptive stimuli. In our dispositional model, affects and to the somatic enteroceptive conditions of the core-Self are represented as images (see also Damasio, 2010). It is actually an affective image schema that carries a fundamentally emotional-cognitive content, which will then confer value to perceptions and which, therefore, precedes outer perception.

[20]The term "maps" integrates (or at least tries to integrate) both sides of our "dual monistic" reality–the neurological/"material" and the psychic/immaterial one. These neuropsychological (or psychoneural) maps organize systems of sub-selves that are wholly coherent with Jung's construct of "complex," as with Janet (1913) sub-personalities, or with contemporary psychologists (Bromberg, 2001), who refer–often implicitly–the core of their theory to this tradition.

frontiers in Psychology

REVIEW
published: 30 January 2019
doi: 10.3389/fpsyg.2019.00110

Unresolved Trauma and Reorganization in Mothers: Attachment and Neuroscience Perspectives

Udita Iyengar[1†], Purva Rajhans[2,3†], Peter Fonagy[4,5,6], Lane Strathearn[3,7] and Sohye Kim[2,4,8,9]*

[1] Institute of Psychiatry, Psychology, and Neuroscience, King's College London, London, United Kingdom, [2] Department of Pediatrics, Baylor College of Medicine, Houston, TX, United States, [3] Stead Family Department of Pediatrics, University of Iowa Carver College of Medicine, Iowa City, IA, United States, [4] Menninger Department of Psychiatry and Behavioral Sciences, Baylor College of Medicine, Houston, TX, United States, [5] Anna Freud National Centre for Children and Families, London, United Kingdom, [6] Research Department of Clinical, Educational, and Health Psychology, University College London, London, United Kingdom, [7] Center for Disabilities and Development, University of Iowa Stead Family Children's Hospital, Iowa City, IA, United States, [8] Department of Obstetrics and Gynecology, Baylor College of Medicine, Houston, TX, United States, [9] Center for Reproductive Psychiatry, Pavilion for Women, Texas Children's Hospital, Houston, TX, United States

OPEN ACCESS

Edited by:
Anatolia Salone, Università degli Studi G. d'Annunzio Chieti e Pescara, Italy

Reviewed by:
Jeremy Holmes, University of Exeter, United Kingdom
Andrea Scalabrini, Università degli Studi G. d'Annunzio Chieti e Pescara, Italy
Jolien Zevalkink, VU University Amsterdam, Netherlands

***Correspondence:**
Udita Iyengar
udita.iyengar@kcl.ac.uk

† These authors have contributed equally to this work

Specialty section:
This article was submitted to Psychoanalysis and Neuropsychoanalysis, a section of the journal Frontiers in Psychology

Received: *27 May 2018*
Accepted: *14 January 2019*
Published: *30 January 2019*

Citation:
Iyengar U, Rajhans P, Fonagy P, Strathearn L and Kim S (2019) Unresolved Trauma and Reorganization in Mothers: Attachment and Neuroscience Perspectives. Front. Psychol. 10:110. doi: 10.3389/fpsyg.2019.00110

The onset of motherhood is characterized by significant psychological and neurobiological changes. These changes equip the mother to care for her new child. Although rewarding, motherhood is also an inherently stressful period, more so for mothers with unresolved trauma. Past research has looked at how unresolved trauma can hamper a mother's caregiving response toward her infant, which further affects the development of secure attachment in her own infant. The Dynamic Maturational Model of Attachment and Adaptation (DMM) has introduced a unique concept of "attachment reorganization" which can be described as a process whereby individuals with unresolved trauma are transitioning toward attachment security based on their enhanced understanding of past and present experiences. Preliminary results from one of our previous studies have shown that, among mothers with unresolved trauma, mothers who themselves demonstrated "reorganizing attachment" toward security, had infants with secure attachment, thereby indicating the potential to halt the intergenerational transmission of insecure attachment. While this concept is of great clinical relevance, further research is required to assess the benefits of attachment reorganization as a protective factor and its positive implications for child development. Thus, the aim of the current review is to expand on the concept of attachment reorganization in mothers with unresolved trauma from both attachment and neuroscience perspectives. To that effect, we will first review the literature on the transition to motherhood from attachment and neuroscience perspectives. Second, we will use attachment and neuroscience approaches to address deviations from normative experiences during motherhood with a specific focus on the role of a mother's unresolved trauma. Lastly, we will expand on the concept of reorganization and the promise this concept holds in resolving or halting the intergenerational transmission of trauma from mothers to their children.

Keywords: attachment, reorganization, unresolved trauma, intergenerational transmission, maternal brain, neuroscience

INTRODUCTION

Mothers undergo significant adaptation and reorganization throughout pregnancy and postpartum, both on psychological and neurobiological levels. Psychologically, a new mother's emotional investment is drawn away from the outside world and refocused inward toward her infant (Slade et al., 2009). Attachment theory is a useful framework to understand how these formative relationships shape our psychological organization and behavior across the lifespan. Specifically in the maternal caregiving context, attachment theory draws attention to the importance of a mother's sensitive response to her infant as an antecedent to the child's development of secure attachment in adulthood. Neurobiologically, a new mother undergoes neural and endocrine changes that prepare her to respond to her new infant's all-encompassing needs (Swain et al., 2007; Kim et al., 2016; Swain and Ho, 2017).

Despite being an intrinsically rewarding experience for many mothers (Strathearn et al., 2008), motherhood comes with its set of challenges as the new mother adapts to the aforementioned changes. Moreover, these challenges can become heightened in the presence of early-life adversity, unresolved trauma, or psychopathology. These factors may alter a mother's behavioral and neural response to her infant, interfering with the dyadic relationship and setting the stage for disrupted attachment across generations. Identifying potential protective factors may help mitigate this disrupted relationship between at-risk mothers and their infants, potentially halting the intergenerational transmission of insecure attachment.

"Attachment reorganization" is a unique concept introduced by the Dynamic Maturational Model of Attachment and Adaptation (DMM) method of coding the Adult Attachment Interview (AAI). It is defined as a process whereby individuals with unresolved trauma are transitioning toward attachment security based on their increased understanding and resolution of past and present traumatic experiences. We have previously reported that, among mothers with unresolved trauma, those who were "reorganizing" toward secure attachment were the only individuals with unresolved trauma whose children were determined to be securely attached, underscoring the potential of attachment reorganization in halting the intergenerational transmission of insecure attachment (Iyengar et al., 2014). The aim of the present paper is to further expand on our previous work (Iyengar et al., 2014) and evaluate the benefits of attachment reorganization, considering the literature from both attachment and neuroscience perspectives. In what follows, we will first explain adaptive transition to motherhood from attachment and neuroscience perspectives. Second, we will address circumstances that may interfere with adaptive mothering, such as the presence of unresolved trauma and associated clinical features or conditions, drawing from both attachment and neuroscience perspectives. Finally, we will explore protective factors that may halt the transmission of disrupted attachment across generations. For this purpose, we will specifically focus on the concept of attachment reorganization and its potential role in resolving or halting the intergenerational transmission of trauma from mothers to their children.

ADAPTIVE PREGNANCY AND TRANSITION TO MOTHERHOOD

Attachment Perspectives

Maternal sensitivity requires a highly attuned level of reciprocity and synchrony, which is built over time and requires constant adaptation and reorganization (Ainsworth et al., 1978). D.W. Winnicott first saw the interactions between the mother and child as central to the development of the infant's internal world. He described "primary maternal preoccupation," a phase in which the mother is extremely attuned to the needs and wants of the child (Winnicott, 1956). This emotional parenting state is "almost an illness," which allows the mother to reciprocate to her infant's needs (Winnicott, 1960, 1965). The manifestation of "primary maternal preoccupation" can be thought of as a physical, emotional, and *adaptive* process that allows a mother to both identify with her infant while also allowing the infant to develop his/her own self. This extreme amount of focus of the mother on the baby, is the first step of her evolving into a new mother, or a mother to her new child.

Furthermore, John Bowlby was the first to formulate attachment as the quality of relationship between mother and child, which begins during infancy and continues throughout life (Bowlby, 1969, 1972, 1973, 1980, 1988). Decades of research have corroborated the central tenets of his attachment theory showing that emotionally sensitive and responsive mothers are more likely to have infants with secure attachment (Siegel, 1999; Insel and Young, 2001; Sroufe, 2005; Shah et al., 2010). These attachment patterns, which begin as early as infancy, sets a basis for the way adults interact, choose romantic partners, fall in love, and perhaps most importantly, parent their own children. An attuned and predictable attachment experience between the mother and child is therefore fundamental to the development of social, emotional, and psychological health.

Attachment theory is also important for understanding how individuals develop patterns of self-protective strategies, especially when faced with threats. The DMM model of Attachment and Adaptation (Crittenden, 1992, 1995, 2000, 2006; Crittenden and Landini, 2011) is a theory of attachment that is based on the work of Ainsworth and Bowlby but places a large emphasis on the role of danger, including separation and loss, in the development of specific behavior patterns. This theory of attachment posits that ongoing change is constantly interacting with experience to influence later development, and that any kind of threat or danger is powerful in organizing behavior (Crittenden, 2008). The DMM thus views attachment as a self-protective strategy (more so than security) which promotes the survival of a species (Crittenden and Landini, 2011), taking into account the adaptive skills of individuals in dangerous contexts. Thus, an attuned and predictable attachment experience between the mother and child is fundamental to the child's future development of social, emotional, and psychological health when in a safe context.

Neuroscience Perspectives

In addition to the psychological changes from an attachment perspective, motherhood is also characterized by neurobiological and hormonal changes that help establish maternal caregiving behaviors (Kim et al., 2010; Strathearn, 2011; Swain et al., 2014). Neuroimaging studies have demonstrated that the maternal brain undergoes significant structural changes during pregnancy and postpartum. Pregnant first-time mothers were observed to show significant decreases in their gray matter volume compared to their pre-pregnancy volumes (Hoekzema et al., 2017). This structural change was observed specifically in brain areas implicated in social cognition and theory of mind, such as the inferior frontal gyrus and precuneus, and possibly reflecting a specialized pruning which may occur in the expectant mother's brain during pregnancy (Schurz et al., 2014; Hoekzema et al., 2017). Kim et al. (2010) further reported structural changes in the maternal brain during the initial postpartum months. Increases were seen in gray matter volumes of brain areas associated with the expression of maternal behaviors, including the bilateral hypothalamus, amygdala, substantia nigra, and globus pallidus. Increased gray matter volumes seen in these brain areas were associated with positive perception of infants by their mothers. Thus, structural changes in the maternal brain pre- and post-pregnancy are critical for the mother-infant bond.

A growing body of research has addressed attachment-related brain networks that govern maternal response to infant cues. Our prior work (Strathearn et al., 2009) has demonstrated that first-time mothers with secure patterns of attachment show enhanced activation of the key dopamine-associated reward-processing brain regions when viewing happy faces of their own infant. It was hypothesized that this may promote bond formation and attuned caregiving behaviors in these mothers. While mothers with secure attachment demonstrated similar dopaminergic reward responses when seeing their infant's sad faces, mothers with insecure/dismissing attachment demonstrated an enhanced activation in the anterior insular region which is often associated with feelings of pain or disgust (Montague and Lohrenz, 2007). This underscores the importance of attending to the mothers' own attachment history in understanding mother-infant outcomes, as this may influence her neural and behavioral responses to her infant, importantly shaping infant outcomes. In the section that follows, we examine individual differences in the mother's attachment patterns and trauma history.

MATERNAL TRAUMA AND ITS INTERGENERATIONAL TRANSMISSION

Attachment Perspectives

As discussed earlier, pregnancy and early postpartum are crucial periods during which a mother renegotiates her own identity as well as representations of herself and others (Slade et al., 2009) in order to prepare for a unique relationship with her new child. This transition that takes place during pregnancy and the postpartum period is particularly important for parents who have histories of psychological trauma which negatively influences their present experience. A seminal paper by Fraiberg et al. (1975) described this influence of memories or traumas in the past as "ghosts in the nursery." These "ghosts" refer to emotionally painful memories experienced by the parent, which linger and impede their ability to sensitively respond to their own child, with the process being likely perpetuated across generations. Fraiberg's work, while evocative, mirrored the idea that a parent's inner world influences the child, and lays the foundation for understanding maternal mental health and infant outcome.

Exposure to trauma may lead to several possible outcomes. One is that an individual may garner new information from the situation and integrate the information into the present situation, resulting in adaptation and a newfound understanding that eventually helps the individual to avoid future danger. These individuals would be considered "resolved" with regard to the trauma or loss. In another scenario, an individual experiencing trauma or loss may either retain too much information about the traumatic event or dismiss the importance of it, in ways that are maladaptive to future processing of information (Crittenden and Landini, 2011). These individuals will be classified as having unresolved trauma, which refers to an individual's maladaptive psychological response to a dangerous event that continues to adversely affect the individual's strategic functioning (Crittenden and Landini, 2011). For example, mothers with what is termed a "preoccupied unresolved trauma" may maintain a focus on bringing their past trauma to the present and exaggerating emotions or affect, whereas mothers with a "denied or blocked unresolved trauma" may rely on omitting details or feelings associated with the past trauma (Crittenden and Landini, 2011). While both types of traumas have associated behaviors which allow the mother to protect against overwhelming feelings, such patterns of behavior may become maladaptive when directly applied to mother-infant relationships. Perhaps a mother with preoccupied unresolved trauma may be hyper-vigilant in response to her infant's distress, while a mother with a denied unresolved trauma may under-respond to her infant's distress.

The literature discussed above parallels the larger trauma literature both within and outside of the attachment framework. Specifically, two behavioral subtypes of trauma have been identified, hyperarousal and dissociation (Perry et al., 1995; Schore, 1997). While hyperarousal is defined by a heightened emotional and physiological response to trauma, dissociation represents a disconnection from or shutting down of the traumatic memory (American Psychiatric Association, 2013, DSM-V). Frewen and Lanius (2006), described the hyperarousal state as "reliving traumatic events in the form of flashbacks and experience-associated psychophysiological hyperarousal," and Lanius et al. (2005) described the dissociative state as "an escape from the overwhelming emotions associated with the traumatic memory." As a construct that has some overlap with unresolved trauma, PTSD has been shown to increase the risk for later psychosocial problems in affected individuals (Cicchetti and Toth, 1999; Easterbrooks et al., 2000), while also negatively affecting their caregiving of their own children.

Past research has identified the role of unresolved trauma in a range of psychiatric disorders, including borderline personality disorder (BPD) and substance use disorders (SUD). Prior work

has shown that compared to normative mothers, mothers with BPD report higher instances of childhood abuse and neglect, display a higher prevalence of unresolved trauma, and demonstrate diminished reflective capacity (Fonagy et al., 1996; Barone, 2003), while also displaying exaggerated affect as well as signs of dissociation (Sieswerda et al., 2007; Scalabrini et al., 2017). Similarly, SUD has been strongly linked to the presence of adverse childhood experiences, high prevalence of unresolved trauma, and impaired parenting behavior (Rodning et al., 1991; Dube et al., 2003). From the perspective of attachment and trauma, key clinical features of BPD and SUD may be understood in light of the aforementioned subtypes of trauma (i.e., hyperarousal vs. dissociation and preoccupied vs. denied unresolved trauma) that may underlie these clinical presentations (Jacobsen et al., 2001; Watson et al., 2006; Sieswerda et al., 2007; Najavits and Walsh, 2012; Scalabrini et al., 2017). The presence of the unresolved trauma, in turn, impairs parental attunement and behavior (Rodning et al., 1991; Dube et al., 2003) when these individuals transition to motherhood.

Neuroscience Perspectives

The presence of unresolved trauma not only visibly affects the mother's attachment behaviors and emotional attunement but also the more invisible neurobiological responses to her infant's cues. One such brain structure that is involved in the processing of trauma is the amygdala, which shows both structural (Rauch et al., 2000) and functional changes in the aftermath of trauma (Rauch et al., 2000; Protopopescu et al., 2005; Williams et al., 2006a,b). Specifically, neuroimaging studies examining the two subtypes of trauma have shown that distinct patterns of neural activation are associated with the two subtypes (Lanius et al., 2006; Hopper et al., 2007). Trauma patients with hyperarousal symptoms show an increased activation in the amygdala while showing a decreased activation in brain areas that are associated with emotion regulation (Lanius et al., 2006). In contrast, patients who exhibit dissociative symptoms show an increased activation in brain regions associated with emotion regulation while showing decreased activation in the amygdala (Lanius et al., 2006).

Previously we have explored the impact of unresolved trauma on amygdala response when first-time mothers viewed sad images of their infants (Kim et al., 2014). In this study, we found that mothers who were classified as having unresolved trauma displayed reduced activation in the amygdala, in response to seeing their infants in distress. This blunted amygdala response was seen only when these mothers viewed their *own* infant's distressed face, and not that of unknown infants. This may reflect traumatized mothers' disengagement from their infants' distress, which could contribute to the intergenerational transmission of trauma. While our findings appear to be generally in line with the dissociative subtype of trauma, it is important to note that other groups have reported increased amygdala response to infant distress cues in mothers displaying disrupted attachment, possibly reflecting their hyperarousal (Riem et al., 2012).

Neurobiological studies on mothers with psychiatric disorders may further shed light on the ways in which the mother's mental health including her unresolved trauma influences her brain responses to infant cues. Although individuals with BPD have been observed to demonstrate heightened activation of key emotion processing regions of the brain when presented with generic emotional cues (Lynch et al., 2006; Buchheim et al., 2008; Koenigsberg et al., 2009), no study has directly examined maternal brain responses to infant's emotional cues in these individuals. However, there is a growing literature on the role of SUD in maternal brain response to infant cues. In a recent study, we examined brain responses of mothers with SUD and found that viewing happy images of their own infants resulted in a striking pattern of decreased activation in brain regions associated with reward and maternal caregiving, including the hypothalamus, ventral striatum, and medial prefrontal cortex (Kim et al., 2017). This reduced activation in key reward regions of SUD mother's brains is particularly striking when considering that such blunted responsiveness was observed in reaction to the smiling faces of the mother's own infant — likely the most rewarding cue that a mother will receive from her infant. While this may reflect a broader compromised caregiving that has long been reported for mothers with a history of substance use, it is important to note that 98% of the SUD mothers in this sample had a history of unresolved trauma. This raises the possibility that blunted maternal brain response to infant affect cues that we observed in SUD mothers may at least partly reflect the presence of unresolved trauma in these mothers (in line with the blunted responsiveness to salient affective cues that has been linked to a subtype of unresolved trauma).

In summary, studies from both attachment and neuroscience perspectives have demonstrated how unresolved trauma can interfere with a mother's ability to sensitively respond to her infant. Furthermore, studies identifying the two subtypes of trauma, hyperarousal and dissociation, have provided critical insight by outlining specific ways in which unresolved trauma may manifest in mothers and disrupt her caregiving for her children.

PROTECTING AGAINST INTERGENERATIONAL TRANSMISSION OF TRAUMA

Mentalization, Reflective Functioning and Attachment Reorganization

When Fraiberg et al. (1975) conceptualized a mother's traumatic experience of the past and the "ghosts in the nursery," they initially suggested that those mothers who processed and worked through their past traumas were less likely to transmit their trauma to the next generation and more likely to protect their future relationships with their child. Empirical research has since identified maternal factors that have been shown to protect against the intergenerational transmission of trauma, primarily centering around mentalization and reflective functioning (Fonagy et al., 1991a,b; Fonagy, 2002). Mentalization refers to one's psychological ability to understand and interpret one's own and others' behavior as an expression of mental states such as feelings, thoughts, fantasies, beliefs and desires

(Fonagy et al., 1991a; Fonagy, 2002). A closely related term reflective functioning is operationalized as a socio-cognitive capacity to mentalize in attachment-related contexts (Fonagy et al., 1991b; Allen et al., 2008; Ensink et al., 2014). Seminal work by Fonagy and colleagues showed that mothers who experienced substantial past trauma, yet were still highly reflective, were still able to have securely attached children despite their trauma (Fonagy et al., 1991a, 1995), while mothers with diminished reflective capacities went on to have insecurely attached children. This provided the first step in establishing a protective factor hypothesis for reflective functioning-suggesting that reflective functioning may halt the intergenerational cycle in situations where insecure attachment would have repeated across generations.

As described previously, attachment reorganization is another construct that has been identified as a potential protective factor against the intergenerational transmission of trauma (Crittenden, 1995, 1997). The construct of attachment reorganization is derived from the AAI (Crittenden, 1995, 1997) and is identified through a modified DMM-AAI coding scheme. The AAIs of reorganizing individuals reflect their capacity to alter their process of thinking from their self-protective attachment strategy, toward a more adaptive and reflective stance (Crittenden, 2017). While it is not necessary for an individual to experience danger or trauma before undergoing reorganization, the experience and resolution of danger can at times result in an alteration in mental processing and behavior, leading to a change in attachment strategy (Crittenden, 2008). To demonstrate reorganizing patterns, individuals need to be first aware of their discrepant patterns of thinking and altered behavior when they experience danger or trauma. Subsequently they need to work on applying change toward a healthy outlook related to the trauma. However, the individual may not be able to enact this change completely. Therefore, reorganization is a fluid process but one which holds promise to correct maladaptive patterns of thinking (Crittenden and Landini, 2011). During the AAI, reorganizing speakers make reflective and evaluative statements indicative of mental balance, incorporate new information to achieve a new understanding of situations, consider alternate perspectives, and achieve a cooperative relationship with the interviewer to find meaning in their history. Yet, there are slips into the dominant pattern of insecure attachment, and some level of unresolved incoherence noted in the discourse, as the reorganizing speaker attempts to reach an integrative conclusion about their situation.

Earned Security and Attachment Reorganization

Another closely related and overlapping construct is that of earned security. Some theorists have used the term "earned secure" to refer to individuals who have experienced suboptimal parenting or adverse life events, but are able to overcome the effects of these experiences, demonstrate balanced integration, and attain secure attachment later in life (Pearson et al., 1994; Roisman et al., 2002). Earned secure individuals are thought to have interrupted the intergenerational cycle by demonstrating emotional resilience (Fearon et al., 2010). In comparison to earned security, reorganization encompasses the *process* by which those with insecure attachment or unresolved trauma are actively changing their understanding of past and present experiences in the direction of greater balance, resolution, and attachment security (Crittenden and Landini, 2011). Although, not fully secure or balanced in attachment terms, reorganizing individuals demonstrate the transient capacity to re-evaluate their history with a self-evaluative and reflective perspective (Landa and Duschinsky, 2013), which may have positive effects on the security of their progeny. Therefore, attachment reorganization captures a transient process, rather than a socio-cognitive capacity (e.g., mentalizing or reflective functioning) or a final stage of security (e.g., earned security). Dangerous circumstances may not allow the opportunity for self-awareness, nor may it be adaptive for survival. For example, leaving out important details of a trauma or keeping a trauma present at all times may function as self-protective and useful for individuals who find themselves in circumstances which threaten their survival. Therefore, attachment reorganizing is a novel concept in the attachment literature and potentially a more useful concept for individuals who exist in highly dangerous environments and lack the ability to accurately self-reflect.

Clinical Examples of Reorganization

Our previous work (Iyengar et al., 2014) corroborated the intergenerational transmission of insecure attachment previously established in the literature, where mothers with unresolved trauma had insecure attachment themselves and were more likely to have infants with insecure attachment. Uniquely, 100% of the mothers with unresolved trauma who were reorganizing toward secure attachment had infants with secure attachment (although our sample size was small and this group encompassed only 4 infants). This illustrated the potential for change in attachment strategies over time and across generations, as well as the possibility of "attachment reorganization" (or reorganizing) as a protective factor. Our findings suggest that, for a mother who has an insecure pattern of attachment based on her childhood experiences as well as unresolved trauma, the fact that she is reorganizing toward secure attachment is just as advantageous to the intergenerational outcome as her being securely attached. Furthermore our work suggests that a mother with unresolved trauma does not necessarily need to reach the stage of earned security to halt the intergenerational transmission of trauma. The fact that she is in the process of reorganizing toward secure attachment may be enough to mitigate the disrupted relationship between the mother and her infant.

As previously stated, the DMM coding of the AAI regards the presence of unresolved trauma as a discrepancy in how they process information and events, noted in their discourse when asked about specific events and memories (see Iyengar et al., 2014 for more details on discourse and classification on unresolved trauma and reorganizing). The following examples are from the AAIs of two mothers with SUD, Jenny and Blair (names have been changed), who both display insecure attachment and the

presence of unresolved traumas. Jenny is reorganizing toward secure attachment, while Blair is not.

Examples of Reorganizing and Non-reorganizing in Discourse

When asked to reflect on their experiences in the final integrative section of the AAI, we can see how Jenny, a reorganizing speaker, attempts to understand her father's behavior, while Blair finds it difficult to accurately summarize her feelings and thoughts regarding her brother's death.

> *Interviewer: Why do you think your father acted as he did during your childhood?*
>
> *Jenny: Because my dad was raised by the same kind of father. His father was an alcoholic, he was abusive. . . he's never talked to me but I can imagine, that's how it turned him into what he is. So that's why I can forgive him, because I know that he didn't just wake up one day and say, I want to beat my wife and make my kid's lives miserable. He didn't, you know, mentally he had been hurt emotionally.*
>
> *Interviewer: Are there things you wish to do with your child that are different to what your parents did?*
>
> *Jenny: Oh yeah, almost everything. You know, not the loving and affectionate part, cause I'm like that with my kids, I kiss them all, hug them, I love them, but making them feel bad about what they do, or not praising them for good things, um, hitting them, stuff like that. Everything that I didn't, you know, that hurt me as a child, I don't do with my kids because I remember that feeling.*

When reflecting on her past, Jenny includes an awareness that appearances are not always synonymous with reality. We can note a change in perspective, including past misunderstandings and reasonable current understanding *(you know, mentally he had been hurt emotionally*). Jenny also takes a reflective stance with evidence of taking in and using new information to arrive at new understandings (*Because my dad was raised by the same kind of father; he didn't just wake up one day and say, I want to beat my wife and make my kids' lives miserable).* She also demonstrates active efforts to tie past and present together in a psychologically sound manner (*Everything that I didn't, you know, that hurt me as a child, I don't do with my kids because I remember that feeling).*

However, when asked integrative questions that require a reflection on her childhood experiences, we can see how Blair struggles to reflect on her past and future, as seen in this example:

> *Interviewer: And now that you're an adult, are there things that you want to do with your children that are different than what your parents did with you?*
>
> *Blair: Yes. Cause I don't want them to end up like me, you know. I don't want them to have to go through rehab twice. You know, it's a struggle with life. And I think as much as I've been through, like just from the drug life, that what don't kill you makes you stronger. I mean nothing bad, I've never had anything tragic, like I've never been abused, none of that, but just like struggling, because you spend all your money on drugs and your parents aren't there for you no more, and just like having that feeling that hurt.*

Blair's lack of reflection shows that she did not combine old and new ways of thinking about her traumatic experiences to derive accurate thoughts about the future. Rather, she demonstrated the use of optimistic platitudes (*what doesn't kill you makes you stronger*), and while she demonstrates a hopeful wish for her children (*I don't want them to end up like me)* there was no conclusive integration that indicated that connections were being made to elicit change. Blair's discourse is in contrast to the several reorganizing aspects of Jenny's discourse.

Taken together, both Jenny and Blair had unresolved trauma and/or loss, as well as insecure attachment, while only Jenny was reorganizing toward secure attachment. It is important, then, to note that a mother with a pattern of thinking like Jenny's, demonstrates the potential to re-evaluate the past and present and come to new conclusions that may benefit the relationship with her child. In comparison, a mother with a pattern of thinking like Blair's, may not be able to accurately reflect on the needs of her children and may misinterpret or deny their distress, just as she did her own, and may require more support or encouragement to process her past experiences and reflect on the present to embody change.

CONCLUSION

The transition to motherhood is characterized by dramatic changes which prepare the new mother for the optimal rearing of her young. It is a critical period that is both adaptive and conducive to establishing a secure mother-infant relationship. Despite being rewarding, motherhood comes with its own set of challenges, more so for mothers with unresolved trauma. In this review, we have introduced and expanded on the concept of attachment reorganization and evaluated its potential as a protective factor in mothers with unresolved trauma. We have also discussed how the novel concept of attachment reorganization differs from other overlapping concepts of mentalization, reflective functioning, and earned security. The concept of reorganization encapsulates the process of change from insecure attachment to secure attachment, and from unresolved trauma to resolved trauma. This parallels the process of reflection, re-evaluation, and change that often takes place in psychological treatments, but is unique in that it captures the process unfolding specifically in relation to one's past attachment experiences and has promise in positively shaping intergenerational attachment outcomes.

Although novel, promising and indicating potential for clinical implications, the construct of reorganization is relatively new and has not been subject to much empirical examination. For the construct to be widely used in empirical research, additional data is needed on its psychometric properties, including its construct validity and reliability. Future research should examine this novel construct as a critical protective factor that may halt the intergenerational transmission of insecure attachment and trauma. Examining reorganizing in clinical sample of mothers (e.g., mothers with SUD or BPD) would further help researchers and clinicians understand what difference reorganizing toward secure attachment makes in mothers who have psychiatric symptoms involving unresolved trauma.

It is especially valuable to examine attachment reorganization during pregnancy or in the early postpartum, as it captures

the adaptive capability of the human brain and behavior in a measurable attachment-related construct. Perhaps, reorganizing in an attachment context, corroborates what we already know about the brain's ability to form new connections between neurons and change throughout life, with the brain never being fully organized, yet always in the dynamic and adaptive process of change.

AUTHOR CONTRIBUTIONS

UI, PR, PF, LS, and SK conceived and designed the manuscript. UI and PR wrote the manuscript with input from all authors. All authors added critical insight and intellectual contribution to the overall work, and SK supervised the procedure.

FUNDING

This study was supported by the Eunice Kennedy Shriver National Institute of Child Health and Human Development (R01 HD065819), and the National Institute on Drug Abuse (R01 DA026437). The content is solely the responsibility of the authors and does not necessarily represent the official views of these institutes or the National Institutes of Health.

REFERENCES

Ainsworth, M. D. S., Blehar, M. C., and Waters, E. (1978). *Patterns of Attachment: A Psychological Study of the Strange Situation*. Hove: Psychology Press.

Allen, J. G., Fonagy, P., and Bateman, A. W. (2008). *Mentalizing in Clinical Practice*. Arlington, TX: American Psychiatric Pub.

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders (DSM-5®)*. Arlington, TX: American Psychiatric Pub. doi: 10.1176/appi.books.9780890425596

Barone, L. (2003). Developmental protective and risk factors in borderline personality disorder: a study using the adult attachment interview. *Attach. Hum. Dev.* 5, 64–77. doi: 10.1080/1461673031000078634

Bowlby, J. (1969). *Attachment and Loss: Volume 1. Attachment*. New York, NY: Basic Books.

Bowlby, J. (1972). *Attachment: Attachment and Loss. Vol. 1*. London: Penguin Books.

Bowlby, J. (1973). *Attachment and Loss: Separation,* Vol. 2. New York, NY: Basic Books.

Bowlby, J. (1980). *Attachment and Loss: Loss,* Vol. 3. New York, NY: Basic Books.

Bowlby, J. (1988). *A Secure Base*. New York, NY: Basic Books.

Buchheim, A., Erk, S., George, C., Kächele, H., Kircher, T., Martius, P., et al. (2008). Neural correlates of attachment trauma in borderline personality disorder: a functional magnetic resonance imaging study. *Psychiatry Res. Neuroimaging* 163, 223–235. doi: 10.1016/j.pscychresns.2007.07.001

Cicchetti, D., and Toth, S. L. (1999). The development of depression in children and adolescents. *Am. Psychol.* 53, 221–241. doi: 10.1037/0003-066X.53.2.221

Crittenden, P. (2008). *Raising Parents: Attachment. Parenting and Child Safety*. Cullompton: Willan.

Crittenden, P., and Landini, A. (2011). *Assessing Adult Attachment: A Dynamic-Maturational Approach to Disourse Analysis*. New York, NY: W. W. Norton & Company.

Crittenden, P. M. (1992). Children's strategies for coping with adverse home environments: an interpretation using attachment theory. *Child Abuse Neglect* 16, 329–343. doi: 10.1016/0145-2134(92)90043-Q

Crittenden, P. M. (1995). Attachment and risk for psychopathology: the early years. *J. Dev. Behav. Pediatr.* 16(3 Suppl.), S12–S16. doi: 10.1097/00004703-199506001-00004

Crittenden, P. M. (1997). "Toward an integrative theory of trauma: a dynamic-maturation approach," in *Rochester Symposium on Developmental Psychopathology*, Vol. 8, eds D. Cicchetti and S. L. Toth (Rochester, NY: University of Rochester Press), 33–84.

Crittenden, P. M. (2000). "A dynamic-maturational approach to continuity and change in pattern of attachment," in *The Organization of Attachment Relationships: Maturation, Culture, and Context*, eds P. M. Crittenden and A. H. Claussen (New York, NY: Cambridge University Press), 343–357.

Crittenden, P. M. (2006). A dynamic-maturational model of attachment. *Aust. N. Z. J. Fam. Ther.* 27, 105–115. doi: 10.1002/j.1467-8438.2006.tb00704.x

Crittenden, P. M. (2017). *Raising Parents: Attachment, Representation, and Treatment*. Abingdon: Routledge. doi: 10.4324/9781315726069

Dube, S. R., Felitti, V. J., Dong, M., Chapman, D. P., Giles, W. H., and Anda, R. F. (2003). Childhood abuse, neglect, and household dysfunction and the risk of illicit drug use: the adverse childhood experiences study. *Pediatrics* 111, 564–572. doi: 10.1542/peds.111.3.564

Easterbrooks, M. A., Biesecker, G., and Lyons-Ruth, K. (2000). Infancy predictors of emotional availability in middle childhood: the roles of attachment security and maternal depressive symptomatology. *Attach. Hum. Dev.* 2, 170–187. doi: 10.1080/14616730050085545

Ensink, K., Berthelot, N., Bernazzani, O., Normandin, L., and Fonagy, P. (2014). Another step closer to measuring the ghosts in the nursery: preliminary validation of the Trauma reflective functioning scale. *Front. Psychol.* 5:1471. doi: 10.3389/fpsyg.2014.01471

Fearon, R., Bakermans-Kranenburg, M. J., Van Ijzendoorn, M. H., Lapsley, A. M., and Roisman, G. I. (2010). The significance of insecure attachment and disorganization in the development of children's externalizing behavior: a meta-analytic study. *Child Dev.* 81, 435–456. doi: 10.1111/j.1467-8624.2009.01405.x

Fonagy, P. (2002). *Affect Regulation, Mentalization, and the Development of the Self*. New York, NY: Other Press.

Fonagy, P., Leigh, T., Steele, M., Steele, H., Kennedy, R., Mattoon, G., et al. (1996). The relation of attachment status, psychiatric classification, and response to psychotherapy. *J. Consult. Clin. Psychol.* 64, 22–31. doi: 10.1037/0022-006X.64.1.22

Fonagy, P., Steele, H., and Steele, M. (1991a). Maternal representations of attachment during pregnancy predict the organization of infant-mother attachment at one year of age. *Child Dev.* 62, 891–905.

Fonagy, P., Steele, M., Steele, H., Moran, G. S., and Higgitt, A. C. (1991b). The capacity for understanding mental states: the reflective self in parent and child and its significance for security of attachment. *Infant Ment. Health J.* 12, 201–218. doi: 10.1002/1097-0355(199123)12:3<201::AID-IMHJ2280120307>3.0.CO;2-7

Fonagy, P., Steele, M., Steele, H., Leigh, T., Kennedy, R., Mattoon, G., et al. (1995). "The predictive validity of mary main's adult attachment interview: a psychoanalytic and developmental perspective on the transgenerational transmission of attachment and borderline states," in *Attachment Theory: Social, Developmental and Clinical Perspectives*, eds S. Goldberg, R. Muir, and J. Kerr (Hillsdale, NJ: The Analytic Press), 233–278.

Fraiberg, S., Adelson, E., and Shapiro, V. (1975). Ghosts in the nursery. *J. Am. Acad. Child Psychiatry* 14, 387–421. doi: 10.1016/S0002-7138(09)61442-4

Frewen, P. A., and Lanius, R. A. (2006). Toward a psychobiology of posttraumatic self-dysregulation: reexperiencing, hyperarousal, dissociation, and emotional numbing. *Ann. N. Y. Acad. Sci.* 1071, 110–124. doi: 10.1196/annals.1364.010

Hoekzema, E., Barba-Müller, E., Pozzobon, C., Picado, M., Lucco, F., García-García, D., et al. (2017). Pregnancy leads to long-lasting changes in human brain structure. *Nat. Neurosci.* 20, 287–296. doi: 10.1038/nn.4458

Hopper, J. W., Frewen, P. A., Van der Kolk, B. A., and Lanius, R. A. (2007). Neural correlates of reexperiencing, avoidance, and dissociation in PTSD: symptom dimensions and emotion dysregulation in responses to script-driven trauma imagery. *J. Trauma Stress* 20, 713–725. doi: 10.1002/jts.20284

Insel, T. R., and Young, L. J. (2001). The neurobiology of attachment. *Nat. Rev. Neurosci.* 2, 129–136. doi: 10.1038/35053579

Iyengar, U., Kim, S., Martinez, S., Fonagy, P., and Strathearn, L. (2014). Unresolved trauma in mothers: intergenerational effects and the role of reorganization. *Front. Psychol.* 5:966. doi: 10.3389/fpsyg.2014.00966

Jacobsen, L. K., Southwick, S. M., and Kosten, T. R. (2001). Substance use disorders in patients with posttraumatic stress disorder: a review of the literature. *Am. J. Psychiatry* 158, 1184–1190. doi: 10.1176/appi.ajp.158.8.1184

Kim, P., Leckman, J. F., Mayes, L. C., Feldman, R., Wang, X., and Swain, J. E. (2010). The plasticity of human maternal brain: longitudinal changes in brain anatomy during the early postpartum period. *Behav. Neurosci.* 124, 695–700. doi: 10.1037/a0020884

Kim, P., Strathearn, L., and Swain, J. E. (2016). The maternal brain and its plasticity in humans. *Horm. Behav.* 77, 113–123. doi: 10.1016/j.yhbeh.2015.08.001

Kim, S., Fonagy, P., Allen, J., and Strathearn, L. (2014). Mothers' unresolved trauma blunts amygdala response to infant distress. *Soc. Neurosci.* 9, 352–363. doi: 10.1080/17470919.2014.896287

Kim, S., Iyengar, U., Mayes, L. C., Potenza, M. N., Rutherford, H. J., and Strathearn, L. (2017). Mothers with substance addictions show reduced reward responses when viewing their own infant's face. *Hum. Brain Mapp.* 38, 5421–5439. doi: 10.1002/hbm.23731

Koenigsberg, H. W., Siever, L. J., Lee, H., Pizzarello, S., New, A. S., Goodman, M., et al. (2009). Neural correlates of emotion processing in borderline personality disorder. *Psychiatry Res. Neuroimaging* 172, 192–199. doi: 10.1016/j.pscychresns.2008.07.010

Landa, S., and Duschinsky, R. (2013). Crittenden's dynamic–maturational model of attachment and adaptation. *Rev. Gen. Psychol.* 17:326. doi: 10.1037/a0032102

Lanius, R. A., Bluhm, R., Lanius, U., and Pain, C. (2006). A review of neuroimaging studies in PTSD: heterogeneity of response to symptom provocation. *J. Psychiatr. Res.* 40, 709–729. doi: 10.1016/j.jpsychires.2005.07.007

Lanius, R. A., Williamson, P. C., Bluhm, R. L., Densmore, M., Boksman, K., Neufeld, R. W., et al. (2005). Functional connectivity of dissociative responses in posttraumatic stress disorder: a functional magnetic resonance imaging investigation. *Biol. Psychiatry* 57, 873–884. doi: 10.1016/j.biopsych.2005.01.011

Lynch, T. R., Rosenthal, M. Z., Kosson, D. S., Cheavens, J. S., Lejuez, C. W., and Blair, R. J. R. (2006). Heightened sensitivity to facial expressions of emotion in borderline personality disorder. *Emotion* 6, 647–655. doi: 10.1037/1528-3542.6.4.647

Montague, P. R., and Lohrenz, T. (2007). To detect and correct: norm violations and their enforcement. *Neuron* 56, 14–18. doi: 10.1016/j.neuron.2007.09.020

Najavits, L. M., and Walsh, M. (2012). Dissociation, PTSD, and substance abuse: an empirical study. *J. Trauma Dissociation* 13, 115–126. doi: 10.1080/15299732.2011.608781

Pearson, J. L., Cohn, D. A., Cowan, P. A., and Cowan, C. P. (1994). Earned-and continuous-security in adult attachment: relation to depressive symptomatology and parenting style. *Dev. Psychopathol.* 6, 359–373. doi: 10.1017/S0954579400004636

Perry, B. D., Pollard, R. A., Blakley, T. L., Baker, W. L., and Vigilante, D. (1995). Childhood trauma, the neurobiology of adaptation, and "use-dependent" development of the brain: how "states" become "traits". *Infant Ment. Health J.* 16, 271–291. doi: 10.1002/1097-0355(199524)16:4<271::AID-IMHJ2280160404>3.0.CO;2-B

Protopopescu, X., Pan, H., Tuescher, O., Cloitre, M., Goldstein, M., Engelien, W., et al. (2005). Differential time courses and specificity of amygdala activity in posttraumatic stress disorder subjects and normal control subjects. *Biol. Psychiatry* 57, 464–473. doi: 10.1016/j.biopsych.2004.12.026

Rauch, S. L., Whalen, P. J., Shin, L. M., Mcinerney, S. C., Macklin, M. L., Lasko, N. B., et al. (2000). Exaggerated amygdala response to masked facial stimuli in posttraumatic stress disorder: a functional MRI study. *Biol. Psychiatry* 47, 769–776. doi: 10.1016/S0006-3223(00)00828-3

Riem, M. M., Bakermans-Kranenburg, M. J., van IJzendoorn, M. H., Out, D., and Rombouts, S. A. (2012). Attachment in the brain: adult attachment representations predict amygdala and behavioral responses to infant crying. *Attach. Hum. Dev.* 14, 533–551. doi: 10.1080/14616734.2012.727252

Rodning, C., Beckwith, L., and Howard, J. (1991). Quality of attachment and home environments in children prenatally exposed to PCP and cocaine. *Dev. Psychopathol.* 3, 351–366. doi: 10.1017/S0954579400007562

Roisman, G. I., Padrón, E., Sroufe, L. A., and Egeland, B. (2002). Earned–secure attachment status in retrospect and prospect. *Child Dev.* 73, 1204–1219. doi: 10.1111/1467-8624.00467

Scalabrini, A., Cavicchioli, M., Fossati, A., and Maffei, C. (2017). The extent of dissociation in borderline personality disorder: a meta-analytic review. *J. Trauma Dissociation* 18, 522–543. doi: 10.1080/15299732.2016.1240738

Schore, A. N. (1997). Early organization of the nonlinear right brain and development of a predisposition to psychiatric disorders. *Dev. Psychopathol.* 9, 595–631. doi: 10.1017/S0954579497001363

Schurz, M., Radua, J., Aichhorn, M., Richlan, F., and Perner, J. (2014). Fractionating theory of mind: a meta-analysis of functional brain imaging studies. *Neurosci. Biobehav. Rev.* 42, 9–34. doi: 10.1016/j.neubiorev.2014.01.009

Shah, P. E., Fonagy, P., and Strathearn, L. (2010). Is attachment transmitted across generations? The plot thickens. *Clin. Child Psychol. Psychiatry* 15, 329–345. doi: 10.1177/1359104510365449

Siegel, D. J. (1999). *The Developing Mind: How Relationships and the Brain Interact to Shape Who We are*. New York, NY: The Guilford Press.

Sieswerda, S., Arntz, A., Mertens, I., and Vertommen, S. (2007). Hypervigilance in patients with borderline personality disorder: specificity, automaticity, and predictors. *Behav. Res. Ther.* 45, 1011–1024. doi: 10.1016/j.brat.2006.07.012

Slade, A., Cohen, L. J., Sadler, L. S., and Miller, M. (2009). The psychology and psychopathology of pregnancy. *Handb. Infant Ment. Health* 3, 22–39.

Sroufe, L. A. (2005). Attachment and development: a prospective, longitudinal study from birth to adulthood. *Attach. Hum. Dev.* 7, 349–367. doi: 10.1080/14616730500365928

Strathearn, L. (2011). Maternal neglect: oxytocin, dopamine and the neurobiology of attachment. *J. Neuroendocrinol.* 23, 1054–1065. doi: 10.1111/j.1365-2826.2011.02228.x

Strathearn, L., Fonagy, P., Amico, J., and Montague, P. R. (2009). Adult attachment predicts maternal brain and oxytocin response to infant cues. *Neuropsychopharmacology* 34, 2655–2666. doi: 10.1038/npp.2009.103

Strathearn, L., Li, J., Fonagy, P., and Montague, P. R. (2008). What's in a smile? Maternal brain responses to infant facial cues. *Pediatrics* 122, 40–51. doi: 10.1542/peds.2007-1566

Swain, J. E., and Ho, S.-H. S. (2017). Neuroendocrine mechanisms for parental sensitivity: overview, recent advances and future directions. *Curr. Opin. Psychol.* 15, 105–110. doi: 10.1016/j.copsyc.2017.02.027

Swain, J. E., Kim, P., Spicer, J., Ho, S., Dayton, C. J., Elmadih, A., et al. (2014). Approaching the biology of human parental attachment: brain imaging, oxytocin and coordinated assessments of mothers and fathers. *Brain Res.* 1580, 78–101. doi: 10.1016/j.brainres.2014.03.007

Swain, J. E., Lorberbaum, J. P., Kose, S., and Strathearn, L. (2007). Brain basis of early parent-infant interactions: psychology, physiology, and in vivo functional neuroimaging studies. *J. Child Psychol. Psychiatry* 48, 262–287. doi: 10.1111/j.1469-7610.2007.01731.x

Watson, S., Chilton, R., Fairchild, H., and Whewell, P. (2006). Association between childhood trauma and dissociation among patients with borderline personality disorder. *Aust. N. Z. J. Psychiatry* 40, 478–481. doi: 10.1080/j.1440-1614.2006.01825.x

Williams, L., Kemp, A., Felmingham, K., Barton, M., Olivieri, G., Peduto, A., et al. (2006a). Trauma modulates amygdala and medial prefrontal responses to consciously attended fear. *Neuroimage* 29, 347–404.

Williams, L. M., Liddell, B. J., Kemp, A. H., Bryant, R. A., Meares, R. A., Peduto, A. S., et al. (2006b). Amygdala-prefrontal dissociation of subliminal and supraliminal fear. *Hum. Brain Mapp.* 27, 652–661.

Winnicott, D. W. (1956). "Primary maternal preoccupation," in *The Maternal Lineage: Identification, Desire, and Transgenerational Issues*, ed. P. Mariotti (New York, NY: Routledge/Taylor & Francis Group), 59–66.

Winnicott, D. W. (1960). The theory of the parent-infant relationship. *Int. J. Psycho Anal.* 41:585.

Winnicott, D. W. (ed.) (1965). "1960 Ego distortion in terms of true and false self," in *The Maturational Processes and the Facilitating Environment* (Madison, CT: International Universities Press).

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Human Neuroscience

MINI REVIEW
published: 31 January 2019
doi: 10.3389/fnhum.2019.00015

Psychodynamically Oriented Psychopharmacotherapy: Towards a Necessary Synthesis

Angela Iannitelli[1,2,3]*, *Serena Parnanzone*[1,4], *Giulia Pizziconi*[1,4], *Giulia Riccobono*[1] *and Francesca Pacitti*[1,4]

[1]*Department of Biotechnological and Applied Clinical Sciences, University of L'Aquila, L'Aquila, Italy,* [2]*Psychoanalytical Centre of Rome (CPdR), Italian Psychoanalytical Society (SPI), Rome, Italy,* [3]*International Psychoanalytical Association (IPA), London, United Kingdom,* [4]*Psychiatry Unit San Salvatore Hospital, L'Aquila, Italy*

The discovery of psychoanalysis and of psychotropic medications represent two radical events in understanding and treatment of mental suffering. The growth of both disciplines together with the awareness of the impracticality of curing mental suffering only through pharmacological molecules—the collapse of the "Great Illusion"—and the experience of psychoanalysts using psychotropic medications along with depth psychotherapeutic treatment, have led to integrated therapies which are arguably more effective than either modality alone. The authors review studies on the role of pharmacotherapy with psychoanalysis, and the role of the analyst as the prescriber. The psychotic disorders have specifically been considered from this perspective.

Keywords: psychoanalysis, psychotropic drugs, integrated therapies, psychodynamic therapy, psychotic disorders

OPEN ACCESS

Edited by:
Anatolia Salone,
Università degli Studi G. d'Annunzio Chieti e Pescara, Italy

Reviewed by:
Angelo Picardi,
Istituto Superiore di Sanità (ISS), Italy
Marcia Kaplan,
University of Cincinnati, United States

***Correspondence:**
Angela Iannitelli
iannitelliangela@gmail.com

Received: *23 September 2018*
Accepted: *14 January 2019*
Published: *31 January 2019*

Citation:
Iannitelli A, Parnanzone S, Pizziconi G, Riccobono G and Pacitti F (2019) Psychodynamically Oriented Psychopharmacotherapy: Towards a Necessary Synthesis. Front. Hum. Neurosci. 13:15. doi: 10.3389/fnhum.2019.00015

INTRODUCTION

"[...] They don't realize we're bringing them the plague" whispered Freud to Jung sailing into New York Harbor, on August 21, 1909 (Lacan, 1996). It is a fact that psychoanalysis, as formulated by Sigmund Freud halfway between two centuries, brought the "plague" not only to the United States, but the entire world, representing one the most influential intellectual medical movements in the whole of human history. Expanding its observations from human suffering to societal interaction, psychoanalysis would have a profound impact on innumerable cultural products of human creativity such as literature, art, and cinema, and even other epistemological sciences (Tobin, 2011; Buckley, 2012; Scull, 2014; De Fiore, 2017). Despite this, psychoanalysis has undergone a storm of criticism over the last century. Detractors have pointed out that it lacks scientific credibility and that the extent to which it is evidence-based is weak and patchy. However, more recently, there have been a rise in the number of high-quality randomized controlled trials and neuroscientific studies that have provided support for many of Freud's clinical intuitions, leading to the rebuttal of the initial accusations of psychoanalysis as not being scientific (Solm, 2008; Brockman, 2011; Panksepp and Solms, 2012; Salone et al., 2016). Indeed, nowadays, psychoanalysis represents a "living" reality that cannot be ignored, with millions of patients treated worldwide from many "societies" scattered across many countries, including Russia, Iran, and China.

On the other hand, at the beginning of the 1950s, the fortuitous discovery of what would become the first psychotropic drugs—chlorpromazine, iproniazid, imipramine, and chlordiazepoxide—has led to the development of new pharmacological classes, such as antidepressants, antipsychotics, mood stabilizers, and anxiolytics (Ban, 2001). This has allowed the curing of millions of people

worldwide. Furthermore, the broadening of knowledge regarding the pathogenesis of various mental illnesses has contributed to the closure of mental asylums in many countries, including Italy (Scull, 2010).

For many years, psychoanalysis and psychopharmacology have followed parallel paths. The former, aimed at defending its own epistemology and its own growth—generally by its power apparatus—with a particular propensity for theorization; the latter, aimed at exploring the full clinical potential of psychotropic drugs—with its undoubted economic interests—but also genuinely aimed at understanding their specific mechanisms of action and thus the alterations underlying mental disorders (Scull, 2010). The growth of both disciplines together with the awareness of the impracticality of curing mental suffering only through pharmacological molecules, emergence of new forms of psychic suffering, and mutually empowering dialog between neuroscience and psychoanalysis have finally led to the development of so-called integrated therapies pointing to greater effectiveness than the use of psychoanalysis or pharmacotherapy alone. Thus far, there have been only a few studies on the results of combination/comparison and the interaction of proper long-term psychoanalysis with drug therapy. However, in the past two decades, there have been a significant number of studies that have investigated this question for other forms of psychotherapy (e.g., cognitive-behavioral therapy, interpersonal therapy, family therapy) and that have demonstrated, especially for depression and anxiety disorders, a pronounced effectiveness of integrated treatment over psychotherapy or drug therapy alone (Cuijpers et al., 2014; Aaronson et al., 2015).

Given that psychoanalysts today, partially due to the economic crisis, are likely to treat patients who are on drug therapy at the beginning of their analytic process or may need the use of drugs at some point during their analysis, the purpose of our article will be to review existing research concerning the combination of psychoanalysis and pharmacotherapy. In this context, a specific focus will be given to the psychotic dimension, as stated by Holmes (2012), fully exemplifying in miniature, the rise, fall, and tentative rebirth of a modern psychoanalysis. Our hope is that a better understanding of this alternative/integrated approach will benefit the patient and will finally enhance communication between the frequently competing worlds of psychoanalysis and psychiatry.

PHARMACOTHERAPY IN PSYCHOANALYSIS

Reviewing the psychoanalytic literature on the use and efficacy of combined psychoanalysis and drug therapy reveals considerable controversy that is often not openly addressed (Cabaniss and Roose, 2005; Gorman, 2016).

Systematic studies have highlighted how psychoanalysts may present difficulties in shifting from a dynamic model of mind to a phenomenologically based diagnostic system, which is more necessary to provide proper pharmacological treatment (Baumeister and Hawkins, 2005; Cabaniss and Roose, 2005; Purcell, 2008). In addition, regardless of the diagnosis, psychoanalysts may feel that they have failed if they need to "resort" to medication, as psychoanalysis alone is not sufficient in treating a patient (Cabaniss and Roose, 2005). In traditional psychoanalytic practice, the use of medication has always been considered a deviation from the standard analytic process, to be prescribed only if necessary, and to be stopped as soon as possible to return to the analysis of transference. After all, medication reduces the current turmoil, but does not address the underlying psychological factors of that turmoil or maladaptive defenses that predispose patients to symptoms. On the other hand, psychoanalysis can help individuals identify sources of psychic pain, with the patient eventually gaining greater emotional and behavioral adaptability (Normand and Bluestone, 1986; Loeb and Loeb, 1987; Mintz, 2006; Press, 2008; Kaplan, 2014).

Some authors have argued that reducing emotional pain with medication might decrease motivation for the analytic process leading to premature termination or pseudo-successful outcome, thus making psychopathology more likely to recur. Another concern has been that the prescription of psychotropic medication by the analyst would interfere with the phenomenon of transference/countertransference (Kubie, 1958; Normand and Bluestone, 1986; Gibbons et al., 2008; Kaplan, 2014). In fact, patients who are interested in self-exploration tend to continue with psychoanalysis regardless of whether they have been prescribed medication. In contrast, many patients receiving psychopharmacological treatment express the wish to learn about and master the conflicts that cause the symptoms with the hope of making medication unnecessary in the future (Kaplan, 2014). Regarding the possible interaction between medication and transference/countertransference, as stated by some authors, whether it occurs mostly depends on how well the analyst is able to recognize and manage it (Normand and Bluestone, 1986).

These concerns aside, an important consideration that should be addressed involves the concept of the "psychosomatic," the interaction of mind and body, and its role in the causation and curing of diseases. The medical literature has increasingly accepted the importance of psychological factors in the onset and progress of all illnesses. Conversely, many cases of diseases considered purely "mental" have been shown to have physical, possibly remediable, causes (e.g., epilepsy). Almost 50% of psychiatric patients report that fatigue, muscle pain, headache, abdominal pain, and backache are associated with sadness or panic as primary manifestations of anxiety and depression. Depression is indeed increasingly being recognized as a comorbid disorder in patients with severe and chronic medical conditions and pain syndromes. Following this line of thought, emotional disorders should involve a combined treatment approach. Thus, the use of medication should be maintained as long as necessary to control the symptoms, in the case of severe mental illnesses, possibly endangering the patient's life or continuation of the therapy (Gochfeld, 1978; Biondi, 1995; Iannitelli and Tirassa, 2015).

At present, although still considered almost a "nonsanctioned maneuver" that is rarely debated in most psychoanalytic circles,

even in the presentations of cases where drugs have effectively been used, there is a widespread acceptance in clinical practice of a combined use of psychoanalysis and drug therapy, mainly antidepressants (Mandell, 1968). This is in line with studies showing that between 30 and 50% of patients currently entering psychoanalysis present with an Axis I mood and/or anxiety disorder (Vaughan et al., 1997).

As early as 1962, Mortimer Ostow, a psychoanalyst trained in neurology, pointed to the utility of using psychotropic drugs during the course of psychoanalysis (Kandel, 1999). In 1977, a panel discussion at the meeting of the American Psychiatric Association, which included several analysts, agreed that psychotropic drugs "must be used" in certain circumstances. Indeed, the combination of psychoanalysis with drug therapy offers new possibilities for the treatment of seriously ill patients. This applies in particular to patients more vulnerable to stress that could be treated analytically by using medication to prevent serious depression, psychotic decompensation, or destructive behavior (Normand and Bluestone, 1986; Ramos, 2013). In a survey of members of the American Academy of Psychoanalysis, 90% of respondents revealed they were prescribing medications. Similarly, in a study of psychoanalytic candidates' training cases at the Columbia University Centre, psychoanalysis had been combined with drug therapy in 29% of cases (Roose and Stern, 1995).

Regarding outcome studies, the few that have been performed thus far (mostly case studies, but also clinical and randomized controlled studies) suggest that the combination of psychoanalysis and medication may be superior for the treatment of mood and anxiety disorders. However, most of these studies have small sample sizes and involve only short-term psychotherapy (Gorman, 2016). There is no question that for this idea to be taken seriously, larger-scale studies, rigorous controls, and the cooperation of all therapists and patients are required. The impetus to perform such work certainly comes from significant neuroscience data suggesting several routes by which the two treatments could be synergistic including the stimulation of hippocampal neurogenesis, epigenetic regulation, dendritic remodeling, enhanced prefrontal cortical control of limbic activity, and activity at specific neurohormonal and/or neurotransmitter targets (Solm, 2008; Gorman, 2016; Salone et al., 2016).

THE ROLE OF THE ANALYST AS PRESCRIBER: COMBINED OR SPLIT TREATMENTS?

As summarized by Awad (2001), in psychoanalysis there are usually three ways of prescribing medication. The first method is for a medical analyst to diagnose a condition that requires medication, to prescribe it, and be responsible for monitoring dosage and side effects. The second option is to refer the patient to a psychiatrist, who prescribes and monitors the medication. The third is to refer the patient for a consultation to eventually introduce medication and to take responsibility for prescribing and monitoring it.

A number of factors, such as the analytic technique chosen, the patients' diagnosis and personality, and/or the lack of a sufficient medication expertise may contribute to the analyst's decision to split treatment rather than to prescribe medication (Lebovitz, 2004; Olesker, 2006; Kaplan, 2014). Some analysts argue in favor of sending their patients to a psychopharmacologist for consultation in order to preserve an analytic stance and avoid contamination of the transference (Wylie and Wylie, 1995). Others opt for referring their patients to a psychopharmacologist in order to avoid inadequate pharmacological treatment since answering patients' questions about the effects/side effects of their medication may lead to a disruption of the analytic process and a forsaking of technical neutrality (Adelman, 1985; Yudofsky, 1991; Vlastelica, 2013; Sandberg, 2014; Salone et al., 2016). Still others prefer to administer the pharmacological treatment and claim that the discussion regarding medications and symptomatic changes may become a positive part of the complex fabric of the analytic relationship (Kandel, 1999; Greene, 2001; Glucksman, 2006; Scull, 2010). Furthermore, referring patients to others may be viewed negatively by the analysands, not to mention the fact that the shared responsibility may become an arena of conflict and struggle for control (Awad, 2001).

The fact that patients often fail to respond to medication for several reasons including ongoing use of problematic defense mechanisms, hidden use of alcohol and/or other drugs, and nonadherence, is a further claim in favor of a supportive therapeutic alliance with the prescribing doctor (Kaplan, 2014). In line with this statement, an in-depth knowledge of the patient's unique biopsychosocial aspects and psychodynamics, integrated with a variety of attachment theoretical concepts, has been indicated as leading to a more efficient pharmacological prescription, and in the case of non-adherent patients with dismissing attachment behaviors, helping them to receive the recommended pharmacological treatment. It should be noted that non-specific factors, such as adherence to treatment protocols together with a therapeutic alliance and the therapist's competence significantly contribute to treatment outcomes and may account for more of the variance than the specific treatment approach (Chatoor and Krupnick, 2001). In a more holistic perspective, this further confirms the importance of a strong analytic/medical-patient relationship (Alfonso, 2009; Ramos, 2013).

PSYCHODYNAMIC PSYCHOTHERAPY AND PSYCHOPHARMACOLOGY OF MENTAL DISORDERS—A SPECIFIC FOCUS ON PSYCHOSIS

In the 1950s, mental health professionals shared a short-lived hope that drugs could definitively cure mental suffering. However, this did not occur and despite the positive effects of medication on a lot of patients, many symptoms remained untreated. In some cases patients experienced serious side effects. Against this backdrop, the mental health community started to turn its attention to social interventions and psychotherapy

(Tai and Turkington, 2009; Brus et al., 2012; Iannitelli, 2014). Following this line of thought, research outcomes and clinical practice have encouraged psychodynamic psychotherapy, positioning such treatment among recommendations for treating various mental disorders, including patients with psychotic disorders (Ivezic et al., 2017).

Regarding schizophrenia, Freud and his more orthodox followers felt that patients with schizophrenia were not suitable for psychoanalysis. However, numerous dissenters have enthusiastically advocated for their treatment (Brus et al., 2012). For decades, the efficacy in schizophrenia of combined treatment with psychodynamic psychotherapy and drug therapy has been questioned.

In their study with 228 state hospital patients with schizophrenia, May et al. (1981) reported that both patients treated only with medication and those treated with individual supportive psychodynamic psychotherapy in conjunction with antipsychotics had a reduced length of hospitalization and tended to be readmitted less and for shorter period than patients who received only supportive psychodynamic psychotherapy.

After a careful analysis of all randomized trials of individual psychodynamic psychotherapy for people with schizophrenia, Malmberg and Fenton (2001) highlighted the superior effectiveness of medication compared to psychodynamic psychotherapy in achieving a hospital discharge, assuming that psychotherapy had a beneficial effect, even if the data were sparse, only for patients given additional medication in the 12 months to 3 years after discharge. In support of these findings, Michels (2003) stated that even if the psychoanalytic approach was able to offer a better understanding about how patients cope with schizophrenia, it does not tell us much about the disorder itself, and in general has little special relevance to the disorder. He finally defined schizophrenia as a relative contraindication to psychoanalytic treatment and underlined the importance of antipsychotic medication not so much for its sedative effects but for its neuropsychological benefits.

However, other authors have expressed different positions, and some have claimed that psychoses and schizophrenia can no longer be seen as chronic deteriorating conditions, since recovery is possible in many patients with psychosis or schizophrenia treated with approaches that focus on the primacy of psychoanalytically oriented psychotherapeutic intervention (Gibbs, 2007). One of the central tenets of psychotherapy is the therapist and their experience, which plays a significant role in the treatment outcome. Specific therapists' characteristics, such as their attitudes, intellectual and therapeutic skills, and ability to deal with stress or convey acceptance and compassion, have been reported to indirectly influence the treatment outcome (Karon, 1981). Frank and Gunderson's (1990) investigation of the role of the therapeutic alliance in the treatment of patients with schizophrenia also revealed that a good alliance with therapists within the first months was strongly correlated to the treatment course and outcomes, specifically with respect to patients' greater acceptance of both psychotherapy and pharmacological treatments and reduced medication use. Based on the Danish National Schizophrenia Project, some studies (prospective, comparative, longitudinal multi-site investigations) suggest the greater efficacy in the treatment of patients with schizophrenia with individual supportive psychodynamic psychotherapy in addition to treatment as usual compared to treatment as usual alone (Rosenbaum, 2009; Rosenbaum et al., 2012). Patients improved significantly during the 2 years of treatment with moderate to strong effect sizes on positive and negative symptoms, general symptom level, and social function. In line with these findings, other studies found support for improved symptomatology along with changes in some cognitive/social functioning, and quality of life of patients with schizophrenia receiving long-term (up to 3 years) psychodynamic group therapy in addition to regular antipsychotic treatment (Restek-Petrović et al., 2014; Pec et al., 2018).

Taken together, all these studies suggest the importance of patients receiving integrated psychoanalysis and pharmacological treatment, specifically suggesting how psychiatric and psychoanalytic principles are intimately linked together and useful in understanding patients' illness and treating them successfully. In line with these findings, it is our hope that the clinical potential of the theoretical and practical alliance between psychoanalysis and neuroscience will no longer be underestimated and that it instead will be further investigated.

AUTHOR CONTRIBUTIONS

All authors have contributed significantly and are in agreement with the content of the manuscript.

FUNDING

This study was supported by the Department of Biotechnological and Applied Clinical Sciences, University of L'Aquila. AI is a recipient of a research grant (SSD MED/25, Rep. n. 43/2017, Prot. n. 68519.7.2017).

REFERENCES

Aaronson, C. J., Katzman, G., and Moster, R. L. (2015). "Combination pharmacotherapy and psychotherapy for the treatment of major depressive and anxiety disorders," in *A Guide to Treatments that Work*, eds P. E. Nathan and J. M. Gorman (New York, NY: Oxford University Press), 463–506.

Adelman, S. A. (1985). Pills as transitional objects: a dynamic understanding of the use of medication in psychotherapy. *Psychiatry* 48, 246–253. doi: 10.1080/00332747.1985.11024285

Alfonso, C. A. (2009). Dynamic psychopharmacology and treatment adherence. *J. Am. Acad. Psychoanal. Dyn. Psychiatry* 37, 269–285. doi: 10.1521/jaap.2009.37.2.269

Awad, G. A. (2001). The effects of medication on the psychoanalytic process. The case of selective serotonin reuptake inhibitors. *Psychoanal Study Child* 56, 263–285. doi: 10.1080/00797308.2001.11800676

Ban, T. A. (2001). Pharmacotherapy of mental illness—a historical analysis. *Prog. Neuropsychopharmacol. Biol. Psychiatry* 25, 709–727. doi: 10.1016/s0278-5846(01)00160-9

Baumeister, A. A., and Hawkins, M. F. (2005). Continuity and discontinuity in the historical development of modern psychopharmacology. *J. Hist. Neurosci.* 14, 199–209. doi: 10.1080/096470490512562

Biondi, M. (1995). Beyond the brain-mind dichotomy and toward a common organizing principle of pharmacological and psychological treatments. *Psychother. Psychosom.* 64, 1–8. doi: 10.1159/000288985

Brockman, R. (2011). Aspects of psychodynamic neuropsychiatry II: psychical locality and biology: toward the neurobiology of psychotherapy. *J. Am. Acad. Psychoanal. Dyn. Psychiatry* 39, 285–311. doi: 10.1521/jaap.2011.39.2.285

Brus, M., Novakovic, V., and Friedberg, A. (2012). Psychotherapy for schizophrenia: a review of modalities and their evidence base. *Psychodyn. Psychiatry* 40, 609–616. doi: 10.1521/pdps.2012.40.4.609

Buckley, P. J. (2012). Gustav klimt, egon schiele, and fin de siècle vienna. *Am. J. Psychiatry* 169:692. doi: 10.1176/appi.ajp.2012.12030294

Cabaniss, D. L., and Roose, S. P. (2005). Psychoanalysis and psychopharmacology: new research, new paradigms. *Clin. Neurosci. Res.* 4, 399–403. doi: 10.1016/j.cnr.2005.03.002

Chatoor, I., and Krupnick, J. (2001). The role of non-specific factors in treatment outcome of psychotherapy studies. *Eur. Child Adolesc. Psychiatry* 10, S19–S25. doi: 10.1007/s007870170004

Cuijpers, P., Sijbrandij, M., Koole, S. L., Andersson, G., Beekman, A. T., and Reynolds, C. F. (2014). Adding psychotherapy to antidepressant medication in depression and anxiety disorders: a meta-analysis. *World Psychiatry* 13, 56–67. doi: 10.1002/wps.20089

De Fiore, L. (2017). Cinema emedicina In Treatment: se l'analisi finisce. *Recenti. Prog. Med.* 108, 247–248. doi: 10.1701/2695.27563

Frank, A. F., and Gunderson, J. G. (1990). The role of the therapeutic alliance in the treatment of schizophrenia. Relationship to course and outcome. *Arch. Gen. Psychiatry* 47, 228–236. doi: 10.1001/archpsyc.1990.01810150028006

Gibbons, M. B., Crits-Christoph, P., and Hearon, B. (2008). The empirical status of psychodynamic therapies. *Annu. Rev. Clin. Psychol.* 4, 93–108. doi: 10.1146/annurev.clinpsy.4.022007.141252

Gibbs, P. L. (2007). The primacy of psychoanalytic intervention in recovery from the psychoses and schizophrenias. *J. Am. Acad. Psychoanal. Dyn. Psychiatry* 35, 287–312. doi: 10.1521/jaap.2007.35.2.287

Glucksman, M. L. (2006). Psychoanalytic and psychodynamic education in the 21st century. *J. Am. Acad. Psychoanal. Dyn. Psychiatry* 34, 215–222. doi: 10.1521/jaap.2006.34.1.215

Gochfeld, L. G. (1978). Drug therapy and modern psychoanalysis. *Mod. Psychoan.* 3, 203–216.

Gorman, J. M. (2016). Combining psychodynamic psychotherapy and pharmacotherapy. *Psychodyn. Psychiatry* 44, 183–209. doi: 10.1521/pdps.2016.44.2.183

Greene, M. A. (2001). The effects of the introduction of medication on the psychoanalytic process: a case study. *J. Am. Psychoanal. Assoc.* 49, 607–627. doi: 10.1177/00030651010490020901

Holmes, J. (2012). Psychodynamic psychiatry's green shoots. *Br. J. Psychiatry* 200, 439–441. doi: 10.1192/bjp.bp.112.110742

Iannitelli, A. (2014). Psicoanalisi e psicofarmaci: storia e sviluppi di un incontro ravvicinato. *Riv. Psichiatr.* 49:157. doi: 10.1708/1600/17448

Iannitelli, A., and Tirassa, P. (2015). "Pain and depression: the janus factor of human suffering," in *Introduction to Pain and Its Relations to Nervous System Disorders*, ed. A. Battaglia (New York, NY: Wiley-Blackwell), 317–344.

Ivezić, S. Š., Petrović, B. R., Urlić, I., Grah, M., Mayer, N., Stijaćić, D., et al. (2017). Guidelines for individual and group psychodynamic psychotherapy for the treatment of persons diagnosed with psychosis and/or schizophrenia. *Curr. Med. Res. Opin.* 29, 432–440.

Kandel, E. R. (1999). Biology and the future of psychoanalysis: a new intellectual framework for psychiatry revisited. *Am. J. Psychiatry* 156, 505–524.

Kaplan, M. (2014). "Psychoanalysis and psychopharmacology: art and science of combining paradigms," in *TextBook of Biological Psychiatry*, ed. J. Panksepp (Hoboken, NJ: Wiley-Liss, Inc.), 549–569.

Karon, B. P. (1981). "The thematic apperception test," in *Assessment with Projectives Techiques*, ed. A. I. Rabin (New York, NY: Springer), 85–120. doi: 10.1007/springerreference_180658

Kubie, L. S. (1958). Psychoanalysis and psychopharmacology. *Psychiatr. Res. Rep. Am. Psychiatr. Assoc.* 9, 61–67.

Lacan, J. (1996). *Écrits: The First Complete Edition in English.* Transated by Bruce Fink. New York, NY: W. W. Norton and Company.

Lebovitz, P. S. (2004). Integrating psychoanalysis and psychopharmacology: a review of the literature of combined treatment for affective disorders. *J. Am. Acad. Psychoanal. Dyn. Psychiatry* 32, 585–596. doi: 10.1521/jaap.32.4.585.53840

Loeb, F. F. Jr., and Loeb, L. R. (1987). Psychoanalytic observations on the effect of lithium on manic attacks. *J. Am. Psychoanal. Assoc.* 35, 877–902. doi: 10.1177/000306518703500405

Malmberg, L., and Fenton, M. (2001). Individual psychodynamic psychotherapy and psychoanalysis for schizophrenia and severe mental illness. *Cochrane Database Syst. Rev.* 3:CD001360. doi: 10.1002/14651858.cd001360

Mandell, A. J. (1968). "Psychoanalysis and psychopharmacology," in *Modern Psychoanalysis: New Directions and Perspectives*, ed. J. Marmor (New York, NY: Basic Books), 274–290.

May, P. R., Tuma, A. H., Dixon, W. J., Yale, C., Thiele, D. A., and Kraude, W. H. (1981). Schizophrenia. A follow-up study of the results of five forms of treatment. *Arch. Gen. Psychiatry* 38, 776–784. doi: 10.1001/archpsyc.1981.01780320056006

Michels, R. (2003). The relationship between psychoanalysis and schizophrenia—a commentary. *Int. J. Psychoanal* 84, 3–9; discussion 9–15. doi: 10.1516/00207570360509457

Mintz, D. (2006). Psychodynamic Trojan horses: using psychopharmacology to teach psychodynamics. *J. Am. Acad. Psychoanal. Dyn. Psychiatry* 34, 151–161. doi: 10.1521/jaap.2006.34.1.151

Normand, W. C., and Bluestone, H. (1986). The use of pharmacotherapy in psychoanalytic treatment. *Contemp. Psychoanal.* 22, 218–234. doi: 10.1080/00107530.1986.10746123

Olesker, W. (2006). Thoughts on medication and psychoanalysis: a lay analyst's view. *J. Am. Psychoanal. Assoc.* 54, 763–779. doi: 10.1177/00030651060540031201

Panksepp, J., and Solms, M. (2012). What is neuropsychoanalysis? Clinically relevant studies of the minded brain. *Trends Cogn. Sci.* 16, 6–8. doi: 10.1016/j.tics.2011.11.005

Pec, O., Bob, P., Pec, J., and Hrubcova, A. (2018). Psychodynamic day treatment programme for patients with schizophrenia spectrum disorders: Dynamics and predictors of therapeutic change. *Psychol. Psychother.* 91, 157–168. doi: 10.1111/papt.12153

Press, M. (2008). The uses of medications in psychoanalysis: what we know, what is uncertain. Panel reports. *J. Am. Psychoanal. Assoc.* 56, 949–955. doi: 10.1177/0003065108324063

Purcell, S. D. (2008). The analyst's attitude toward pharmacotherapy. *J. Am. Psychoanal. Assoc.* 56, 913–934. doi: 10.1177/0003065108323376

Ramos, M. A. (2013). Drugs in context: a historical perspective on theories of psychopharmaceutical efficacy. *J. Nerv. Ment. Dis.* 201, 926–933. doi: 10.1097/nmd.0000000000000062

Restek-Petrović, B., Gregurek, R., Petrović, R., Orešković-Krezler, N., Mihanović, M., and Ivezić, E. (2014). Social functioning of patients with psychotic disorders in long-term psychodynamic group psychotherapy: preliminary research. *Psychiatr. Danub.* 26, 122–126.

Roose, S. P., and Stern, R. H. (1995). Medication use in training cases: a survey. *J. Am. Psychoanal. Assoc.* 43, 163–170. doi: 10.1177/000306519504300113

Rosenbaum, B. (2009). Early and sustained dynamic intervention in schizophrenia. *Psychiatr. Danub.* 21, 132–134.

Rosenbaum, B., Harder, S., Knudsen, P., Koster, A., Lindhardt, A., Lajer, M., et al. (2012). Supportive psychodynamic psychotherapy versus treatment as usual for first-episode psychosis: two-year outcome. *Psychiatry* 75, 331–341. doi: 10.1521/psyc.2012.75.4.331

Salone, A., Di Giacinto, A., Lai, C., De Berardis, D., Iasevoli, F., Fornaro, M., et al. (2016). The interface between neuroscience and neuro-psychoanalysis: focus on brain connectivity. *Front. Hum. Neurosci.* 10:20. doi: 10.3389/fnhum.2016.00020

Sandberg, L. S. (2014). On the prescribing analyst. *Psychoanal. Q.* 83, 97–120. doi: 10.1002/j.2167-4086.2014.00078.x

Scull, A. (2010). A psychiatric revolution. *Lancet* 375, 1246–1247. doi: 10.1016/S0140-6736(10)60532-6

Scull, A. (2014). Some reflections on madness and culture in the post-war world. *Hist. Psychiatry* 25, 395–403. doi: 10.1177/0957154X14546075

Solm, M. (2008). The scientific standing of psychoanalysis. *BJPsych Int.* 15, 5–8. doi: 10.1192/bji.2017.4

Tai, S., and Turkington, D. (2009). The evolution of cognitive behavior therapy for schizophrenia: current practice and recent developments. *Schizophr. Bull.* 35, 865–873. doi: 10.1093/schbul/sbp080

Tobin, R. D. (2011). Fixing Freud: the Oedipus complex in early twenty-first century US American novels. *Psychoanal. Hist.* 13, 245–264. doi: 10.3366/pah.2011.0091

Vaughan, S. C., Spitzer, R., Davies, M., and Roose, S. P. (1997). The definition and assessment of analytic process: can analysts agree? *Int. J. Psychoanal.* 78, 959–973.

Vlastelica, M. (2013). Psychodynamic approach as a creative factor in psychopharmacotherapy. *Psychiatr. Danub.* 25, 316–319.

Wylie, H. W., and Wylie, M. L. (1995). Resistances and obstructions: Their distinction in psychoanalytic treatment. *J. Clin. Psychoanal.* 2, 27–41.

Yudofsky, S. (1991). Psychoanalysis, psychopharmacology, and the influence of neuropsychiatry. *J. Neuropsychiatry Clin. Neurosci.* 3, 1–5. doi: 10.1176/jnp.3.1.1

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

HYPOTHESIS AND THEORY
published: 05 April 2019
doi: 10.3389/fpsyg.2019.00492

Re-enacting the Bodily Self on Stage: Embodied Cognition Meets Psychoanalysis

*Claudia Scorolli**

Department of Philosophy and Communication Studies, University of Bologna, Bologna, Italy

The embodied approach to cognition consists in a range of theoretical proposals sharing the idea that our concepts are constitutively shaped by the physical and social constraints of our body and environment. Still far from a mutually enriching interplay, in recent years embodied and psychoanalytic approaches are converging on similar constructs as the ones of intersubjectivity, bodily self, and affective quality of verbal communication. Some efforts to cope with the *sentient* subject were already present in classical cognitivism: having expunged desires and conflicts from the *cognitive harmony*, bodily emotions re-emerged but only as a noisy dynamic friction. In contrast, the new, neural, embodied cognitive science with its focus on bodily effects/affects has enabled a dialogue between neuro-cognitive perspectives and clinic-psychological ones, through shared conceptual frameworks. I will address crucial issues that should be faced on this reconciling path. With reference to two kinds of contemporary addictions – internet addiction disorder and eating disorders – I will introduce a possible therapeutic approach that is built upon the core role of the acting-sentient bodily self in a dynamic-social and affective environment. In Psychoanalytic Psychodrama, the spontaneous re-enactment of a past (socially and physically constrained) experience is actualized by means of the other, the Auxiliary Ego. This allows homeostatic and social-emotional affects, i.e., drives and instincts, to be re-experienced by the agent, the Protagonist, in a safe scenario. The director-psychoanalyst smoothly traces back this simulation to the motivated, and constrained, early proximal embodied interactions with significant others, and to the related instinctual conflicting aims. The psychoanalytic reframing of classical psychodrama does not merely exploit its original cathartic function, rather stands out for exploring the interpersonal constitution of the self, through an actual "re-somatization" of psychoanalytic therapy. Unspoken/unspeakable feelings pop up on stage: the strength of this treatment mainly rests on re-establishing the priority of the *embodied Self* over the *narrative Self*. By pointing out the possible conflicts between these two selves, this method can broaden the embodied cognition perspective. The psychodramatic approach will be briefly discussed in light of connectionist models, to finally address linguistic and methodological pivotal issues.

Keywords: psychoanalysis, embodied cognition, psychoanalytic psychodrama, intersubjectivity, sentient bodily self, affects, internet addiction disorders, eating disorders

OPEN ACCESS

Edited by:
Anatolia Salone,
Università degli Studi G. d'Annunzio Chieti e Pescara, Italy

Reviewed by:
Giuliana Lucci,
Università degli Studi Guglielmo Marconi, Italy
Omar Carlo Gioacchino Gelo,
University of Salento, Italy
Paolo Migone,
University of Parma, Italy

***Correspondence:**
Claudia Scorolli
claudia.scorolli@unibo.it

Specialty section:
This article was submitted to Psychoanalysis and Neuropsychoanalysis, a section of the journal Frontiers in Psychology

Received: *27 August 2018*
Accepted: *19 February 2019*
Published: *05 April 2019*

Citation:
Scorolli C (2019) Re-enacting the Bodily Self on Stage: Embodied Cognition Meets Psychoanalysis. Front. Psychol. 10:492. doi: 10.3389/fpsyg.2019.00492

INTRODUCTION

The aim of this work is to prepare the ground for an enriching dialogue between cognitive science and psychoanalysis by identifying common theoretical constructs and potential new methods. In this view, the introduction is dedicated to clarify the specific nature of cognition assumed by the present article, that is, an "embodied" nature. It denies that representations are built out of amodal symbols and claims that sensory, motor, and affective processes are intrinsic to cognition.

The argument is articulated by first discussing recent neuroscience literature. From a "cognitive" to an "affective" neuroscientific perspective, scientists are nowadays converging on themes that traditionally belonged to psychoanalytical approaches as the ones of the bodily self, intersubjectivity, unconscious, and prosodic-affective quality of verbal communication. Along with the common questions, divergences are also addressed and traced back to two scarcely reconcilable objectives. In cognitive science view the objective is to generalize and to predict; in psychoanalysis the objective is to dig deep into the unique self and its conflicting states.

To clarify the convergences, in what follows four thematic cores are addressed (environment; drives, instincts, and unconscious conflicts; intersubjectivity; perception of the body) and are connected with two disorders: internet addiction disorder and eating disorders (EDs). This problematization will allow the introduction of the psychodramatic method and the contrast between an "acting" cure and a "talking" cure. Next, the psychoanalytic reframing of classical psychodrama is introduced: *psychoanalytic psychodrama* does not merely exploit the cathartic function but stands out for exploring the self in its interpersonal constitution, through an actual somatization of psychoanalytic models, prioritizing the embodied self over the narrative self. Its distinctive features are discussed against traditional psychoanalytical approaches and body-oriented therapies.

To further ease an effective interdisciplinary collaboration, a possible integration with ecological connectionists models (implementing the grounding in sensory, motor, and affective processes as intrinsic to cognition) is outlined. Finally, linguistic and methodological issues are addressed: shared constructs across disciplines are necessary to make effective and substantial advancements within this new science. To encompass the sentient bodily self, by empirically supporting this exploration also outside the therapeutic setting, the further challenge of neuropsyhcoanalysis requires the exploitation, and the integration, of the most promising methodologies. This effort would guarantee the necessary flexibility with respect to different settings-contexts, as well the opportunity to investigate different issues.

WHICH COGNITIVE SCIENCE?

Nowadays the adjective "cognitive" is abused, generating a lot of confusion about its meaning. The reason is that there is not a single cognitive science, but at least two. The first one is the classical cognitive science, "Cognitivism": a computational science according to which the mind, similarly to the software of a computer, is a mechanism for manipulating arbitrary and amodal symbols. This science basically arose from the ashes of behaviorism. Consistently it had a twofold aim: rejecting behaviorism while maintaining scientificity and preserving the "science of mind" separated by neuroscience (Parisi, 2002).

Progress in neuroscientific research, as well as gradual awareness that computing machines lack human-like intelligence, created the demand for a new cognitive science. This science had to consider not only the brain, but also the body (Glenberg, 1997; Barsalou, 1999; Gallese and Lakoff, 2005): this neural cognitive science can be identified with "Embodied Cognition". Embodied cognition has led to a conceptual revolution by demonstrating that concepts consist in the reactivation of the same neural activation pattern involved when we perceive objects/entities they refer to and when we interact with them (Scorolli and Borghi, 2007; Scorolli et al., 2012; Borghi et al., 2013; Scorolli, 2014). The plethora of recent theories, labels, and approaches traceable within this perspective may appear puzzling: a clear conceptual clarification is provided by Pezzulo et al. (2013). While the label "grounded" refers to the physical foundation of cognition, affected for instance by the laws of physics, the label "embodied" specifically points to the physical constraints of our body, i.e., to the sensory-motor experiences shaping our cognition. Finally, the label "situated" nicely refers to the dependence of cognitive processing on both current constraints and tasks demands. These level-specific modulations exert additive effects on cognition. They can be conceptualized as a cascade, ranging from the physical properties of the world to the sensorimotor, affective and interoceptive processes, and in the end to the specific characteristics of the environment, including its social and cultural features (Pezzulo et al., 2013).

Regardless of the taken perspective, these theoretical proposals share the idea that grounding phenomena are constitutive of cognition, thus are not just optional add-ons. In the present work, the label "embodied" is privileged to directly point to bodily, affective, and emotional states (Niedenthal et al., 2005; Wilson-Mendenhall et al., 2011), though without disregarding the role, functions, and requirements of the physical and social context.

EMBODIED COGNITION AND PSYCHOANALYSIS

Previous attempts towards a mutually enriching dialogue between neuroscience and psychoanalysis have been mainly focused on "the new neuropsychological theoretical and methodological apparatus of cognitive neuroscience (that) can be easily and profitably incorporated into theoretical psychoanalysis without any cost" (Semenza, 2014, p. 3). This kind of approach assumes that emotions, feelings, affects, and drives can be first neglected, as a background noise with respect to the investigation of action and perception, or memory and language processes; they can

be re-integrated into the cognitive scaffolding at a later stage. The risk is not providing an account for "authenticity, individuality, feeling, and character" (Brown, 2014, p. 10). In contrast, embodied theories claim that mind is not just cognition, intelligence, language, skills, but also motivation, perceived sensations, and felt emotions (i.e., bodily effects). Despite this theoretical claim, only in recent years there has been a growing attention (also) for empirical data pertaining to the emotional and the motivational spheres (thus belatedly with respect to the breakthrough of *affective neuroscience*: Panksepp, 1998, 2005; Damasio, 2000; Damasio et al., 2000). This interest has been fostered by several factors and new scientific challenges:

– The emergence of an embodied *social* cognition, and thus the interest not just in motor automatic resonance mechanisms, but also in complementary (non-imitative) actions involved for instance in joint activity (Rumiati and Bekkering, 2003; Sartori and Betti, 2015; see also the upcoming research issue by Brunel et al., 2019).
– The notable advances in artificial life simulations, that have shifted the attention to populations of organisms that evolve biologically, to their specific needs for survival and reproduction, and hence to the motivations deriving from them (Parisi, 2013, 2014).
– The acknowledgment that psychological phenomena are complex, determined by a huge number of variables interacting with each other non-linearly (e.g., the emergence of mental disorders from the interactions of different symptoms), and thus the necessity to approach them from a complex systems perspective (e.g., Borsboom et al., 2018).
– The novel evidence and theoretical accounts of the representation of abstract concepts, which emphasize the role of emotions and sociality in grounding abstractness (see the recent theme issue by Borghi et al., 2018).
– The new frontier research on interoception, and its central role for cognition, that breaks out of corticocentricity. In the special issue on the impact of interoception beyond the homeostatic/allostatic reflexes (Tsakiris and Critchley, 2016), authors from different perspectives address how information about the internal states of the body are integrated with thoughts, feelings, and behaviors. A compelling body of empirical evidence and neurobiological insights is discussed to explore also clinical implications and methodological issues.
– The final factor impacting current embodied perspectives definitely is the widespread availability of neuroimaging techniques for the investigation of those brain regions that are associated with cognitive-emotional interactions. Both indirect measurements (based on hemodynamic responses) and direct measurements (based on brain electrical dynamics) are making a difference in the examination of the interplay between emotional control and cognitive regulation (Tyng et al., 2017).

Beyond these factors, in last years neuroscientists, philosophers, computer scientists, and roboticists have re-evaluated psychological schools that ruled in Europe in the first half of the twentieth century: Gestalt theory of perception, Piagetian and Vygotskian theories of cognitive development, and Freudian theory of psychosexual development. The theoretical frameworks of these scholars range from affective neuroscience to embodied cognition (e.g., Panksepp and Solms, 2012; Rizzolatti et al., 2014): they share with the psychoanalytic approach the idea that the supremacy of "the cognitive" is made unsettled by "the dynamic".

Regardless of the attempts of a worthwhile dialogue, cognitivism can hardly be integrated with psychodynamic theorization, which instead appears inherently related to new embodied approaches. With them, it shares at least the following views: (1) The rationality is seen as the tip of the iceberg; (2) the refusal of the primacy of the intellect over the emotions and the primacy of the mind over the body; (3) the "core self" is conceived as the continuous interaction between intero- and exteroceptive stimuli (Northoff, 2012); (4) the individual mind is not simply "brainbound" but also distributed beyond the body's edges (Hutchins, 1995) across non-bodily devices but also bodily social ones (Clark, 2003; Thompson and Stapleton, 2009; Wilson, 2010) through interpersonal body representations (Costantini et al., 2011); (5) a "genetic epistemology" approach, meaning that we can better understand X if we reconstruct how X has become what it is (Piaget, 1952; Parisi and Schlesinger, 2002): accordingly, our mind cannot be conceived as just extended but, for the immature infant, also in need of boundaries for the overwhelming ambivalent stimuli (Freud, 1920; a skin to the mind: Levy and Lemma, 2004; a containing mind: Bion, 1962); (6) many simultaneous causes produce many effects on the self, in largely unpredictable ways: to grasp the complex interplay of brain, body, and environment, a dynamical system approach is needed (Clark, 1999); (7) the acknowledgment of the limitations of science in predicting effects before they occur, and controlling all variables; and (8) the concerns about the scientific method: not the only way, and perhaps not even the best, for our knowledge of reality.

SHARED CONCEPTS AND OBJECTIVES BUT CENSORSHIPS

Unconscious, Empathy, and Intersubjectivity

As insightfully reviewed by Kihlstrom (2015), the term "unconscious" was used by Freud with three different meanings: to refer to thoughts, feelings, or desires that are not aware at any particular time; or available to consciousness in principle, even if they are not accessible at the present moment ("preconscious"); or not even available to consciousness. Nevertheless, in the *dynamic* sense of the term, only repressed mental contents were conceived as "unconscious", like sexual and aggressive impulses prevented from being represented in consciousness (though still determinants of our thoughts and actions). The goal of the psychoanalytic treatment is to bring these contents into consciousness in order to be dealt with.

We can easily guess that within the scientific-academic milieu this construct was not welcomed. While widely popular and evocative among clinicians and the public, the first blow was knocked by the behaviorist revolution. Concerned about raising psychology to the level of science, behaviorism has drastically cut off the unobservable mental life. The following breakthrough

of cognitivism led to progressive evidence on implicit perception, like in subliminal priming effects (e.g., Pesciarelli et al., 2019), or on the distinction between automatic and controlled cognitive processes, like in the Stroop effect (e.g., Scorolli et al., 2015). This new evidence in some way legitimized the construct of unconscious to refer to "unconscious cognition" (Kihlstrom, 1987), thus in a descriptive-systematic sense, not in its dynamic foundational meaning. If we define cognition as pertaining to any mental activity, unconscious cognition could not disregard feelings and desires (Kihlstrom, 2013). Nevertheless, the unsolved issue was still related to how, in the absence of conscious awareness, emotions and motivations can affect our thoughts and actions. The "explicit"/"implicit" distinction is more difficult to be dealt with when encompassing the emotional sphere. Some behavioral and/or physiological components of implicit emotions can be objectively measured (though it is challenging to link them to the corresponding "source of stimulation"). Some other components can be caught only through "projective" measurements, dream imagery, and free associations (considering that the same cause can produce different effects, and not all these effects are synchronous). Kihlstrom (2015) foresees a future for the dynamic unconscious in the current renewed interest in consciousness, though recognizing that "carefully controlled experiments (…) have not yielded much evidence favoring the view of the dynamic unconscious as conceived in psychoanalytic theory, with its unconscious conflicts over primitive sexual and aggressive motives" (p. 996). To achieve a substantial breakthrough, it is probably necessary to change the perspective, introducing new concepts as well.

The concept of empathy, neglected by classical cognitive science, has been retrieved by the new neural embodied science. "A path leads from identification by way of imitation to empathy" (Freud, 1921, p. 110): such a farsighted statement has been neuro-physiologically accounted for by embodied cognition. The discovery of mirror neurons, and embodied simulation, has laid the foundation for the neuroscientific study of intersubjectivity and empathy as means of inter-individual transfer of meaning, opening the way to connect Freudian theory of the psyche with the most advanced scientific theories and discoveries (Rizzolatti and Sinigaglia, 2006; Gallese, 2007a).

With regard to the internal world, recently embodied approaches have emphasized the importance of emotions (Caruana and Gallese, 2011, 2012), bodily self (e.g., Ferri et al., 2012), and indirectly of the unconscious as well. Damasio (1999) refers to "nuclear consciousness", whose foundation does have an emotional nature, thus it does not imply language. This implicit memory of the perceptions of self-with-others, which follow over time during the first year of life, is tacit, non-declarative, procedural, and, similarly to the Freudian unconscious, does have a crucial role in adult social life and relationships. The related "unconscious emotions" seem to be controlled by a subcortical circuit (amygdala, superior colliculus, and pulvinar). The so characterized unconscious does not correspond to Freudian "topical" unconscious (the id in the second topical), and there is no reference to Freudian repression; nevertheless the role of *what is not accessible to consciousness* is acknowledged and emphasized in the psychoanalytic relationship (for a recent reconsideration of the anatomical localization of consciousness with cross-references to Freudian view, see Solms 2017b, 2019). The patient and the psychoanalyst can unconsciously grasp, in a continuous and reciprocal motion, subtle stimuli of the other, that activate shared neural patterns (Gallese et al., 2006; Ginot, 2015).

Verbal Communication and Its Prosodic-Affective Quality

Unlike psychoanalytic approaches, cognitivist ones seem to suggest first to ignore the affective noise, desires, and conflicts (at intrapersonal and interpersonal/intergroup level) and later to attach them to the impoverished reconstructed mind. Conversely, Freudian and embodied views share striking similarities, for instance, when accounting for speech (Freud, 1915b; Gallese, 2007b, 2008). As masterly reviewed by Gallese (2009), within the analytic relation the affective quality of verbal communication assumes a critical role in terms of prosody (Rizzuto, 2008), rhythm, tone, timbre, and musicality, as well as syntax and tempi of speech (Mancia, 2006; Rizzuto, 2008; Gallese, 2011).

Recent evidence on language acquisition has shown that the ability of 4-day-old infants to distinguish utterances in their native languages from those of another language depends on prosodic cues (Mehler et al., 1998). Gervain and Werker (2013) have shown that in 7-month-old bilinguals (succeeding in mastering their mother tongues as efficiently as monolinguals), the precocious and effortless acquisition of grammar is actually accounted by their skill on exploiting characteristic prosodic cues (pitch and duration). Furthermore, when investigating the development of language-specific trochaic bias in German-French bilinguals (i.e., languages with and without a trochaic lexical stress), Bijeljac-Babic et al. (2016) found that listening preferences of these 6-month-old infants were comparable to those of German-learning monolinguals but differed from those of same age French-learning monolinguals (i.e., no preference: Höhle et al., 2009). This precocious emergence of a trochaic bias even in simultaneous bilinguals further supports the importance of prosodic information. Finally, it seems that precocious language learning processes (9-month-old infants) are specifically enhanced by social interaction, while not requiring long-term listening (Kuhl et al., 2003). Overall, this evidence unveils the intimate link among embodied language, prosody, and intersubjectivity: the human language learning system flexibly adapts to and exploits the linguistic, affective-social environment (for a recent work on emotional word processing also in the domain of social cognition, see Herbert et al., 2018).

Towards a Unique Total Self

A further contact point between embodied cognition and psychoanalysis can be found in their objectives. While cognitivism was aimed at discovering a supposed "normative averageness," the new neural science is pointing out the significance of idiosyncratic profiles of cortical activation (Gallese, 2007a), as well as the individual characteristics in light of life experiences and unconscious facets ("Unique Total Self": Schaefer and Northoff, 2017). Similarly, psychoanalytic approaches underline the uniqueness of the patient and the role of the environment

in which she grew up (family), which may have fitted or not her basic personality tendencies, as introversion and extroversion (Rapaggi, 1994; John and Srivastava, 1999).

Limits

The limits, or rather "censorships," of the new embodied science consist in not having adequately considered that perception is always accompanied by feelings of pleasure or pain, lust or grief (Panksepp, 1998; Cuccio et al., 2013; Alcaro et al., 2017; Solms, 2017a; Moccia et al., 2018): behavior cannot be explained apart from this Aristotelian interweaving (Lo Piparo, 2003). Actually, an analogous tendency to quit digging into bodily drives, repudiating the centrality of sexuality, characterizes also current developments of psychoanalytic approaches (for a critical discussion, see Green, 1995; Fonagy, 2008; Fotopoulou and Tsakiris, 2017). In spite of numerous studies on psychosomatic medicine (e.g. Lisi et al., 2014), only a few empirical studies have tried to approach the appetitive dimension of sexuality, that is, the libido. Embodied evidence has made much progress on the investigation of how we understand the emotions of others, *but:* how do we understand ours? Where do they come from?

Sexual drives (specifically defined by source, aim, and object; Freud, 1915a) and the possible fixation of the libido (Freud, 1905) are basically cut out from contemporary neuroscience, even if they laid the foundation, as well as the absolute novelty, of Freudian theorization. The general censorship is at least puzzling. There are a few enlightening exceptions, for instance from a neuropsychoanalytic perspective (e.g., Solms, 2012; Stoléru, 2014) or in a strictly embodied-grounded view (Papies and Barsalou, 2015; for an ethological approach to the study of the early modulation of sexual preferences, see Enquist et al., 2011). These works raise new challenging questions on desires that do not directly result from physiological deprivation.

While *psychic conflicts* may or may not be conscious, *drives* are not conscious per se: they arise from the interaction between biological and environmental stimuli and are dialectically constructed from both pressures (Dunn, 1993). But psychoanalytical theory has actually provided an account for the conscious phenomenology of sexual desire. Considering the oral stage of psychosexual development (0–18/24 months), the mouth is conceived as the primary erogenous zone; remarkably the mouth is also central in babies' exploration. The time window ranging from 0 to 24 months corresponds to the Piagetian sensorimotor period (Piaget, 1945, 1952); coherently Piaget emphasized the mouthing behavior (mostly in the second stage of the first period, from 1 to 4 months). Recently, changes in mouthing of objects have been empirically identified exactly in this period: children $\leq$24 months exhibit the highest frequency of mouthing behavior, while children >24 months exhibit the lowest frequency (Tulve et al., 2002; for an observational study on children up to 3 years old, see Juberg et al., 2001). Mouthing has been accounted for as crucial to proactively expose the gastrointestinal tract to environmental antigens (Fessler and Abrams, 2004). But this is not the whole story. Early mouthing is related to the objects it is applied to: the rigidity of an object affects the frequency and pattern of mouthing (and grasping) behavior, suggesting that this activity is not merely under the control of reflexive mechanisms (Rochat, 1987). The interplay between the normal cognitive development, certifying a growing interest in the world, and the normal affective development, rooted on bodily drives and instincts, is deserving to be systematically addressed, beyond the borders of sectorial scientific disciplines.

NEEDS, DESIRES, AND ADDICTIONS

Cyber Presence and Eating Disorders

In recent years, new addictions are spreading: they are generically labeled as internet addiction disorder (IAD). They are in some way peculiar as not related to substance abuse, even if they could be still explained by evolutionary models, by referring to the emotional systems of reward seeking and separation distress (Panksepp et al., 2002). There is a debate on whether the last version of the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5; American Psychiatric Association, 2013) should have classified these disorders as "mental disorders". Currently, they are variously assessed: dependency on virtual relationships, cognitive overload, virtual sex addiction, and online gaming. Young (1998) identified three main stages in IAD progress: involvement, characterized by initial curiosity; substitution, when the activities that previously were central do not matter anymore; escape, when more frequent and longer time periods are spent using a PC or a smartphone. To date, the most reliable and updated assessment instrument is the Smartphone Addiction Scale (SAS, Kwon et al., 2013). Diagnoses associated with IAD are anxiety, mood disorders, and impulse control disorders. IAD occurs more frequently in individuals with low self-esteem, social difficulties, notable interpersonal sensitivity, obsessive thinking modalities, compulsive behaviors and/or personalities tending to social withdrawal (Cash et al., 2012; for a theoretical framework on molecular underpinnings of IAD, see Montag et al., 2016).

IAD can be particularly disturbing in adolescents and it is basically related to social aspects: it can be better labeled as "cyber-presence." Studying 1,500 adolescents, between 14 and 24 years old, the Royal Society for Public Health (2017) has identified the following symptoms: anxiety and depressive states, lack of sleep, obsession related to how appearing, cyberbullying, and a new phenomenon, the "fear of missing out". The central issues shared by embodied and psychodynamic approaches suggest four possible thematic cores:

– *Environment*: IAD is a post-modernity disease (Valleur and Matysiak, 2004) characterized by a multiform group of disorders in which the object is a lawful and socially accepted-encouraged activity. Both the constant connection and the continuous social pressure towards certain models push to conform to an ideal that is not only aesthetic but also emotional: the specific environment can affect the spread of IAD.
– *Drives, instincts, and unconscious conflicts*: immediate gratification is allowed by the continuous accessibility of the network; in the long term this gratification is often accompanied

by subsequent negative effects (Marlatt et al., 1988; Lee et al., 2008; for the assessment see Hoerger et al., 2011). It is interesting that elements of orality (analogously with the oral stage fixation present in some EDs) can be identified in IAD: they result from the ability of the eyes to ingest the images more easily than the mouth can do with food (Rapaggi, personal communication).
– *Intersubjectivity*: the strongest component of the "selfie" (i.e., a photograph that one takes of herself, typically taken with a smartphone and shared *via* social media) is its inner contradiction. What might seem a clear act of narcissism hides strong insecurity and deep anxiety of reassurance, which apparently can only be satisfied by others' approval, the "likes". Nevertheless, far from calming the neurosis, publishing a selfie only amplifies it (Diefenbach and Christoforakos, 2017). These adolescents are characterized by a loss of interest for actual friendship and/or affective offline sharing; thus, the social network is no longer an instrument, but it appears as the final gratification goal.
– *Perception of the body*: the social network allows a high (illusory) level of control over one's body image (e.g., on Instagram, the body becomes the one photographed and shared), as well as over emotions and relational contexts to be shown to "online others". The selection and photoshopping of the bodily image allow to obtain a broad consensus: the success is quantifiable in the number of "likes".

The *environment* and the (not) felt body, as well as bodily control (the repression of *drives* and *unconscious conflicts*), do have a crucial role also in EDs. These disorders, although well known, in recent years have reached a transversal distribution: they no longer involve only young women. In anorexia nervosa (AN), the control over the (weight of) own body is realized through stoic restrictions in the quantity (and often the variety) of ingested food. Success is measured through the balance needle and the visual comparison with the mirror. As IAD, AN is also characterized by *interpersonal* social difficulties (Cardi et al., 2018), *body misperception* (Linardon et al., 2018), and problematic sexual functioning (Castellini et al., 2012). Hypothesizing that AN is associated with reduced perceived pleasantness during social interactions, Crucianelli et al. (2016) examined the perception of interpersonal affective touch: tactile optimal touch (3 cm/s) elicited significantly lower pleasantness in patients than in healthy controls. Remarkably, cultural and social factors, that is, the *environment*, can affect the variability of EDs symptoms and their diffusion (e.g., orthorexia, a new disorder more common among the male than female population). As to possible relations between IAD and EDs, in a recent work Rodgers et al. (2013) found that for both males and females the avoidance of body image is associated with social network addiction: for females, IAD and avoidance of body image are predictors of EDs.

WHY ADOPT PSYCHOANALYTIC PSYCHODRAMA?

The Body I Show, The Body I Feed

In both IAD and EDs, the body is not lived-felt, but rather it is conceived as an instrument: a shape to be photoshopped (IAD) or to be weighted (EDs), in any case a thing to be "fixed" before delivering it to the (virtual) others (IAD), or to the mirror (EDs). In this painful game, there is no space for the actual others and the actual relationships. While behavioral-cognitivist therapies cope with these disorders by focusing on the symptom, the psychoanalytic treatment traces back to the symptom's affective matrix. Consistently with embodied approaches, it does not conceive the body in an objectifying dimension, but as "the body that I am", thus rejecting the Cartesian dualism mind-body (Merleau-Ponty, 1945; Husserl, 1952). The body is seen in its entirety: not only as a perceptual and motor system, but also as a set of needs and desires (often to be unmasked). Thus, the body is present in every stage of the psychoanalytic path: for example, during the diagnosis the body is interrogated to trace the root of the symptom and/or its symbolic meaning. Triggering and perpetuating factors of EDs are often related to the relationship with one's own body and sexuality: an objectified body in which the subject does not recognize herself, thus a body that she avoids. It is no coincidence that EDs, such as IAD, though transversal, have great incidence in adolescence, when the body quickly changes and the internal pressures-drives are as pressing as they are unknown. Synchronic and diachronic aspects of the self are crucial to understand these disorders' symptoms in light of the attachment functioning, from infancy to adolescence (Amianto et al., 2016). Actually many other "contemporary obsessions" revolve around the body and the (fictitious) need for its control. Consistently, in last years professional roles promising to teach how to exercise the best control over the body are exponentially spreading (e.g., beauticians, personal trainers, and nutritionists). Of course, the bodily self, encompassing instinctual, social and affective components, cannot be grasped by these approaches.

Language in the Talking versus the Acting Cure

For psychoanalysis language is fundamental: the talking cure is enabled by intentional and affective attunement established within the analytic setting through the flow of words (Gallese et al., 2007; see also Cimatti, 2016). This affective attunement closely resembles how mother and baby perceive each other's emotional state (Emde, 1988a,b; for an overview on psychoanalytic infant research, see Beebe, 2018).

Embodied evidence has shown how language understanding activates motor simulations, but recent theoretical proposals have also highlighted how words are not only the "recording" of our past experiences, but they can be conceived also as instruments that allow us to perform actions in the external world (Borghi et al., 2013; Scorolli et al., 2016; Borghi et al., 2017). Moreover, through internalized language we can speak to ourselves, supporting our thought processes (Borghi et al., 2017). If words are (social) tools, within a clinical setting it is legitimate to expect possible conflicts between the *self instantiated by language*, in its symbolic, reflective, and narrative aspects, and the *bodily self*, emerging from interpersonal relations (Fotopoulou and Tsakiris, 2017). Words seem to originate from communicative gestures (Corballis, 2002; Arbib, 2005), but

during the development (i.e., in the course of a progressive abstraction-symbolization process), they can go far away from authentic-spontaneous actions, becoming the most perfect tool of rationalization and intellectualization (i.e., defense mechanisms). Thus a tool that allows combining symbols/events in a logical way but that fails when dealing with unconscious conflicts, the "noisy frictions." Frictions that the logic and the hic et nunc boundaries cannot grasp.

The Original Method and Its Analytic Reframing

For these reasons, an action method seems more suitable to shed new light on the unique total self. *Psychodrama*, conceived and developed by Moreno (1937, 1946, 1951; see also Apter, 2003), employs guided dramatic action to examine various issues raised by the individual (the *Protagonist*). The techniques used are intrinsically social and affective; the key ones are: *doubling, role reversal, mirroring, soliloquy, and symbolized role playing* (for details, see the section on Specificities of Psychoanalytic Psychodrama). Through the action on stage, psychodrama enables past, present, and future life events to be explored. Problems and their possible solutions are enacted rather than just talked about.

Psychodrama, unlike classical psychoanalytic therapy, gives space to the body in action, together with the acting bodies of the others. The *Auxiliary Egos* are participants from the audience taking part to the play in order to enact the specific scene. Psychodrama's powerfulness has to be found in the spontaneous emergence of possible (unconscious) conflicts between verbal and bodily messages. The glaring example is the one of a patient playing on stage and saying to the chosen auxiliary ego "I love you" while stepping back, thus expressing proximity by words, but acting a distance through the body. When the word is "detached" from the body, psychodrama allows the patient to feel this distance, which cannot be effectively grasped in the talking cure. This distance can be brought to consciousness and even measured on stage. The "talking phase" comes after the drama, i.e., offstage: in this final phase, conscious logical thinking is gradually re-integrated. This phase, the *interpretation* proper, characterizes *Psychoanalytic Psychodrama* with respect to its classical counterpart. Psychoanalytic psychodrama had different definitions across years (see Lemoine and Lemoine, 1972; Jeammet and Kestemberg, 1987). The form to which I am referring to is the therapeutic approach suitable for dealing with the core role of the acting-sentient bodily self in a dynamic-social and affective environment. It is characterized by the spontaneous re-enactment of a socially and physically constrained experience actualized by means of auxiliary egos, in a fixed, intimate and trusted group.

Psychodramatic action can portray events already happened, but also reconstructed dreams, fantasies, or future events (planned or just imagined). The play unveils as a real event, allowing homeostatic and emotional-social affects (i.e., drives and instincts: id's signature; Solms, 2017a) to be re-experienced by the protagonist in a safe scenario. The core role of the director-psychoanalyst consists in smoothly tracing back the current simulation to the motivated, and constrained, early proximities and interactions. Early interpersonal relations with significant others account for current ones: such early experiences shaped "the constitution of the minimal self, including the progressive sophistication of mental distinctions between 'subject-object,' 'self-other' and even 'pleasure-pain'" (Fotopoulou and Tsakiris, 2017, p. 7).

Differently from classical psychodrama, this knowledge method does not have a merely cathartic function. Even if using similar action techniques, it stands out for three main reasons: (a) acted loops (repetition compulsion) are traced back to the source (i.e., the relationships with significant others) directly on stage; (b) instead of listening to words at the expense of the body (i.e., reflective and narrative self), psychoanalytic psychodrama encourages embodied interactions in a given environment, as well as social and affective touch (i.e., proximal intersubjectivity and shared interoception: Fotopoulou and Tsakiris, 2017; von Mohr et al., 2017); (c) at the end of the acted drama, the psychoanalyst (linguistically) delivers the interpretation suggested by the previous action, through retrieving embedded words. Thus, words "follow" the body, rather than constraining its intimate-relational-affective dimension: "the mind is there to serve the body's needs in a given environment" Fotopoulou and Tsakiris, 2017, p. 9). Importantly, the psychoanalyst never provides "instructions," neither answers: the point is not replacing the old-wrong behavior with a new-right one, but bringing to consciousness the affective, and adaptive, meaning of the current behavior.

To instantiate the converging issues of embodied and psychodynamic approaches, four thematic cores have been addressed with respect to novel and widespread disorders (IAD), in parallel with already well-known disorders which are taking different context-specific facets (EDs). For the sake of completeness, it is worth noting that several other suffering conditions can benefit from psychoanalytic psychodrama treatment, for example, mood disorders, depression, anxiety, psychosomatic disorders (Dayton, 2006), as well as post-traumatic stress disorders, and grief issues, associated with addiction or related to traumas triggered by many causes (ranging from divorce to death of a loved one, Dayton, 2005).

Embodied Simulation: Traditional Psychoanalysis and Psychoanalytic Psychodrama

As outlined in the sections dealing with unconscious and verbal communication, traditional psychoanalytic approaches already foresee convergences with "embodied" constructs. Below I further address the connections between psychodynamic and embodied cognition referring to the mechanism of embodied simulation, to finally highlight the intrinsic relation of psychoanalytic psychodrama with embodied theories. The neurophysiological foundation for simulation theories was provided by the discovery of the mirror neurons (di Pellegrino et al., 1992). In order to be visually triggered, these neurons require an interaction between the agent of the action and the object of it (Gallese et al., 2006), thus forming a system for matching observation and execution of motor actions. The homology between macaque

monkey F5 neurons and human Broca's region suggested that the development of the lateral verbal communication system in humans derives from a more ancient communication system based on recognition of hand and face gestures (Rizzolatti et al., 1996; see also Gallese et al., 2004). Consistently mirroring phenomena have also been shown in relation to semantic aspects of language: the same motor areas are recruited when a person is understanding action sentences or actually performing the action (e.g., Buccino et al., 2005; Borghi and Scorolli, 2009; Scorolli et al., 2009). Importantly, evidence of parallel neural responses in speaker and listener talking does have crucial implications for psychoanalysis, since it unfolds through verbal communication, which conceivably constitutes the basis for unconscious communication (Gallese, 2009).

A substantial impact on the scrutiny of the neural underpinnings of social behavior comes from findings showing the critical role of internally generated somatosensory representations in recognizing the other's emotional state conveyed by facial expression (Adolphs et al., 2000; Adolphs, 2003). Mirroring mechanisms and emotional resonance have been variously underlined across different psychoanalytic concepts: projective identification (Klein, 1946), emotional attunement (Stern, 1985), empathic understanding (Kohut, 2010), mirror role of the mother (Winnicott, 1971), and containing "digesting" mind (Bion, 1962). Nonetheless in classical psychoanalysis the interpersonal emotional exchange between patient and therapist basically occurs through verbal communication, thus in principle it cannot exploit visually conveyed messages. The psychoanalyst resonates to the emotions linguistically expressed by the patient. In a recent work attempting to integrate cognitive behavioral theories, embodied simulations, and psychoanalysis for the treatment of post-traumatic stress disorder, Peri et al. (2015) emphasized the importance of having a therapist present in face-to-face contact.

To sum up, embodied simulation does undoubtedly have crucial implications for classical psychoanalytic approaches: Gallese et al. (2007) even suggested possible neural underpinnings of different psychoanalytic concepts, as the ones of unconscious communication, projective identification, empathic understanding, and therapeutic process. However, the idea that the present work intends to propose is that the psychoanalytic psychodrama, compared to the most classical psychodynamic approaches, allows to better emphasize the common ground between embodied cognition and psychoanalysis, by means of the spontaneous re-enactment of the bodily self in the effective intersubjective interaction with the auxiliary egos. The dramatization facilitates the shifting of the focus on somatic sensations through the first-person experience to be touched, intimately related to the interpersonal dimension (Gallese, 2003, 2005; Keysers et al., 2004; Blakemore et al., 2005; Ebisch et al., 2016). For instance, the possibility to re-experience our own tactile sensations, and to experience the ones of the other (through the *role reversal*), allows to reflect upon bodily conveyed messages that we are not always aware of. Furthermore, re-enacting a scene in a safe-controlled environment allows to suspend acting for pauses and *soliloquies*. Paced by the therapist, soliloquy allows the patient to be led to greater sensitivity to bodily interoceptive signals (Critchley and Garfinkel, 2017), to eventually analyze the responses to one's own/other's sensations (e.g., fight or flight, or freezing reactions), disentangling their spontaneous components from the socially learned ones. Crucial in this respect is the evidence of automatic embodiment in the observer's motor system of the sensory qualities of others' pain (Avenanti et al., 2005). Another peculiar aspect of the psychodramatic method is the way in which it deals with *projection*, i.e., the archaic and primitive defense mechanism that consists in moving feelings, characteristics, or parts of oneself onto other objects or people. The stage and the auxiliary egos provide a different physical and social context from the one to which the person is accustomed. Acting/re-acting in a novel environment is less constrained by previous associations: this fosters the occurence of spontaneous responses and re-emerging of deep (unconditioned) desires and motivations. Projection mechanisms are progressively unmasked. Finally, psychoanalytic psychodrama allows the subject to really experience, in a protected setting, how much her own slight changes in responding to the same requests can determine an effective change of the current situation. The chronical repetition of events often depends on acquired dysfunctional responses to social environment, as well as on erroneous attributions of desires, motivations, and intentions to others. The repetition compulsion is characterized by circumstances that seem to repeat themselves, over and over again, *beyond subjective agency*: the acting cure seems more effective than the talking cure in dealing with it. In the acting cure, the new adaptation emerges spontaneously, disanchoring the individual from her acquired and rationalized responses. The sensory-motor and affective experience on stage provides the patient with a tangible evidence on the potentiality of her action, that is on the efficacy and persistence of her agency.

Body-Oriented Therapies and Psychoanalytic Psychodrama

Before addressing the specificities of psychoanalytic psychodrama, along with its original techniques, it is worth examining other body-oriented therapies. Indeed, from a clinical point of view the idea that the body can record, recall, and fix what a disembodied mind represses and loses is not completely original. Other psychoanalytic and non-psychoanalytic methods call upon the body. Let us think to Gestalt therapy or to the various body-oriented psychotherapies. Psychoanalytic psychodrama is not "superior" to these other treatments, not even in contrast to them, although distinguishable by its specificities.

The concept of creative adaptation aligns the theoretical elaborations of Perls (1969) and Moreno (1946; Moreno and Moreno, 1969). Gestalt psychotherapy emphasizes the balance between adaptation and creativity, typical of spontaneous contact processes. Psychodrama underlines the different roles that constitute the individual, to make them less rigid, more suitable and effective in relation to the context, in order to progressively detach them from the influences of significant others. Therefore, both models share the final purpose of enhancing the possibilities of adaptation to the environment. This commonality of objectives derives from the fact that

both Moreno and Perls move from a relational anthropological perspective: the development of the individual depends on how she interacts with her living context. While Moreno believes that the self emerges from the roles and that the crystallization of them determines a loss of spontaneity and the inability of creative adaptations, for Perls the psychic functioning is determined by the type of relationship that the individual has with her internal and external environment. Consistently a Gestalt technique is the one of the "empty chair": the client sits next to the therapist, in front of an empty chair. She can project on the chair a person of real life, an emotional aspect of the self, or even an imaginary character. Thus, she can talk to whom is not in front of her eyes, but present as a fantasy: an internal representation. Entering into the relationship (i.e., the actual experience of feeling) should transform the individual's internal perception of traumatically distorted relationships, to lastly get in touch with her actual needs. As in the case of psychodrama, the therapeutic intervention does not aim to modify the external situation but rather to reshape its misrepresentation. If projecting emotions onto an empty chair is certainly effective, the actual interaction with another sentient self (in the psychodramatic form, the auxiliary ego), which in turn reacts spontaneously to our verbal and bodily messages, greatly improves the intensity and extent of the exploration, and the powerfulness of the experience (Yablonsky, 1976). Indeed, Gestalt therapy often uses elements similar to the ones of psychodrama (e.g., role reversal), but with a critical difference: in Gestalt clinical approaches, the roles are all played by the patient (or, in the role reversal, by the empty chair), not by other people. Since these roles are all conceived only as projections of the self, there is no need for someone else to actually be there; but this choice refrains from exposing the individual to the unpredictability of the other. Finally, in Gestalt therapy, the group can only identify itself as an observer, never as a participant, while in psychodrama the members of the group experience a deep sense of involvement by interpreting auxiliary and double egos (Rapaggi, 2008).

Among the body-oriented psychotherapy, we could also include other forms of therapies: bioenergetic analysis, revolving around the Reichian idea of "character armor" (muscular tensions reflecting repressed emotion: Reich, 1945; Lowen, 1975); psychosomatic practice, with its holistic approach to patient management, encompassing psychosocial factors (Fava et al., 2017); different kinds of group psychotherapy (e.g., Schermer, 2010); massage therapy, gaining popularity as complementary to medical treatment (Moyer et al., 2004); mindfulness, aimed at reducing cognitive vulnerability to stress and emotional distress (Bishop et al., 2004; Bedford, 2012); and new clinical approaches that integrate bodily and psychological aspects as, for instance, neo-functionalism (Ottoboni, 2013). While acknowledging the important clinical value and theoretical interest of these approaches, psychoanalytic psychodrama differs from all of them not only for its extreme flexibility but also for the following distinctive aspects: the individual on stage is permanently an *active* subject; on stage, the subject does have the opportunity of *directly* experiencing that the change is achieved through a shift in physical-psychological perspective; her own actions' reshaping allows to break through immutable dynamics. Finally, on stage the physical-tangible *symptom* falls into the background, to be then called back in the analysis of its symbolic *meaning* and its "*usefulness*" in legitimizing the suffering of the patient (Jung, 1938). It is worth noting that this relationally oriented approach not only fosters a full mind-body integration but allows the patient to resolve the past and to visit *her future*. Conceptualizing, planning for, and moving towards the future in a realistic manner can be critical for some suffering conditions as, for instance, post-traumatic stress disorders (Dayton, 2006).

Specificities of Psychoanalytic Psychodrama

After clarifying to what extent more traditional psychoanalytic theorizations already enable to grasp the connection between psychodynamic and embodied cognition, below I summarize the specificities of the psychoanalytic psychodrama with respect to embodied cognition and classical talking cure:

– *Somatization*. Despite the contemporary general "de-somatization" of psychoanalytic models (Fonagy, 2008), psychoanalytic treatment should actually remain a path throughout the history of the subject's life, back to early infancy (Bazan, 2018), i.e., a stage in which drives and instincts cannot be represented/encoded/conveyed/unveiled by language. The talking cure inevitably shifts the attention on symbolic, "meaning-based", mentalistic components of the self (Fotopoulou and Tsakiris, 2017), leaving the body "in the waiting room of the therapist's office" (Conger, 1994, p. 211). Even when keeping out the components of warmth and intimacy that characterize the relationships with caregivers ("attachment"; Bowlby, 1969), action methods prioritize the rooting and structuring of the self in embodied and enacted experiences. At a very basic level, when the protagonist has to place different auxiliary egos on stage, deciding the specific distance one's from each other, she re-experiences physical proximity and brings her attention to the social messages conveyed by this distance. This experience should affect also the sense of body: body boundaries are not only flexibly modified by tool use (Tessari et al., 2010), but they are also affected by social interacting, as suggested by the analysis of IAD and EDs.

– *Embodied vs. narrative self*. Embodied simulations occur when we process language, when we perceive a visual scene, and even when we imagine doing or perceiving something, since both real action and mental motor imagery activate a common network of cortical and subcortical motor centers (for an analysis on embodied narratology, see Wojciehowski and Gallese, 2011). Evidence has also shown that the simulation shaped during language processing reflects the real interrelations between our body and external referents, suggesting that the simulation triggered by language is quite precise (Ambrosini et al., 2012). The analyst's full listening can benefit from the resulting empathy. Nevertheless, if we create our own experience through our actions, if what we experience is shaped by how we act (enactive view, Varela et al., 1991; Noë, 2004), attention should be first paid to the embodied self. By using specific action techniques, and/or restructuring the scene (in a more or less symbolized

way), within psychodrama the sentient subject gradually emerges. Unspoken/unspeakable feelings pop up on stage. Interestingly silence is also taken into account. In contrast to silences that indicate awkwardness or distraction, "connectional silence" points to reflective suspensions or to mixed and ambiguous emotions. While clinical research is exploring pauses within speaking turns (Bartels et al., 2016; Durieux et al., 2018; Hill et al., 2018; Visser et al., 2019), in the embodied view not enough attention has been paid to communicative silence, which can convey social intentions and requests.

– *Rationalized words vs. spontaneous body.* Evidence on embodied simulation triggered by observing others challenged the notion that interpersonal understanding consists solely of our explicitly attributing propositional attitudes to others. Indeed, embodied simulations create (within the observer) internal non-linguistic representations of the body states associated with actions, emotions, and sensations (embodied empathic inference, e.g., Avenanti et al., 2005). Consistently when the psychoanalyst (as well as the auxiliary ego) observes the play, she maps the protagonist's actions onto her own motor system and the protagonist's emotions onto her own visceromotor and somatosensory systems (Gallese and Sinigaglia, 2011).

However, in the psychodramatic scene, the observer is also a listener. Embodied proposals have suggested to conceive words also in their social and public aspects (i.e., instruments for action) and speaking as performing actions in coordination with someone else (Clark, 1996; Borghi et al., 2013; Scorolli et al., 2016; Borghi et al., 2017). Interestingly, the instrument "word" can detach from the body. It happens because the sentient individual is not "a cognitive harmony": homeostatic and social affects can conflict with our internalized moral standards and ideals. That is, the bodily self can conflict with the self emerging from reasonable prohibitions and rational aspirations (i.e., the Freudian superego), which are mainly instantiated by language. The phenomenological counterpart of the inner dynamic friction is the action/word conflict. The meaning conveyed by language can conflict with the one conveyed by action, as it dramatically emerges on stage (e.g., the verbally conveyed message "I do not trust you" while physically approaching the auxiliary ego, thus acting a proximity despite the distance expressed by the words). If language is a tool, probably it is also the best tool for intellectualization and rationalization (as to defense mechanisms, see Freud, 1936), i.e., a tool at the service of the reflective and narrative aspects of the self. When on stage (but not necessarily on the psychoanalytic couch), if forced to choose between two conflicting messages, we choose the one conveyed by the "unrationalized–unrationalizable" bodily self.

– *Role reversal*. The protagonist becomes aware of her actual-effective messages mainly through a powerful technique of psychodrama: role reversal (Yablonsky, 1976; Blatner and Blatner, 1988; Holmes and Karp, 1990). That is, the auxiliary ego roles into the protagonist position, re-enacting her actions, and verbal messages. Symmetrically, the protagonist roles into the significant other position and enacts that role, experiencing possible inconsistencies between the mentalized messages and the bodily conveyed ones. Thus, the protagonist looks at herself not just as if in a mirror: the role reversal favors the unveiling of protagonist's intrapersonal conflicts. Furthermore, this technique allows the protagonist to gain an in-depth understanding of the other, of her intimate affects together with her implicit social pressure (let us think about a student rolling into the teacher position). Embodied evidence has demonstrated the motor effects of changing physical, social, and linguistic perspective (Gianelli et al., 2013): psychodrama shows also the affective effects of preventing the individual from being stuck in her own viewpoint (for a review on the interplay between spatial and social spheres, see Proulx et al., 2016). This technique favors transcending the limitations of egocentricity and prevents the protagonist from being trapped in her own defenses. During the action on stage, also the observing audience gets a deeper understanding of the human dynamic interactions.

For the sake of brevity, I will not address other techniques, such as mirroring (the protagonist looks at the scene re-enacted only by auxiliary egos, thus without participating in the scene, but observing herself from outside), soliloquy (the protagonist expresses her thoughts and feelings aloud), and symbolized role playing, in which the director chooses an object, or an auxiliary ego, to portray a specific emotion/symptom/addiction (e.g., an addition can be portrayed by a tug-of-war with the auxiliary ego; see Rapaggi, 2008). Future events can be enacted too, still in a constrained environment: this further differentiates psychodrama from pure imaginative techniques, drawing it near to virtual reality methodologies (e.g., Parsons et al., 2017).

– *Doubling*. In the technique of doubling, a person from the audience goes into the scene, puts a hand on the shoulder of the protagonist, and expresses a message in her shoes. The double gives voice to the unspeakable emotions of the protagonist. (The auxiliary egos cannot double the protagonist as they are already enacting an affective role in the scene.) She can also perform what the protagonist is unable to do (e.g., expressing anger physically). By touching the protagonist's shoulder, the double establishes physical proximity and contact, as an extension of the protagonist's body-mind. The double ego attempts to make conscious unexpressed materials. Both her verbal and physical intervention are often disowned by the protagonist: this resistance is discussed in the interpretative final phase. In the "choral doubling" all the people from the audience, one by one, double the protagonist, prompting more than one view. The evoked feelings and/or creative solutions allow an emotional and cognitive restructuring of the scene.

The double, and the members of the group as well, must refrain from both judging behaviors and suggesting interpretations. When the scene is over, the audience can share evoked events/feelings. Only the psychoanalyst is entitled to suggest hypotheses on unconscious conflicts (for a recent discussion of interpretation in psychoanalysis, see Kernberg, 2016). Remarkably, transference is better handled through the psychodramatic techniques. Symmetrically, the analysis of countertransference (i.e., the analyst's affective reaction activated by the patient's materials) takes advantages of the right emotional

distance allowed by the continuous distributed reallocation of engaging emotions. Still maintaining the necessary affective resonance, this setting outdistances the analyst from taking part in the patient's internal conflicts and from influencing the patient with her own value systems ("technical neutrality").

The points sketched above suggest that psychoanalytic psychodrama can reconcile embodied and psychoanalytic approaches through the spontaneous actual re-enactment of significant relationships. In this sense, this method represents a turning point with respect to traditional verbal psychoanalysis: by prioritizing early reciprocal interactions and emotional engagements, it allows to explore the original interpersonal constitution of the self, by actually conceiving the self as rooted in and structured by embodied and enacted experiences (Fotopoulou and Tsakiris, 2017). For instance, as far as IAD and EDs are concerned, this method *immediately* leads the attention to "the body that I am", thus on muscles tensions, somatic resistance (Lowen, 1969), homeostatic affects (drives) and emotional social affects (instincts) (Wright and Panksepp, 2012; Solms, 2017a,b). The other on stage allows to re-experience recursive loops in a safe setting and through different perspectives, coming back into contact with authentic needs. A mask can still be used (cf. photoshopped picture in IAD), but then it is removed. The only mirror on stage is the other (cf. EDs and AN), which gives back to the protagonist a complex image of her lived/living body. The gradual re-structuring of the scene allows an actual nutritive experience. Differently from the cyber space (cf. IAD), all the emotions are accepted and not censored (e.g., not only joy but also sadness). Finally, the word (rationality), abused in social networks, is downgraded: if it conflicts with the action, action is what the person trusts.

POSSIBLE INTEGRATION WITH ECOLOGICAL CONNECTIONIST MODELS AND ROBOTICS

The psychodramatic approach is not far from ecological connectionist approaches. These relatively new proposals conceive the neural network as a model of the nervous system of an organism living in a certain environment. This environment is both natural and social, as it contains other organisms with which the (artificial) organism interacts (Cangelosi et al., 2010). In these distributed models a psychological entity (e.g., a concept, a word, a perceived object or its property) is not represented by a single unit, as in localist models, but by a particular pattern of activation of a set of units, thus different entities can be represented by different patterns of activation of the same units. Psychotherapy can be conceived as a sensorial input to the neural network, which, unlike psychotropic drugs, acts in a specific way and does have different effects depending on the specific individual. The current weights of the network can be conceived as the result of all past experiences and learning: the treatment should remove the root causes of the patient's discomfort by modifying a specific set of weights. Resulting changes in "patient's network" should be slower but long lasting (Parisi, 1989). In the case of an action method, the input would be not only verbal but also motoric, thus enhancing accumulation of experience.

Interestingly, simulations of a certain learning with neural networks allow to investigate the stages through which that learning is achieved, without the need to postulate the existence of rules (Rumelhart and McClelland, 1986; Plunkett and Marchmann, 1991). In contrast to cognitive-behavioral view, the change (the new adaptive behavior) would not be subordinate to the discovery and the incorporation of rules. With regard to the ecological approach, further possible advantages can be identified in the adoption of an action-based group therapy: the organism is examined in conjunction with its natural and social environment. In a similar vein, recent work in robotics underlines the need for new robots to be equipped with mechanisms of neural and perceptual readiness (Cangelosi and Schlesinger, 2015) but also with "affects" mediating and regulating the sensorimotor behaviors (Zhong et al., 2016). Testing these robots would allow a breakthrough on developmental models, providing crucial hints on the developmental stages of affective subjectivity, to finally scrutinize the interplay between the adaptive brain, the growing body, the responsive social context, and the physical environment (Belpaeme et al., 2016).

CONCLUSIONS AND OUTLOOK

Traditionally far away from each other, in very last years the "poorly evidence-based" psychoanalysis and the "censored" cognitive neuroscience are making a common effort towards a possible dialogue. On the cognitive-neuroscientific side, embodied cognition seems inherently suitable to achieve this fruitful and effective dialogue as it lays its foundations on concepts intrinsically shared with psychoanalytic approaches.

Across the present work, these shared constructs are sketched in relation to recent contemporary disorders, IAD and EDs, to finally introduce a therapeutic method suitable to approach the acting-sentient bodily self in a dynamic-social and affective environment. Psychoanalytic psychodrama copes with the spontaneous re-enactment of an actual (socially and physically constrained) experience, actualized by means of auxiliary egos. Drives and instincts can be re-experienced by the protagonist in a safe scenario. The psychotherapist is a "listener" and an "observer", and also the director: she gradually restructures the play to trace it back to the early reciprocal interactions with significant others, as well as to motivations often in conflict with each other. Unspoken/unspeakable feelings pop up on stage. The strength of this method mainly rests on re-establishing the priority of the embodied social nature of the multifaceted self, eclipsed by the classical talking cure.

Psychoanalytic psychodrama is basically aimed for clinical treatment, but it can provide interesting hints on embodied neuro-cognitive exploration for the following reasons:

– It actualizes embodied theoretical proposals, particularly the ones addressing the bodily self, intersubjectivity, affective

quality of verbal and bodily communication, and egocentric/allocentric spatial reference framing, to gradually approach the social-affective realm.

– Psychoanalytic psychodrama puts forward an in-depth investigation of certain concepts, typically neglected by neuroscience, as the ones of internalized moral standards and ideals (Freudian superego) and unconscious conflicts.

– Regarding language, this method puts the accent on social communication, thus on the non-referential aspects of verbal messages. Even more, it emphasizes the "defensive" use of language. This defensive use, aimed at re-establishing a cognitive balance thorough a non-authentic narrative self, is unmasked on stage.

– Through the recursive use of explicit processes of symbolization, psychoanalytic psychodrama handles psychosomatic symptoms by reframing them in a complex affective structure, where to recognize instincts' sources, aims, and objects (Freud, 1915a).

– From a theoretical and methodological point of view, this technique provides insights into the activation of motor simulation in an ecological context. In recent years, interesting work has been conducted on social cognition. Pioneering research has shown that newborns come into the world wired to socially interact (Castiello et al., 2010) and that is possible to quantify the specific contribution of direct gaze and kinematic information on subjective involvement during interactions (Betti et al., 2018). Moreover, the problem of direct social perception has been reframed in terms of establishing a measurable relationship between movement features and perceived mental states (Becchio et al., 2018). The study of different contexts has highlighted a large increase of self-other integration in divergent-thinking contexts over convergent-thinking ones (Colzato et al., 2016). As far as motor resonance is concerned, a subject of discussion is whether, in some contexts, mirroring the observed action can be disadvantageous, as when we have to perform a joint action. Both physical and social cues affording non-identical complementary actions have been identified (Sartori et al., 2012; Scorolli et al., 2014, 2018; Sacheli et al., 2015; Vesper et al., 2017), but little is yet known about actions and contexts affectively connoted (Bastiaansen et al., 2009; Kuhbandner et al., 2010; Costantini and Ferri, 2013; Lowe et al., 2016; on group membership, see Iani et al., 2011; on motivations for joint actions, see Godman, 2013). Through a specific re-framing or re-adaptation of psychodramatic method, these challenging issues seem feasible to be tackled.

– The acted scene can lead to disentangle the bodily self and the social product of its development, making explicit the individual's navigation across the internal conflicts. The "social product" of the self-development is affected by the specific environment the individual has had to deal with. The environment may have been more or less responsive to her requests, more or less conflicting with her biological drives and her own personality traits (Scalabrini et al., 2018). The social role is specifically addressed by sociodrama (Moreno, 1934; Rapaggi, 2008), but psychodrama also offers the opportunity to study its impact on the bodily self.

– So far embodied cognition has been mainly focused on investigating the role of sensorimotor system in activating existing repertoires of knowledge: not enough attention has been paid on how body-mind linkages do influence processes of knowledge generation. Some interesting attempts have been fostered by using embodying metaphors to give rise to novel ideas (Leung et al., 2012), or by focusing on measures of creativity assessing both convergent and divergent thinking (Simonton, 2003; Cheng et al., 2008; Kuo and Yeh, 2017). Data converge in suggesting that creativity implicating physical acts does activate processes involved in overcoming mental fixedness, facilitating the psychological process of creative problem solving. Psychoanalytic psychodrama does have lots of potentialities to explore these new perspectives, testing how embodied representations can enlarge existing repertoires of knowledge and/or trigger cognitive processes necessary for generating creative solutions.

To conclude, recent advances in brain connectivity research are providing evidence supporting the convergence of neuroscientific findings and psychoanalysis, emphasizing how this knowledge can impact the "Neuropsychoanalysis" (e.g., Salone et al., 2016). Neuroscientific data often enhance our descriptive knowledge, without substantially improving our understanding of brain functions (Kotchoubey et al., 2016): the atomistic reduction can be overcome through a common effort of both these disciplines. There are excellent premises for a future productive exchange between embodied neuroscientific approaches and psychoanalytic ones: first of all, the common aim should be to integrate the affective and the cognitive aspects of conscious and unconscious mental processes. Mainstream cognitive neuroscience has classically coped with the issue of consciousness focusing on "exteroceptive" objectified forms of consciousness, especially visual consciousness (Solms, 2013, 2014). By considering human subjective experience as the result of higher order cortical processes, the "corticocognitive anthropocentrism" has prevented from considering that having a subjective experience does not necessarily correspond to the fact of being self-aware of such an experience (Alcaro et al., 2017). Both embodied cognition and psychoanalysis recognize and aim to investigate the existence of subjective experiences without self-awareness.

The *cognitive* unconscious and the *psychoanalytic* unconscious still appear to differ. The psychoanalytic (dynamic) unconscious, i.e., a boiling cauldron of impulses and desires, presupposes forces (whose nature is linked to unconscious motivations) that determine the passage of mental contents from the conscious state to the unconscious one, and vice-versa. By cognitive unconscious, instead, it is generally (still) meant the part of mental functioning that is unconscious not because it has been suppressed, but because it has never been known, and therefore, it will never be remembered (neither it would be useful, or therapeutic, to know this part). In the case of the cognitive unconscious, the focus is not on "contents" and emotions, but instead on "processes". We could also claim that the cognitive unconscious is the part of us that we can never remember, neither forget (Migone, 1995, 2001). Actually, some recent constructs are enlightening on this respect: the "phenomenal minimal self" is defined by Northoff (2013) as the pre-reflexive form of subjectivity that presupposes an experience, defined

by certain (pre)conscious qualities, and the implicit sense of being part of such experience. This definition underlines the two necessary and sufficient features of the self: intentionality and conscious sensitivity (Searle, 1991; Alcaro et al., 2017).

For this fruitful dialogue between psychoanalysis and neuroscience to be possible, the theoretical issue to be urgently solved is the agreement on conceptual frameworks through which neuroscientists, psychoanalysts, and philosophers could profitably understand each other. To avoid confusion within the current plethora of psychological constructs (i.e., "core-self," Panksepp, 1998; "proto-self," Damasio, 1999; "total self," Rizzuto, 2008, Gallese, 2009; "phenomenal minimal self," Northoff, 2013; "minimal self," Fotopoulou and Tsakiris, 2017; "affective core-self," Alcaro et al., 2017; "embodied inter-subjectivity," Fotopoulou and Tsakiris, 2017; "minimal affective subjectivity," Solms, 2017a), when defining them it could be valuable to systematically refer to the Freudian second topical of the psychic apparatus (id, ego, superego). By this effort, new shared constructs can come up: they may even challenge the founding psychoanalytic ones (e.g., Solms, 2013), however, it is crucial they are systemic concepts, entailing also the human-environment relation (Solms and Panksepp, 2012; Kotchoubey et al., 2016; Solms, 2017a,b).

To deal with the challenge of a mutually productive interchange between neuroscience and psychoanalysis, we also need to carefully examine suitable methodologies and possible novel paradigms. Techniques based on hemodynamic responses, as functional magnetic resonance imaging (fMRI) and positron-emission tomography (PET), have been critical to investigate the impact of emotions on cognitive processes. It has been showed that the amygdala does have a crucial role in the recollection of emotional and motivational memories (fMRI: Dolcos et al., 2005), and that emotional information enhances visual memory recognition (PET: Taylor et al., 1998). Electrophysiological studies (EEG), in spite of the electroencephalography poor spatial resolution, have also provided interesting evidence, such as showing the amygdala neurons' theta activity (4–8 Hz) during the consolidation of emotional aroused memories (Paré et al., 2002). Nevertheless, the promising technique to be deeply exploited in future research is the functional near-infrared spectroscopy (fNIRS): it allows to investigate cortical responses in face-to-face naturalistic scenarios involving two adult co-actors (Costantini et al., 2013), or infants and their parents (Lloyd-Fox et al., 2015). The advantages of fNIRS encompass non-invasiveness and portability, making this methodology potentially suitable to the psychodramatic setting. Finally, it is noteworthy the current renewed interest for the autonomic nervous system activity: its investigation is feasible through measuring the heart rate variability (extracted from the electrocardiography), the galvanic skin response, and the skin temperature. All these physiological measures, widely used to scrutinize emotions, require fewer sensors (that are often portable), and produce fewer artifacts on respect to EEG. Their use, still suitable to the enacted scene, is particularly promising to investigate the impact of interoception on motivation, emotions, social cognition, and self-awareness.

Beyond linguistic issues and inter-/intra-disciplinary methodological concerns, a framework encompassing embodied proposals and psychoanalytic theorizations should be sketched in a developmental and evolutionary perspective, by integrating philosophical and neuropsychological constructs, and considering ecological connectionist advances. Future interdisciplinary research should embrace action methods, as psychoanalytic psychodrama, since they are suitable candidates to explore the embodiedness and the embeddedness of human beings.

AUTHOR CONTRIBUTIONS

CS is the only author and she developed the article structure, wrote the manuscript, and performed the final editing of the text.

ACKNOWLEDGMENTS

I wish to thank Prof. Anna M. Borghi, Dr. Alfredo Rapaggi, and Dr. Luca Tummolini for their careful comments and valuable exchanges.

REFERENCES

Adolphs, R. (2003). Cognitive neuroscience of human social behavior. *J. Neurosci.* 4, 165–178.

Adolphs, R., Damasio, H., Tranel, D., Cooper, G., and Damasio, A. R. (2000). A role for somatosensory cortices in the visual recognition of emotion as revealed by three-dimensional lesion mapping. *J. Neurosis* 20, 2683–2690.

Alcaro, A., Carta, S., and Panksepp, J. (2017). The affective core of the self: a neuro-archetypical perspective on the foundations of human (and animal) subjectivity. *Front. Psychol.* 8:1424. doi: 10.3389/fpsyg.2017.01424

Ambrosini, E., Scorolli, C., Borghi, A. M., and Costantini, M. (2012). Which body for embodied cognition? Affordance and language within actual and perceived reaching space. *Conscious. Cogn.* 21, 1551–1557. doi: 10.1016/j.concog.2012.06.010

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders*. 5th edn. Washington, DC.

Amianto, F., Northoff, G., Daga, G. A., Fassino, S., and Tasca, G. A. (2016). Is anorexia nervosa a disorder of the self? A psychological approach. *Front. Psychol.* 7:849. doi: 10.3389/fpsyg.2016.00849

Apter, N. (2003). The human being: J.L. Moreno's vision in psychodrama. *Int. J. Psychother.* 8, 31–36. doi: 10.1080/1356908031000124340

Arbib, M. A. (2005). From monkey-like action recognition to human language: an evolutionary framework for neurolinguistics. *Behav. Brain Sci.* 28, 105–167.

Avenanti, A., Bueti, D., Galati, G., and Aglioti, S. M. (2005). Transcranial magnetic stimulation highlights the sensorimotor side of empathy for pain. *Nat. Neurosci.* 8, 955–960. doi: 10.1038/nn1481

Barsalou, L. W. (1999). Perceptual symbol systems. *Behav. Brain Sci.* 22, 577–660.

Bartels, J., Rodenbach, R., Ciesinski, K., Gramling, R., Fiscella, K., and Epstein, R. (2016). Eloquent silences: a musical and lexical analysis of conversation between oncologists and their patients. *Patient Educ. Couns.* 99, 1584–1594.

Bastiaansen, J. A. C. J., Thioux, M., and Keysers, C. (2009). Evidence for mirror systems in emotions. *Philos. Trans. R Soc. B Biol. Sci.* 364, 2391–2404. doi: 10.1098/rstb.2009.0058

Bazan, A. (2018). Psychoanalysis and academia: psychoanalysis at the crossroads between exact and human sciences. *Int. Forum Psychoanal.* 27, 90–97. doi: 10.1080/0803706X.2017.1392040

Becchio, C., Koul, A., Ansuini, C., Bertone, C., and Cavallo, A. (2018). Seeing mental states: an experimental strategy for measuring the observability of other minds. *Phys. Life Rev.* 24, 67–80. doi: 10.1016/j.plrev.2017.10.002

Bedford, F. L. (2012). A perception theory in mind-body medicine: guided imagery and mindful meditation as cross-modal adaptation. *Psychon. Bull. Rev.* 19, 24–45. doi: 10.3758/s13423-011-0166-x

Beebe, B. (2018). "My journey in infant research and psychoanalysis: microanalysis, a social microscope" in *Moments of meeting in psychoanalysis: Interaction and change in the therapeutic encounter. Relational perspectives book series*. ed. S. Lord (New York, NY: Routledge/Taylor & Francis Group), 13–44.

Belpaeme, T., Adams, S., de Greeff, J., di Nuovo, A., Morse, A., and Cangelosi, A. (2016). "Social development of artificial cognition" in *Toward robotic socially believable behaving systems-volume I: Modeling emotions*. eds. A. Esposito and C. J. Lakhmi (Switzerland: Springer International Publishing), pp. 53–72.

Betti, S., Zani, G., Granzio, L. U., Guerra, S., Castiello, U., and Sartori, L. (2018). Look at me: early gaze engagement enhances corticospinal excitability during action observation. *Front. Psychol.* 9:1408. doi: 10.3389/fpsyg.2018.01408

Bijeljac-Babic, R., Höhle, B., and Nazzi, T. (2016). Early prosodic acquisition in bilingual infants: the case of the perceptual trochaic bias. *Front. Psychol.* 7:210. doi: 10.3389/fpsyg.2016.00210

Bion, W. R. (1962). A theory of thinking. *Int. J. Psychoanal.* 43, 306–310. (Reprinted in: E. B. Spillius (ed.), (1988) Melanie Klein Today, Vol. 1, Mainly Theory, London/New York: Routledge. pp. 178–186).

Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. C., Carmody, J., et al. (2004). Mindfulness: a proposed operational definition. *Clin. Psychol.* 11, 230–241. doi: 10.1093/clipsy.bph077

Blakemore, S.-J., Bristow, D., Bird, G., Frith, C., and Ward, J. (2005). Somatosensory activations during the observation of touch and a case of vision-touch synaesthesia. *Brain* 128, 1571–1583.

Blatner, A., and Blatner, A. (1988). *The foundations of psychodrama. History, theory and practice*. New York: Springer Publishing.

Borghi, A. M., and Scorolli, C. (2009). Language comprehension and dominant hand motion simulation. *Hum. Mov. Sci.* 28, 12–27. doi: 10.1016/j.humov.2008.07.002

Borghi, A. M., Scorolli, C., Caligiore, D., Baldassarre, G., and Tummolini, L. (2013). The embodied mind extended: using words as social tools. *Front. Psychol.* 4:214. doi: 10.3389/fpsyg.2013.00214

Borghi, A. M., Binkofski, F., Castelfranchi, C., Cimatti, F., Scorolli, C., and Tummolini, L. (2017). The challenge of abstract concepts. *Psychol. Bull.* 143, 263–292. doi: 10.1037/bul0000089

Borghi, A. M., Barca, L., Binkofski, F., and Tummolini, L. (2018). Varieties of abstract concepts: development, use and representation in the brain. *Philos. Trans. R Soc. B Biol. Sci.* 373. doi: 10.1098/rstb.2017.0121

Borsboom, D., Cramer, A., and Kalis, A. (2018). Brain disorders? Not really… Why network structures block reductionism in psychopathology research. *Behav. Brain Sci.* 1–54. doi: 10.1017/S0140525X17002266

Bowlby, J. (1969). *Attachment. Attachment and loss.* Vol. 1. Loss. New York: Basic Books.

Brown, J. (2014). "Divide and Conquer" or "Murder to Dissect"? Commentary by Jason Brown (New York). *Neuropsychoanalysis* 3, 10–16. doi: 10.1080/15294145.2001.10773327

Brunel, L., Morgado, N., Quesque, F., Zerhouni, O., and Gianelli, C. (2019). Upcoming Frontiers research topic: https://www.frontiersin.org/research-topics/8181/what-is-social-and-embodied-about-situated-embodied-social-cognition-current-issues-and-perspectives#overview

Buccino, G., Riggio, L., Melli, G., Binkofski, F., Gallese, V., and Rizzolatti, G. (2005). Listening to action related sentences modulates the activity of the motor system: a combined TMS and behavioral study. *Cogn. Brain Res.* 24, 355–363.

Cangelosi, A., and Schlesinger, M. (2015). *Developmental robotics: From babies to robots*. Cambridge, MA: MIT Press.

Cangelosi, A., Metta, G., Sagerer, G., Nolfi, S., Nehaniv, C., Fischer, K., et al. (2010). Integration of action and language knowledge: a roadmap for developmental robotics. *IEEE Trans. Auton. Ment. Dev.* 2, 167–195. doi: 10.1109/TAMD.2010.2053034

Cardi, V., Mallorqui-Bague, N., Albano, G., Monteleone, A. M., Fernandez-Aranda, F., and Treasure, J. (2018). Social difficulties as risk and maintaining factors in anorexia nervosa: a mixed-method investigation. *Front. Psychiatr.* 9:12. doi: 10.3389/fpsyt.2018.00012

Caruana, F., and Gallese, V. (2011). Sentire, esprimere, comprendere le emozioni: una nuova prospettiva neuroscientifica. *Sist. Intell.* 2, 223–234. doi: 10.1422/35347

Caruana, F., and Gallese, V. (2012). Overcoming the emotion experience/expression dichotomy. *Behav. Brain Sci.* 35, 145–146. doi: 10.1017/S0140525X11001476

Cash, H., Rae, C. D., Steel, A. H., and Winkler, A. (2012). Internet addiction: a brief summary of research and practice. *Curr. Psychiatr. Rev.* 8, 292–298. doi: 10.2174/157340012803520513

Castellini, G., Lelli, L., Lo Sauro, C., Fioravanti, G., Vignozzi, L., Maggi, M., et al. (2012). Anorectic and bulimic patients suffer from relevant sexual dysfunctions. *J. Sex. Med.* 9, 2590–2599. doi: 10.1111/j.1743-6109.2012.02888.x

Castiello, U., Becchio, C., Zoia, S., Nelini, C., Sartori, L., Blason, L., et al. (2010). Wired to be social: the ontogeny of human interaction. *PLoS One* 5:e13199. doi: 10.1371/journal.pone.0013199

Cheng, C.-Y., Sanchez-Burks, J., and Lee, F. (2008). Connecting the dots within: creative performance and identity integration. *Psychol. Sci.* 19, 1178–1184. doi: 10.1111/j.1467-9280.2008.02220.x

Cimatti, F. (2016). "Philosophy and psychoanalysis: Wittgenstein, on "language-games" and ethics" in *Interdisciplinary studies in pragmatics, culture and society. Perspectives in pragmatics, philosophy & psychology*. Vol. 4. eds. A. Capone and J. Mey (Cham: Springer).

Clark, H. H. (1996). *Using language*. Cambridge: Cambridge University Press.

Clark, A. (1999). An embodied cognitive science? *Trends Cogn. Sci.* 3, 345–351. doi: 10.1016/s1364-6613(99)01361-3

Clark, A. (2003). *Natural-born cyborgs: Minds, technologies and the future of human intelligence*. New York: Oxford University Press.

Colzato, L. S., van den Wildenberg, W. P. M., and Hommel, B. (2016). Increasing self-other integration through divergent thinking. *Psychon. Bull. Rev.* 20, 1011–1016. doi: 10.3758/s13423-013-0413-4

Conger, J. P. (1994). *The body in recovery: Somatic psychotherapy and the self*. Berkeley, CA: Frog Books.

Corballis, M. C. (2002). *From hand to mouth: The origins of language*. Princeton, NJ: Princeton University Press.

Costantini, M., and Ferri, F. (2013). Action co-representation and social exclusion. *Exp. Brain Res.* 227, 85–92. doi: 10.1007/s00221-013-3487-3

Costantini, M., Committeri, G., and Sinigaglia, C. (2011). Ready both to your and to my hands: mapping the action space of others. *PLoS One* 6:e17923. doi: 10.1371/journal.pone.0017923

Costantini, M., Di Vacri, A., Chiarelli, A. M., Ferri, F., Romani, G. L., and Merla, A. (2013). Studying social cognition using near-infrared spectroscopy: the case of social Simon effect. *J. Biomed. Opt.* 18:25005. doi: 10.1117/1.JBO.18.2.025005

Critchley, H. D., and Garfinkel, S. N. (2017). Interoception and emotion. *Curr. Opin. Psych.* 17.

Crucianelli, L., Cardi, V., Treasure, J., Jenkinson, P. M., and Fotopoulou, A. (2016). The perception of affective touch in anorexia nervosa. *Psychiatry Res.* 239, 72–78. doi: 10.1016/j.psychres.2016.01.078

Cuccio, V., Ferri, F., and Costantini, M. (2013). Percepire, desiderare, rappresentare. *Giorn. Ital. Psicolog., Rivista trimestrale* 1, 73–78. doi: 10.1421/73978

Damasio, A. (1999). *The feeling of what happens: Body and emotion in the making of consciousness*. New York, NY: Harcourt Brace.

Damasio, A. R. (2000). "A second chance for emotions" in *Cognitive Neuroscience for Emotion*. eds. R. Lane and L. Nadel (New York: Oxford Books), 12–23.

Damasio, A. R., Grabowski, T. J., Bechara, A., Damasio, H., Ponto, L. L., Parvizi, J., et al. (2000). Subcortical and cortical brain activity during the feeling of self-generated emotions. *Nat. Neurosci.* 3, 1049–1056. doi: 10.1038/79871

Dayton, T. D. (2005). The use of psychodrama in dealing with grief and addiction-related loss and trauma. *J. Group Psychother. Psychodrama Sociom.* 58, 15–34. doi: 10.3200/JGPP.58.1.15-34

Dayton, T. (2006). "Neuroscience and psychodrama: validating the mind/body approach of psychodrama" in *Opening Plenary at the 64th Annual Conference in San Francisco, CA, Society of Group Psychotherapy and Psychodrama.*

di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., and Rizzolatti, G. (1992). Understanding motor events: a neurophysiological study. *Exp. Brain Res.* 91, 176–180.

Diefenbach, S., and Christoforakos, L. (2017). The selfie paradox: nobody seems to like them yet everyone has reasons to take them. An exploration of psychological functions of selfies in self-presentation. *Front. Psychol.* 8:7. doi: 10.3389/fpsyg.2017.00007

Dolcos, F., LaBar, K. S., and Cabeza, R. (2005). Remembering one year later: role of the amygdala and the medial temporal lobe memory system in retrieving emotional memories. *Proc. Natl. Acad. Sci. USA* 102, 2626–2631. doi: 10.1073/pnas.0409848102

Dunn, J. (1993). Psychic conflict and the external world in Freud's theory of the instinctual drives in light of his adherence to Darwin. *Int. J. Psychoanal.* 74, 231–240. https://www.ncbi.nlm.nih.gov/pubmed/8491529#

Durieux, B. N., Gramling, C. J., Manukyan, V., Eppstein, M. J., Rizzo, D. M., Ross, L. M., et al. (2018). Identifying connectional silence in palliative care consultations: a tandem machine-learning and human coding method. *J. Palliat. Med.* 21. doi: 10.1089/jpm.2018.0270

Ebisch, S. J. H., Salone, A., Martinotti, G., Carlucci, L., Mantini, D., Perrucci, M. G., et al. (2016). Integrative Processing of Touch and Affect in Social Perception: An fMRI Study. *Front. Hum. Neurosci.* 10. doi: 10.3389/fnhum.2016.00209

Emde, R. (1988a). Development terminable and interminable: 1. Innate and motivational factors from infancy. *Int. J. Psychoanal.* 69, 23–42.

Emde, R. (1988b). Development terminable and interminable: 11. Recent psychoanalytic theory and therapeutic considerations. *Int. J. Psychoanal.* 69, 283–296.

Enquist, M., Aronsson, H., Ghirlanda, S., Jansson, L., and Jannini, E. A. (2011). Exposure to mother's pregnancy and lactation in infancy is associated with sexual attraction to pregnancy and lactation in adulthood. *J. Sex. Med.* 8, 140–147. doi: 10.1111/j.1743-6109.2010.02065.x

Fava, G. A., Cosci, F., and Sonino, N. (2017). Current psychosomatic practice. *Psychother. Psychosom.* 86, 13–30.

Ferri, F., Frassinetti, F., Ardizzi, M., Costantini, M., and Gallese, V. (2012). A sensorimotor network for the bodily self. *J. Cogn. Neurosci.* 24, 1584–1595. doi: 10.1162/jocn_a_00230

Fessler, D. M. T., and Abrams, E. T. (2004). Infant mouthing behavior: the immunocalibration hypothesis. *Med. Hypotheses* 63, 925–932. doi: 10.1016/j.mehy.2004.08.004

Fonagy, P. A. (2008). A genuinely developmental theory of sexual enjoyment and its implications for psychoanalytic technique. *J. Am. Psych. Assoc.* 56, 11–36. doi: 10.1177/0003065107313025

Fotopoulou, A., and Tsakiris, M. (2017). Mentalizing homeostasis: the social origins of interoceptive inference. *Neuropsychoanalysis* 19, 3–28. doi: 10.1080/15294145.2017.1294031

Freud, S. (1905). "Three essays on the theory of sexuality" in *The standard edition of the complete psychological works of Sigmund Freud*. Vol. 7. ed. J. Strachey (London: The Hogarth Press), 125–245.

Freud, S. (1915a). "Instincts and their vicissitudes" in *The standard edition of the complete psychological works of Sigmund Freud*. Vol. 14. ed. J. Strachey (London: The Hogarth Press), 109–140.

Freud, S. (1915b). *Appendix C to the unconscious. Standard edition, 14*, 159–215.

Freud, S. (1920). "Beyond the pleasure principle" in *The standard edition of the complete works of Sigmund Freud*. Vol. 18. ed. J. Strachey (London: Hogarth), 1920–1922.

Freud, S. (1921). *Massenpsychologie und Ich-analyse Leipzig*. Vienna and Zurich: Internationaler Psychoanalytischer Verlag. iii + 140. (*Group Psychology and the Analysis of the Ego.* (1922). London and Vienna: International Psycho-Analytical Press. viii + 134., Strachey, J. Tr. *Psicologia delle masse ed analisi dell'Io. Opere*, vol. 9. Bollati-Boringhieri).

Freud, A. (1936). *The ego and the mechanisms of defense*. New York: International Universities Press.

Gallese, V. (2003). The manifold nature of interpersonal relations: The quest for a common mechanism. *Philosophical Transactions of the Royal Society of London Series B*. 358, 517–528.

Gallese, V. (2005). "Being like me": Self-other identity, mirror neurons and empathy. In *Perspectives on Imitation: From Cognitive Neuroscience to Social Science*. ed. S. Hurley, and N. Chater, Vol. 1. Cambridge: MIT Press.

Gallese, V. (2007a). Dai neuroni specchio alla consonanza intenzionale. *Riv. Psicoanal.* 53, 197–208.

Gallese, V. (2007b). Before and below "theory of mind": embodied simulation and the neural correlates of social cognition. *Philos. Trans. R Soc. B Biol. Sci.* 362, 659–669. doi: 10.1098/rstb.2006.2002

Gallese, V. (2008). Mirror neurons and the social nature of language: the neural exploitation hypothesis. *Soc. Neurosci.* 3, 317–333. doi: 10.1080/17470910701563608

Gallese, V. (2009). We-ness, embodied simulation, and psychoanalysis: reply to commentaries. *Psychoanal. Dialogues* 19, 580–584. doi: 10.1080/10481880903231928

Gallese, V. (2011). embodied simulation theory: imagination and narrative. *Neuropsychoanalysis* 13, 196–200. doi: 10.1080/15294145.2011.10773675

Gallese, V., Keysers, C., and Rizzolatti, G. (2005). A unifying view of the basis of social cognition. *Trends in Cognitive Sciences* 8, 396–403.

Gallese, V., and Lakoff, G. (2005). The brain's concepts: the role of sensory-motor system in reason and language. *Cogn. Neuropsychol.* 22, 455–479. doi: 10.1080/02643290442000310

Gallese, V., and Sinigaglia, C. (2011). What is so special with embodied simulation. *Trends Cogn. Sci.* 15, 512–519. doi: 10.1016/j.tics.2011.09.003

Gallese, V., Migone, P., and Eagle, M. N. (2006). La simulazione incarnata: i neuroni specchio, le basi neurofisiologiche dell'intersoggettività ed alcune implicazioni per la psicoanalisi. *Psicoter. Sci. Um.* 3, 543–580. https://psycnet.apa.org/record/2006-21596-015

Gallese, V., Eagle, M. N., and Migone, P. (2007). Intentional attunement: mirror neurons and the neural underpinnings of interpersonal relations. *J. Am. Psychoanal. Assoc.* 55, 131–176.

Gervain, J., and Werker, J. F. (2013). Prosody cues word order in 7-month-old bilingual infants. *Nat. Commun.* 4, 1490. doi: 10.1038/ncomms2430

Gianelli, C., Scorolli, C., and Borghi, A. M. (2013). Acting in perspective: the role of body and language as social tools. *Psychol. Res.* 77, 40–52. doi: 10.1371/journal.pone.0085151

Ginot, E. (2015). *The neuropsychology of the unconscious: Integrating brain and mind into psychotherapy*. Norton & Company: New York W. W.

Glenberg, A. M. (1997). What memory is for. *Behav. Brain Sci.* 20, 1–55.

Godman, M. (2013). Why we do things together: the social motivation for joint action. *Philos. Psychol.* 26, 588–603. doi: 10.1080/09515089.2012.670905

Green, A. (1995). Has sexuality anything to do with psychoanalysis? *Int. J. Psychoanal.* 76, 871–883.

Herbert, C., Ethofer, T., Fallgatter, A. J., Walla, P., and Northoff, G. (2018). Editorial: the Janus face of language: where are the emotions in words and where are the words in emotions? *Front. Psychol.* 9:650. doi: 10.3389/fpsyg.2018.00650

Hill, C. E., Kline, K. V., O'Connor, S., Morales, K., Li, X., Kivlighan, D. M. Jr., et al. (2018). Silence is golden: a mixed methods investigation of silence in one case of psychodynamic psychotherapy. *Psychotherapy.* doi: 10.1037/pst0000196

Hoerger, M., Quirk, S. W., and Weed, N. C. (2011). Development and validation of the delaying gratification inventory. *Psychol. Assess.* 23, 725–738. doi: 10.1037/a0023286

Höhle, B., Bijeljac-Babic, R., Herold, B., Weissenborn, J., and Nazzi, T. (2009). The development of language specific prosodic preferences during the first half year of life: evidence from German and French. *Infant Behav. Develop.* 2, 262–274. doi: 10.1016/j.infbeh.2009.03.004

Holmes, P., and Karp, M. (1990). *Psychodrama: Inspiration and technique*. London and New York: Tavistock/Routledge.

Husserl, E. (1952). *Ideen zu einer reinen Phänomenologie und phänomenologischen Philosophie*. Zweites Buch, hrsg. von M. Biemel, Den Haag 1952 (trad. it. V. Costa, *Idee per una fenomenologia pura e per una filosofia fenomenologica, vol. II*, l. II. Ricerche fenomenologiche sopra la costituzione, Torino 2002).

Hutchins, E. (1995). *Cognition in the wild*. Cambridge: MIT Press.

Iani, C., Anelli, F., Nicoletti, R., Arcuri, L., and Rubichi, S. (2011). The role of group membership on the modulation of joint action. *Exp. Brain Res.* 211, 439–445. doi: 10.1007/s00221-011-2651-x

Jeammet, P., and Kestemberg, E. (1987). *Le psychodrame psychanalytique*. Paris: Presses universitaires de France.

John, O. P., and Srivastava, S. (1999). "The big five trait taxonomy: history, measurement, and theoretical perspectives" in *Handbook of personality: Theory and research*. 2nd edition. eds. L. A. Pervin and O. P. John (New York, NY: Guilford Press), 102–138.

Juberg, D. R., Alfano, K., Coughlin, R. J., and Thompson, K. M. (2001). An observational study of object mouthing behavior by young children. *Pediatrics* 107, 135–142. doi: 10.1542/peds.107.1.135

Jung, C. G. (1938). *Psychology and religion*. Oxford, England: Yale Univ. Press.

Keysers, C., Wickers, B., Gazzola, V., Anton, J.-L., Fogassi, L., and Gallese, V. (2004). A touching sight: SII/PV activation during the observation and experience of touch. *Neuron* 42, 1–20.

Kernberg, O. F. (2016). The four basic components of psychoanalytic technique and derived psychoanalytic psychotherapies. *World Psychiatr.* 15, 287–288. doi: 10.1002/wps.20368

Kihlstrom, J. F. (1987). The cognitive unconscious. *Science* 237, 1445–1452. doi: 10.1126/science.3629249

Kihlstrom, J. F. (2013). "Unconscious processes" in *Oxford handbook of cognitive psychology*. ed. D. Reisberg (Oxford: Oxford University Press), 176–186.
Kihlstrom, J. F. (2015). "Dynamic versus cognitive unconscious" in *The encyclopedia of clinical psychology*. eds. R. L. Cautin and S. O. Lilienfeld (New York, NY: John Wiley and Sons), 988–996.
Klein, M. (1946). Notes on some schizoid mechanisms. *Int. J. Psychoanal.* 27, 99–110. https://psycnet.apa.org/record/1948-02558-001
Kohut, H. (2010). On empathy. *Int. J. Psych. Self Psychol.* 5, 122–131. doi: 10.1080/15551021003610026
Kotchoubey, B., Tretter, F., Braun, H. A., Buchheim, T., Draguhn, A., Fuchs, T., et al. (2016). Methodological problems on the way to integrative human neuroscience. *Front. Integr. Neurosci.* 10. doi: 10.3389/fnint.2016.00041
Kuhbandner, C., Pekrum, R., and Maier, M. A. (2010). The role of positive and negative affect in the "mirroring" of other person's actions. *Cognit. Emot.* 24, 1182–1190. doi: 10.1080/02699930903119196
Kuhl, P. K., Tsao, F. M., and Liu, H. M. (2003). Foreign-language experience in infancy: effects of short-term exposure and social interaction on phonetic learning. *PNAS* 100, 9096–9101. doi: 10.1073/pnas.1532872100
Kuo, C., and Yeh, Y. (2017). Sensorimotor-conceptual integration in free walking enhances divergent thinking for young and older adults. *Front. Psychol.* 7. doi: 10.3389/fpsyg.2016.01580
Kwon, M., Lee, J. Y., Won, W. Y., Park, J. W., Min, J. A., Hahn, C., et al. (2013). Development and validation of a smartphone addiction scale (SAS). *PloS One* 8:e56936. doi: 10.1371/journal.pone.0056936
Lee, P., Lan, W., Wang, C., and Chiu, H. (2008). Helping young children to delay gratification. *Early Childhood Educ. J.* 35, 557–564.
Lemoine, G., and Lemoine, P. (1972). *Le psychodrame*. Paris: R. Laffont.
Leung, A. K., Kim, S., Polman, E., Ong, L. S., Qiu, L., Goncalo, J. A., et al. (2012). Embodied metaphors and creative "Acts". *Psychol. Sci.* 23, 502–509. doi: 10.1177/0956797611429801
Levy, S., and Lemma, A. (2004). *The perversion of loss psychoanalytic perspectives on trauma*. London: Whurr.
Linardon, J., Phillipou, A., Castle, D., Newton, R., Harrison, P., Cistullo, L. L., et al. (2018). Feeling fat in eating disorders: testing the unique relationships between feeling fat and measures of disordered eating in anorexia nervosa and bulimia nervosa. *Body Image* 25, 163–167. doi: 10.1016/j.bodyim.2018.04.001
Lisi, L., Plessi, E., Scorolli, C., Meliconi, R., and Rapaggi, A. (2014). Sclerodermic patients: an interdisciplinary approach. *Clin. Exp. Rheumatol.* 32, S104-S104. ISSN: 0392-856X. Accession Number: WOS:000 335936400273 doi: 10.1186/s13071-014-0560-0
Lloyd-Fox, S., Széplaki-Kollod, B., Yin, J., and Csibra, G. (2015). Are you talking to me? Neural activations in 6-month-old infants in response to being addressed during natural interactions. *Cortex* 70, 35–48. doi: 10.1016/j.cortex.2015.02.005
Lo Piparo, F. (2003). *Aristotele e il linguaggio. Cosa fa di una lingua una lingua*. Laterza: Roma-Bari.
Lowe, R., Almér, A., Lindblad, G., Gander, P., Michael, J., and Vesper, C. (2016). Minimalist social-affective value for use in joint action: a neural-computational hypothesis. *Front. Comput. Neurosci* 10:88. doi: 10.3389/fncom.2016.00088
Lowen, A. (1969). *The betrayal of the body*. New York: Collier Books, 1976.
Lowen, A. (1975). *Bioenergetics*. New York: Penguin.
Mancia, M. (2006). Implicit memory and early unrepressed unconscious: their role in the therapeutic process (how the neurosciences can contribute to psychoanalysis). *Int. J. Psychoanal.* 87, 83–103. https://www.ncbi.nlm.nih.gov/pubmed/16635862#
Marlatt, G. A., Baer, J. S., Donovan, D. M., and Kivlahan, D. R. (1988). Addictive behaviors: etiology and treatment. *Annu. Rev. Psychol.* 39, 223–252. doi: 10.1146/annurev.ps.39.020188.001255
Mehler, J., Jusczyk, P., Lambertz, G., Halsted, N., Bertoncini, J., and Amiel-Tison, C. (1998). A precursor of language acquisition in young infants. *Cognition* 29, 143–178.
Merleau-Ponty, M. (1945). *Phénoménologie de la perception.* Paris (trad. it. Bonomi, A. (2003). *Fenomenologia della percezione*. Milano).
Migone, P. (1995). *Terapia psicoanalitica*. Milano: Franco Angeli.
Migone, P. (2001). Psychoanalysis and cognitive-behavior therapy. *Int. J. Psychoanal.* 85, 984–988.
Moccia, L., Mazza, M., Di Nicola, M., and Janiri, L. (2018). The experience of pleasure: a perspective between neuroscience and psychoanalysis. Research topic: the interface between psychoanalysis and neuroscience: the state of the art. *Front. Hum. Neurosci.* doi: 10.3389/fnhum.2018.00359
von Mohr, M., Kirsch, L. P., and Fotopoulou, K. (2017). The soothing function of touch: affective touch reduces feelings of social exclusion. *Sci. Rep.* 7:13516.
Montag, C., Sindermann, C., Becker, B., and Panksepp, J. (2016). An affective neuroscience framework for the molecular study of internet addiction. *Front. Psychol.* 7:1906. doi: 10.3389/fpsyg.2016.01906
Moreno, J. L. (1934). *Who shall survive?* 3rd edn. Washington, DC: Nervous and Mental Disease Publications (Rev. ed. Beacon, NY: Beacon House, 1953).
Moreno, J. L. (1937). "Interpersonal therapy and the psychopathology of interpersonal relations" in *Psychodrama (Vol. 1)* (N.Y: Beacon).
Moreno, J. L. (1946). *Psychodrama. (Vol. 1)*. Beacon, N.Y: Beacon House.
Moreno, J. L. (1951). *Sociometry, experimental method and the science of society*. Beacon, N.Y: Beacon House.
Moreno, J. L., and Moreno, Z. T. (1969). *Psychodrama*. Vol. 3. Beacon, NY: Beacon House.
Moyer, C. A., Rounds, J., and Hannum, J. W. (2004). A meta-analysis of massage therapy research. *Psychol. Bull.* 130, 3–18. doi: 10.1037/0033-2909.130.1.3
Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., and Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Pers. Soc. Psychol. Rev.* 9, 184–211.
Noë, A. (2004). *Action in perception (representation and mind)*. MIT Press.
Northoff, G. (2012). Psychoanalisis and the brain-why did Freud abandon neuroscience? *Front. Psychol.* 3:71. doi: 10.3389/fpsyg.2012.00071
Northoff, G. (2013). *Unlocking the brain: Consciousness, Vol. 2*. Oxford: Oxford University Press.
Ottoboni, G. (2013). Grounding clinical and cognitive scientists in an interdisciplinary discussion. *Front. Psychol.* 4:630. doi: 10.3389/fpsyg.2013.00630
Panksepp, J. (1998). *Affective neuroscience: The foundations of human and animal emotions*. New York, NY: Oxford University Press.
Panksepp, J. (2005). Affective consciousness: core emotional feelings in animals and humans. *Conscious. Cogn.* 14, 30–80. doi: 10.1016/j.concog.2004.10.004
Panksepp, J., and Solms, M. (2012). What is neuropsychoanalysis? Clinically relevant studies of the minded brain. *Trends Cogn. Sci.* 16, 6–8. doi: 10.1016/j.tics.2011.11.005
Panksepp, J., Knutson, B., and Burgdorf, J. (2002). The role of brain emotional systems in addictions: a neuro-evolutionary perspective and new 'self-report' animal model. *Addiction* 97, 459–469. doi: 10.1046/j.1360-0443.2002.00025.x
Papies, E. K., and Barsalou, L. W. (2015). "Grounding desire and motivated behavior: a theoretical framework and review of empirical evidence" in *The psychology of desire*. eds. W. Hofmann and L. F. Nordgren (New York, NY, US: Guilford Press), 36–60.
Paré, D., Collins, D. R., and Pelletier, J. G. (2002). Amygdala oscillations and the consolidation of emotional memories. *Trends Cogn. Sci.* 6, 306–314. doi: 10.1016/S1364-6613(02)01924-1
Parisi, D. (1989). *Intervista sulle reti neurali*. Bologna.
Parisi, D. (2002). "Sulla scienza cognitiva" in *Sistemi intelligenti, Rivista quadrimestrale di scienze cognitive e di intelligenza artificiale*. 109–128.
Parisi, D. (2013). Embodied Cognition sì, ma tradotta in robotica. *Giorn. Ital. Psicolog., Rivista trimestrale*. 1, 105–108.
Parisi, D. (2014). *Future robots: Towards a robotic science of human beings*. Amsterdam, Netherlands; Philadelphia, Pennsylvania: John Benjamins Publishing Company.
Parisi, D., and Schlesinger, M. (2002). Artificial life and piaget. *Cogn. Dev.* 17, 1301–1321. doi: 10.1016/S0885-2014(02)00119-3
Parsons, T. D., Gaggioli, A., and Riva, G. (2017). Virtual reality for research in social neuroscience. *Brain Sci.* 7, 42. doi: 10.3390/brainsci7040042
Peri, T., Gofman, M., Tal, S., and Tuval-Mashiach, R. (2015). Embodied simulation in exposure-based therapies for posttraumatic stress disorder—a possible integration of cognitive behavioral theories, neuroscience, and psychoanalysis. *Eur. J. Psychotraumatol.* 6, 29301. doi: 10.3402/ejpt.v6.29301
Perls, F. S. (1969). *Gestalt therapy verbatim*. New York: Bantam.
Pesciarelli, F., Scorolli, C., Cacciari, C. (2019). Neural correlates of the implicit processing of grammatical and stereotypical gender violations: a masked and unmasked priming study. Manuscript submitted for publication.
Pezzulo, G., Barsalou, L., Cangelosi, A., Fischer, M., McRae, K., and Spivey, M. (2013). Computational grounded cognition: a new alliance between grounded cognition and computational modeling. *Front. Psychol.* 3:612. doi: 10.3389/fpsyg.2012.00612

Piaget, J. (1945). *Play, dreams and imitation in childhood*. London: Heinemann.
Piaget, J. (1952). *The origin of intelligence in children*. New York: International Universities Press.
Plunkett, K., and Marchmann, V. (1991). U-shaped learning and frequency effects in a multi-layered perceptron: implications for child language acquisition. *Cognition* 38, 43–102. doi: 10.1016/0010-0277(91)90022-V
Proulx, M. J., Todorov, O. S., Taylor, A. A., and de Sousa, A. A. (2016). Where am I? Who am I? The relation between spatial cognition, social cognition and individual differences in the built environment. *Front. Psychol.* 7:64. doi: 10.3390/ani7010002
Rapaggi, A. (1994). *Amore, Sintomo e Carattere. Storia e storie per una nuova psicoanalisi*. Bologna, Italy: Edizioni Mosaico.
Rapaggi, A. (2008). *Lo Psicodramma anche in Azienda*. Milano, Italy: Edizioni Franco Angeli.
Reich, W. (1945). *Character-analysis*. New York: Orgone Institute Press.
Rizzolatti, G., and Sinigaglia, C. (2006). *So quel che fai. Il cervello che agisce e i neuroni specchio*. ed. R. Cortina (Milano).
Rizzolatti, G., Fadiga, L., Gallese, V., and Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cogn. Brain Res.* 3, 131–141. doi: 10.1016/0926-6410(95)00038-0
Rizzolatti, G., Semi, A. A., and Fabbri-Destro, M. (2014). Linking psychoanalysis with neuroscience: the concept of ego. *Neuropsychologia* 55, 143–148. doi: 10.1016/j.neuropsychologia.2013.10.003
Rizzuto, A. M. (2008). The talking cure and the analyst's intentions. *Psychoanal. Rev.* 95, 729–749. doi: 10.1521/prev.2008.95.5.729
Rochat, P. (1987). Mouthing and grasping in neonates: evidence for the early detection of what hard or soft substances afford for action. *Infant Behav. Dev.* 10, 435–449. doi: 10.1016/0163-6383(87)90041-5
Rodgers, R. F., Melioli, T., Laconi, S., Bui, E., and Chabrol, H. (2013). Internet addiction symptoms, disordered eating, and body image avoidance. *Cyberpsychol. Behav. Soc. Netw.* 16, 56–60. doi: 10.1089/cyber.2012.1570
Royal Society for Public Health. (2017). *Instagram ranked worst for young people's mental health: Report*. https://www.rsph.org.uk/about-us/news/instagram-ranked-worst-for-young-people-s-mental-health.html
Rumelhart, D. E., and McClelland, J. L. (1986). On learning the past tense of English verbs, in Parallel distributed processing. Explorations in the microstructure of cognition, a cura di D.E. Rumelhart, J.L. McClelland, Cambridge (Mass.) 1986 (trad. it., PDP. Microstruttura dei processi cognitivi, Bologna 1991).
Rumiati, R. I., and Bekkering, H. (2003). To imitate or not to imitate? How the brain can do it, that is the question! *Brain Cogn.* 53, 479–482. doi: 10.1016/S0278-2626(03)00208-2
Sacheli, L. M., Aglioti, S. M., and Candidi, M. (2015). Social cues to joint actions: the role of shared goals. *Front. Psychol.* 6:1034. doi: 10.3389/fpsyg.2015.01034
Salone, A., Di Giacinto, A., Lai, C., De Berardis, D., Iasevoli, F., Fornaro, M., et al. (2016). The interface between neuroscience and neuro-psychoanalysis: focus on brain connectivity. *Front. Hum. Neurosci.* 10:20. doi: 10.3389/fnhum.2016.00020
Sartori, L., and Betti, S. (2015). Complementary actions. *Front. Psychol.* 6:557. doi: 10.3389/fpsyg.2015.00557
Sartori, L., Cavallo, A., Bucchioni, G., and Castiello, U. (2012). From simulation to reciprocity: the case of complementary actions. *Soc. Neurosci.* 7, 146–158. doi: 10.1080/17470919.2011.586579
Scalabrini, A., Mucci, A., and Northoff, G. (2018). Is our self related to personality? A neuropsychodynamic model. Research topic: the interface between psychoanalysis and neuroscience: the state of the art. *Front. Hum. Neurosci*. doi: 10.3389/fnhum.2018.00346
Schaefer, M., and Northoff, G. (2017). Who am I: the conscious and the unconscious self. *Front. Hum. Neurosci*. 11:126. doi: 10.3389/fnhum.2017.00126
Schermer, V. L. (2010). Mirror neurons: their implications for group psychotherapy. *Int. J. Group Psychother.* 60, 486–513. doi: 10.1521/ijgp.2010.60.4.486
Scorolli, C. (2014). "Embodiment and language" in *The Routledge handbook of embodied cognition*. Routledge. ed. L. Shapiro (Taylor & Francis), 127–138. ISBN 978-0-415-62361-2.
Scorolli, C., and Borghi, A. M. (2007). Sentence comprehension and action: effector specific modulation of the motor system. *Brain Res.* 1130, 119–124. doi: 10.1016/j.brainres.2006.10.033
Scorolli, C., Borghi, A. M., and Glenberg, A. (2009). Language-induced motor activity in bi-manual object lifting. *Exp. Brain Res.* 193, 43–53. doi: 10.1007/s00221-008-1593-4
Scorolli, C., Jacquet, P. O., Binkofski, F., Nicoletti, R., Tessari, A., and Borghi, A. M. (2012). Abstract and concrete phrases processing differentially modulates cortico-spinal excitability. *Brain Res.* 1488, 60–71. doi: 10.1016/j.brainres.2012.10.004
Scorolli, C., Miatton, M., Wheaton, L., and Borghi, A. M. (2014). I give you a cup, I get a cup: a kinematic study on social intention. *Neuropsychologia* 57, 196–204. doi: 10.1016/j.neuropsychologia.2014.03.006
Scorolli, C., Pellicano, A., Nicoletti, R., Rubichi, S., and Castiello, U. (2015). The Simon effect in action: planning and/or on-line control effects? *Cogn. Sci.* 39, 972–991. ISSN: 0364-0213 print/1551-6709 online. doi: 10.1111/cogs.12188
Scorolli, C., Daprati, E., Nico, D., and Borghi, A. M. (2016). Reaching for objects or asking for them: distance estimation in 7- to 15-years-old children. *J. Mot. Behav.* 48, 183–191. doi: 10.1080/00222895.2015.1070787
Scorolli, C., Borghi, A. M., and Tummolini, L. (2018). Cues of control modulate the ascription of object ownership. *Psychol. Res.* 82, 929–954. doi: 10.1007/s00426-017-0871-9
Searle, J. R. (1991). Consciousness, unconsciousness, and intentionality. *Philos. Issues* 1, 45–66. doi: 10.2307/1522923
Semenza, C. (2014). Psychoanalysis and cognitive neuropsychology: theoretical and methodological affinities. *Neuropsychoanalysis* 3, 3–10. doi: 10.1080/15294145.2001.10773326
Simonton, D. K. (2003). Scientific creativity as constrained stochastic behavior: the integration of product, person, and process perspectives. *Psychol. Bull.* 129, 475–494. doi: 10.1037/0033-2909.129.4.475
Solms, M. (2012). Are Freud's "Erogenous Zones" sources or objects of libidinal drive? *Neuropsychoanalysis* 14, 53–56. doi: 10.1080/15294145.2012.10773688
Solms, M. (2013). The conscious Id. *Neuropsychoanalysis* 15, 5–19. doi: 10.1080/15294145.2013.10773711
Solms, M. (2014). A neuropsychoanalytical approach to the hard problem of consciousness. *J. Integr. Neurosci.* 13, 173–185. doi: 10.1142/S0219635214400032
Solms (2017a). Some innate predictions are social in nature: commentary on "Mentalizing homeostasis" by Fotopoulou and Tsakiris. *Neuropsychoanalysis* 19, 55–57. doi: 10.1080/15294145.2017.1309622
Solms, M. (2017b). What is "the unconscious," and where is it located in the brain? A neuropsychoanalytic perspective. *Ann. N.Y. Acad. Sci.* 1406, 90–97.
Solms, M., and Panksepp, J. (2012). The "Id" knows more than the "Ego" admits: neuropsychoanalytic and primal consciousness perspectives on the interface between affective and cognitive neuroscience. *Brain Sci.* 2, 147–175. doi: 10.3390/brainsci2020147
Solms, M. (2019). The Hard Problem of Consciousness and the Free Energy Principle. *Front. Psychol.* 9:2714. doi: 10.3389/fpsyg.2018.02714
Stern, D. N. (1985). *The interpersonal world of the infant: A view from psychoanalysis and developmental psychology*. London: Basic Books.
Stoléru, S. (2014). Reading the Freudian theory of sexual drives from a functional neuroimaging perspective. *Front. Human Neurosci.* 8:157. doi: 10.3389/fnhum.2014.00157
Taylor, S. F., Liberzon, I., Fig, L. M., Decker, L. R., Minoshima, S., and Koeppe, R. A. (1998). The effect of emotional content on visual recognition memory: a PET activation study. *NeuroImage* 8, 188–197. doi: 10.1006/nimg.1998.0356
Tessari, A., Tsakiris, M., Borghi, A. M., and Serino, A. (2010). *The sense of body: A multidisciplinary approach to body representation. Introduction to the special number on the sense of body*.
Thompson, V., and Stapleton, M. (2009). Making sense of sense-making: reflections on enactive and extended mind theories. *Topoi* 28, 23–30. doi: 10.1007/s11245-008-9043-2
Tsakiris, M., and Critchley, H. (2016). Interoception beyond homeostasis: affect, cognition and mental health. *Philos. Trans. R Soc. B Biological. Sci. B* 371:20160002. doi: 10.1098/rstb.2016.0002
Tulve, N. S., Suggs, J. C., McCurdy, T., Choen Hubal, E. A., and Moya, J. (2002). Frequency of mouthing behavior in young children. *J. Expos. Anal. Environ. Epidemiol.* 12, 259–264. doi: 10.1038/sj.jea.7500225
Tyng, C. M., Amin, H. U., Saad, M. N. M., and Malik, A. S. (2017). The influences of emotion on learning and memory. *Front. Psychol.* 8:1454. doi: 10.3389/fpsyg.2017.01454

Valleur, M., and Matysiak, J.C. (2004). Les nouvelles formes d'addiction. L'amour. Le sexe. Le jeux vidéo. (New addictions. Love. Sex. Video game). Paris: Flammarion.

Varela, F., Thompson, E. T., and Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*: MIT Press.

Vesper, C., Abramova, E., Bütepage, J., Ciardo, F., Crossey, B., Effenberg, A., et al. (2017). Joint action: mental representations, shared information and general mechanisms for coordinating with others. *Front. Psychol.* 7:2039. doi: 10.3389/fpsyg.2016.02039

Visser, L. N. C., Tollenaar, M. S., van Doornen, L. J. P., de Haes, H. C. J. M., and Smets, E. M. A. (2019). Does silence speak louder than words? The impact of oncologists' emotion-oriented communication on analogue patients' information recall and emotional stress. *Patient Educ. Couns.* 102, 43–52. doi: 10.1016/j.pec.2018.08.032

Wilson, M. (2010). The re-tooled mind: how culture re-engineers cognition. *Soc. Cogn. Affect. Neurosci.* 5, 180–187. doi: 10.1093/scan/nsp054

Wilson-Mendenhall, C. D., Barrett, L. F., Simmons, W. K., and Barsalou, L. W. (2011). Grounding emotion in situated conceptualization. *Neuropsychologia* 49, 1105–1127. doi: 10.1016/j.neuropsychologia.2010.12.032

Winnicott, D. W. (1971). *Playing and reality*. Oxford: Penguin.

Wojciehowski, H. C., and Gallese, V. (2011). How stories make us feel: toward an embodied narratology. *Calif. Ital. Stud.* 2. https://cloudfront.escholarship.org/dist/prd/content/qt3jg726c2/qt3jg726c2.pdf?t=ncvx10

Wright, J. S., and Panksepp, J. (2012). An evolutionary framework to understand foraging, wanting, and desire: the neuropsychology of the seeking system. *Neuropsychoanalysis* 14, 5–39. doi: 10.1080/15294145.2012.10773683

Yablonsky, L. (1976). *Psychodrama: Resolving emotional problems through role-playing*. New York: Basic Books.

Young, K. S. (1998). Internet addiction: the emergence of a new clinical disorder. *Cyber Psychol. Behav.* 1:3. doi: 10.1089/cpb.1998.1.237

Zhong, J., Novianto, R., Dai, M., Zhang, X., and Cangelosi, A. (2016). "A hierarchical emotion regulated sensorimotor model: case studies" in *IEEE International Conferences*. 4965-4970.

Conflict of Interest Statement: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Human Neuroscience

ORIGINAL RESEARCH
published: 05 April 2019
doi: 10.3389/fnhum.2019.00077

Phonological Ambiguity Detection Outside of Consciousness and Its Defensive Avoidance

Ariane Bazan†, Ramesh Kushwaha†, E. Samuel Winer†, J. Michael Snodgrass†, Linda A. W. Brakel† and Howard Shevrin‡*

Program of Research on Unconscious Processes, Ormond and Hazel Hunt Laboratory, Department of Psychiatry, University of Michigan, Ann Arbor, MI, United States

Freud proposes that in unconscious processing, logical connections are also (heavily) based upon phonological similarities. Repressed concerns, for example, would also be expressed by way of phonologic ambiguity. In order to investigate a possible unconscious influence of phonological similarity, 31 participants were submitted to a tachistoscopic subliminal priming experiment, with prime and target presented at 1 ms. In the experimental condition, the prime and one of the 2 targets were phonological reversed forms of each other, though graphemically dissimilar (e.g., "nice" and "sign"); in the control condition the targets were pseudo-randomly attributed to primes to which they don't belong. The experimental task was to "blindly" pick the choice most similar to the prime. ERPs were measured with a focus on the N320, which is known to react selectively to phonological mismatch in supraliminal visual word presentations. The N320 amplitude-effects at the electrodes on the midline and at the left of the brain significantly predicted the participants' net behavioral choices more than half a second later, while their subjective experience is one of arbitrariness. Moreover, the social desirability score (SDS) significantly correlates with both the behavioral and the N320 brain responses of the participants. It is proposed that in participants with low SDS the phonological target induces an expected reduction of N320 and this increases their probability to pick this target. In contrast, high defensive participants have a perplexed brain reaction upon the phonological target, with a negatively peaking N320 as compared to control and this leads them to avoid this target more often. Social desirability, which is understood as reflecting defensiveness, might also manifest itself as a defense against the (energy-consuming) ambiguity of language. The specificity of this study is that all of this is happening totally out of awareness and at the level of very elementary linguistic distinctions.

Keywords: phonology, subliminal, unconscious, N320, ambiguity, avoidance, consciousness, defense

OPEN ACCESS

Edited by:
Anatolia Salone,
Università degli Studi G. d'Annunzio Chieti e Pescara, Italy

Reviewed by:
Francesca Ferri,
University of Essex, United Kingdom
Gerd Thomas Waldhauser,
Ruhr-Universität Bochum, Germany

****Correspondence:***
Ariane Bazan
ariane.bazan@ulb.ac.be

†Present Address:
Ariane Bazan,
Service de Psychologie Clinique et Différentielle, Centre de Recherche en Psychologie Clinique, Psychopathologie et Psychosomatique, Université libre de Bruxelles, Brussels, Belgium
Ramesh Kushwaha,
Department of Neurology, University of Michigan Hospitals, Ann Arbor, MI, United States
E. Samuel Winer,
Department of Psychology, Mississippi State University, Starkville, MS, United States
J. Michael Snodgrass,
Department of Psychology, University of Michigan, Ann Arbor, MI, United States
Linda A. W. Brakel,
Departments of Philosophy and Psychiatry, University of Michigan, Ann Arbor, MI, United States

‡Howard Shevrin died January 18, 2018 in Ann Arbor, Michigan

Received: *02 September 2018*
Accepted: *14 February 2019*
Published: *05 April 2019*

Citation:
Bazan A, Kushwaha R, Winer ES, Snodgrass JM, Brakel LAW and Shevrin H (2019) Phonological Ambiguity Detection Outside of Consciousness and Its Defensive Avoidance. Front. Hum. Neurosci. 13:77. doi: 10.3389/fnhum.2019.00077

INTRODUCTION

While language is decoded consciously along semantic lines, different psychoanalytic authors, chiefly among whom Sigmund Freud, have stressed the importance of the word form, this is its phonology, when it comes to unconscious mental processes (for a systematic review, see Bazan, 2007, 2011). In the *Interpretation of dreams* Freud (1900/1958 p. 530; Italics added) proposes

that "psychic elements" in free association are connected by associations, which are often based on "*assonance, verbal ambiguity*, and temporal coincidence, without inner relationship of meaning; in other words (…), they are connected by all those associations which we allow ourselves to exploit in *wit and playing upon words*." Or again, for dreams: "The ideas which transfer their intensities to each other stand in the loosest mutual relations. They are linked by associations of a kind that is scorned by our normal thinking and relegated to the use of jokes. In particular, we find associations based on *homonyms and verbal similarities* treated as equal in value to the rest." (Freud, 1900/1958, p. 596[1]). Repressed concerns, for example, would express themselves by way of phonologic ambiguity (Freud, 1901/1974). This is a pithy example: "a patient tried to attribute his nervousness to business worries (…) during the cotton crisis. He went on to say: 'My trouble is all due to that d—frigid wave; there isn't even any seed to be obtained for new crops.' He referred to a cold wave which had destroyed the cotton crops, but instead of writing 'wave' he wrote 'wife.' In the bottom of his heart he entertained reproaches against his wife on account of her marital frigidity and childlessness" (Freud, 1901/1974[2]). A patient of the first author, troubled by the increasingly feminine ways of his 4-year-old daughter, spoke of his "fear year old daughter." In a footnote of *Psychopathology of everyday life*, which only appears in the French translation, Freud (1901/1953, p. 239) holds: "We think we are generally free to choose words and images to express our ideas. But a closer observation shows that it is often considerations extraneous to the ideas that decide this choice and that the form in which we mold our ideas often reveals a deeper meaning, which we do not realize ourselves. (…) some of these images and ways of speaking are often allusions to subjects which, while remaining in the background, exert a powerful influence on the speaker. I know someone who, at one time, continuously used, (...) the following expression: "When something suddenly crosses the head of someone." Now I knew that the man who spoke in this way had recently received the news that a Russian projectile had passed through the field-cap which his son, a fighting soldier, had on his head[3]" The same would hold true in dreams, in symptoms and in psychotic delusions. For symptoms, e.g., Breuer and Freud (1893-95/1955, p. 216; Italics added) indicate that there is an irrational "symbolic relation between the precipitating cause and the pathological phenomenon" which, indeed, is "often based on the *most absurd similarities of sound and verbal associations*."

All this has fuelled the interest for phonology in the unconscious processing of language in some of the studies of (late) Howard Shevrin and his team. For example, in a study with subliminal priming of reversible words (such as "sleep"/"peels") a tachistoscopic paradigm was used to test for the unconscious recognition of the reversed readings (Klein Villa et al., 2006). In this experiment, a 1 ms reversible target, such as e.g., the word "dog," was followed by a semantically related target and a distracter. In the forward condition, the related target was a straightforward semantic associate of "dog" (e.g., "canine") while in the reverse condition, it was a semantic associate of the reversed word (i.e., "god," e.g., "angel"). There was only straightforward priming with supraliminal presentation. But in subliminal presentation of the targets, there was semantic priming in *both* forward and reverse conditions in anxious participants. At the other hand, and strikingly, with low self-evaluation of anxiety there was a proportionate avoidance of the semantic associate in both conditions subliminally.

These observations are in line with previous results with subliminal priming at 1 ms priming (unmasked) and with a stimulus detectability parameter of d' not different from zero. Snodgrass and colleagues (Snodgrass et al., 2004; Snodgrass and Shevrin, 2006) have extensively argued that under these stringent conditions, priming effects only revealed themselves as an interaction effect with personality factors. Indeed, Shevrin (1992) has suggested before that, whereas at a conscious level, personality factors generally do not interfere with cognitive tasks, this becomes a different matter at a subliminal, or unconscious, level. In the Klein Villa study, it was found that participants with low trait anxiety did not show an absence of semantic priming, but an inhibition, meaning that they chose the distracter at higher levels than chance. Likewise, Snodgrass et al. (1993) had their participants to identify one out of four words, known to them, presented at 1 ms. They were are asked to use one of two strategies: in the *look* strategy, subjects were instructed to attend carefully to the visual field and look hard for any trace of the stimuli; in the *pop* strategy, subjects were urged to allow one of the four stimulus words to pop into their minds—to say whichever of the four words comes to mind. Subjects were also asked which of the two conditions they preferred; they were called "lookers" or "poppers" according to their preference. The 1993 experiment was replicated both in the Shevrin lab (Snodgrass and Shevrin, 2006) and by Van Selst and Merikle (1993). The main consistent finding in the original experiment and in its replications, then, is that "poppers" facilitated slightly in the pop condition, giving more correct answers than chance level (25%), while "lookers" did better than chance in the look condition and performed significantly below chance in the pop condition (for meta-analysis, see Snodgrass and Shevrin, 2006). This pattern of results illustrates an important qualitative characteristic of unconscious processes, namely that inhibition can occur in situations in which conscious perception would characteristically produce facilitation.

In the present study we wished to further investigate the subliminal processing of word phonology at the same stringent

[1]For example, Freud (1900/1958: 560) qualifies the homophony dysenteria/diphteria in one of his dreams (« Irma's injection ») as a « paraphasic assonance ».

[2]This example is given by Dr. A. A. Brill.

[3]Our translation of: « On se croit en général libre de choisir les mots et les images pour exprimer ses idées. Mais une observation plus attentive montre que ce sont souvent des considérations étrangères aux idées qui décident de ce choix et que la forme dans laquelle nous coulons nos idées révèle souvent un sens plus profond, dont nous ne nous rendons pas compte nous-mêmes. (…) certaines de ces images et manières de parler sont souvent des allusions à des sujets qui, tout en restant à l'arrière-plan, exercent une influence puissante sur celui qui parle. Je connais quelqu'un qui, à une certaine époque, se servait à chaque instant, (…) de l'expression suivante: 'Lorsque quelque chose traverse tout à coup la tête de quelqu'un.' Or, je savais que celui qui parlait ainsi avait reçu, peu de temps auparavant, la nouvelle qu'un projectile russe avait traversé d'avant en arrière le bonnet de campagne que son fils, soldat combattant, avait sur la tête. ».

priming conditions with d' = 0. In the experimental trials, one of the targets was a direct phonological reversed form of the prime (e.g., "door" and "road"), while the other target was a non-related distracter (e.g., "lung"). Moreover, to be able to disentangle phonology and orthography, the phonological targets were perfect phonological reversed forms, though they were orthographically dissimilar (e.g., "lakes" and "scale," "talk" and "caught," "moan" and "gnome"). In contrast to the Klein Villa et al. (2006) study, both the prime and the two targets were presented at 1 ms. Though the participants did not see anything during the whole sequence, they were urged to make a choice as to which target they thought was most similar to the prime (after having had fully visible practice sequences): they said "one" for the upper choice and "two" for the lower choice. Moreover, we measured Event Related Potentials (ERPs) to explore for physiological markers of the recognition of subliminal phonological similarity. Indeed, Shevrin and colleagues had shown that subliminal stimuli elicit ERP patterns that are structured similarly to supraliminal ERP patterns at all electrodes, be it at a lesser amplitude (Shevrin and Fritzler, 1968; Shevrin et al., 1992, 2010, 2013; Bernat et al., 2001a,b; Silverstein et al., 2015). Since we wanted to verify if participants were unconsciously able to detect the phonological similarity between pairs of reversed words, we focused in particular on a negative N320 component sensitive to phonology and known to peak between 300 and 450 ms after target presentation in phonological oddball paradigms in particular.

Indeed, previous work that has investigated participant response to consciously presented, phonologically similar stimuli and their associated brain indices has found that the N320 is indicative of phonological processing. For example, Bentin et al. (1999), using a visual word presentation paradigm, proposed a rhyme task in which the targets were words or pseudowords rhyming with the word *vitrail*, with orthographically possible endings being "aille," "ail," "aye," or "aï." Nontarget stimuli did not rhyme and elicited a negative potential peaking at about 320 ms after stimulus onset, which was called N320. Bentin et al. (1999) concluded that the N320 could represent an early lexical or prelexical process of grapheme-to-phoneme-to-phone translation. In addition, Grossi et al. (2001) also used a visual rhyme task with orthographically dissimilar rhyming pairs (ex. "juice" and "moose") and found a negative deflection which began between 250 and 300 ms, peaked between 300 and 400 ms, and which was larger for non-rhyming than rhyming targets. They concluded that this slow wave asymmetry "may reflect the allocation of resources to areas specific to phonological decoding of written words" (Grossi et al., 2001, p. 621). Simon et al. (2004) and Simon et al. (2006) instructed participants to passively attend to the visual presentations of words and pseudowords. They found that adult skilled readers in French displayed a specific component (N320) with a left occipito-temporal scalp distribution. This component was implicated in phonologic transcription and taken to mark the use of grapheme-phoneme conversion. Interestingly, Proverbio et al. (2004) have proposed a relation between this negativity in response to written word presentation and an error mismatch negativity in response to auditory word presentation occurring at 270–300 ms, i.e., the "phonological mismatch/mapping negativity" (PMN; Connolly et al., 1995, 2001; D'Arcy et al., 2000; Dehaene-Lambertz et al., 2000) which is selectively sensitive to phonology. It is thought to index a response that reflects phonological processing in all relevant circumstances but is larger when the analysis of an incoming acoustic signal mismatches phonemic expectations (Newman et al., 2012, p. 145). In conclusion, the N320 component, both in the visual rhyme and word judgement tasks (Bentin et al., 1999; Grossi et al., 2001; Simon et al., 2004, 2006) and in the acoustic tasks, is thought to reflect mismatch with phonological expectation, which in visual tasks specifically requires a higher activation of the grapheme-to-phoneme conversion process.

In the present research, there was only phonological similarity in one of the targets of the experimental trials while in control trials, none of the targets was similar to the prime. Consistent with previous findings, we expected that this design would produce a *subliminal* N320-effect if phonological mismatch was recognized in the control trials as compared to the experimental trials and that this effect would depend upon personality factors. Moreover, if a correlation between the ERPs and the behavioral choices made by the participants is found, this would suggest that, though the participants are convinced they made their choices in a totally arbitrary way—since they couldn't see anything consciously—their choices were nevertheless informed by processes they are unaware of.

MATERIALS AND METHODS

Participants

Thirty-two right-handed paid participants took part in the study. They had a mean age of 21.8 (range 18–33, *SD* = 3.07), 22 were women, all had vision correctable to 20/20 and all reported no history of neurological or psychiatric problems. Participants were recruited through a newspaper advertisement. One participant claimed he sometimes could see the stimulus. Accordingly, he has the highest score of phonological choices of all participants (20 out of 30) and a fairly high detectability score (d' = 0.32). These atypical scores make him an outlier; therefore he was excluded from data-analysis. Therefore, the *N* of this experiment is 31.

Materials: Apparatus, Masking Technique and Word Stimuli

The stimuli were presented on 4 X 6 inch white cards in the two fields of a three-field Gerbrands Model T3-8 tachistoscope. The first field was the prime, the second field was the target field and the third field was used as a fixation field. Luminance levels for the stimulus fields, as well as the ambient light level in the subject chamber, were set at 5 foot/lamberts luminance and the duration for the subliminal presentation was 1 ms.

A prime word was followed by a target card with two target alternatives, a phonological choice and a non-related choice. The two target alternatives were at equal distances above and below the position of the fixation point and counterbalanced over the different items. All words were one-syllable in length. The phonological target alternative was the exact phonological reversed form of the prime word (Webster dictionary),

although it was orthographically dissimilar. Sometimes the orthographic dissimilarity was substantial such as e.g., "nice-sign," "chance-snatch," "moan-gnome," "caught-talk," sometimes the orthographic dissimilarity was very limited such as e.g., "boss-sob," "spill-lips," "till-lit," "sap-pass" (see **Table S1** for the full list with the phonological transcriptions).

The orthographic similarity between each target word and the prime word was calculated using Weber's graphemic similarity index (Weber, 1970): OS = 10 * [((50*F + 30*V + 10*C)/A) + 5*T + 27*B + 18*E] with F = Number of common bigrams in both words, V = Number of common inverted bigrams, C = Number of common letters, A = Mean number of letters in both words, T = Proportion of number of letters in the shorter words with respect to the longer word, B = Common starting letter, and E = Common ending letter.

Each subject is presented 30 experimental trials and 30 control trials in a random order. For the construction of the control trials we divided a total of 60 triads in two lists. A subject is presented either the 30 triads of list 1 (experimental trials) and 30 recomposed triads of list 2 (control trials) or vice versa (list 1 serves as the control list, list 2 is the experimental list); this alternation is rotated over the subjects. The list of control trials is composed by pseudo-randomly attributing the target words to the primes to which they don't belong in within the same list.

The behavioral dependent variable is the number of phonological choices. In the experimental condition, the phonological choice is the target choice, which is the phonological reversed version of the prime; in the control condition the "phonological choice" is the target choice, which is the phonological reversed version of the original prime it belonged to. The experimental effect is the difference between the number of phonological choices in the experimental condition (out of 30) and the number of phonological choices in the control condition (out of 30).

Experimental Procedure

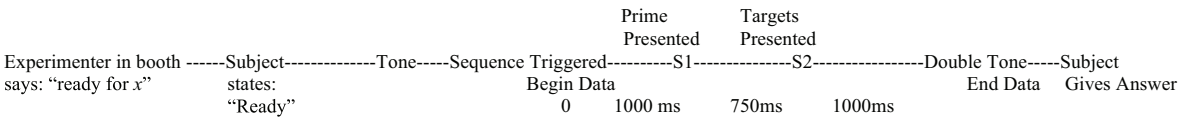
Main Experiment

After a brief introduction to the laboratory, participants completed an informed consent statement; informed consent and all procedures were approved by the Institutional Review Board of the Department of Psychiatry of the University of Michigan. Electrodes were attached prior to seating participants in a sound-proof, electrically shielded, temperature-controlled booth.

In order to familiarize the participants with the unusual experimental task, we presented a series of practice stimuli prior to the experiment proper. There were no obvious similarities between prime and targets in any of the practice trials to avoid inducing a systematic search for any type of similarity, semantic, phonological or orthographic; participants were not informed of the type of similarity used for the experimental presentations. First, a fully supraliminal practice trial was presented "YEAR" (prime; 500 ms) followed by "HOLE NIECE" (targets; 4,000 ms) in order to familiarize the participant with the experimental task: "*give the choice that in your opinion is most similar to the first word*." Second, a second practice trial "JUICE" followed by "BELT EARN" was presented 4 times subsequently whereby the presentation times of both prime and targets were gradually decreased from 30 to 10, then to 5 and finally to 1 ms in order to familiarize the participant with the subliminal presentations. Participants had to say "one" if they picked the upper word and "two" for the lower word (no numbers were indicated on the card). Third, a third practice trial "AGE" followed by "DOLL NERVE" was presented directly at 1 ms for both prime and targets, in order to familiarize the participant with the subliminal experimental condition. Finally, two last practice trials "BARN" followed by "MOLD QUICK" and "CALM" followed by "PINK STOVE" were presented at 1 ms for both prime and targets and including the EEG measurements (as indicates below) to familiarize the participant with the full experimental conditions.

The main experiment consisted of 60 subliminal random presentations. For all trials, participants were instructed to remain as still as possible, focus on the fixation point, pay attention, and keep eye blinks to a minimum during each stimulus presentation. This instruction was repeated periodically during the experiment.

The stimulus delivery sequence was as follows:



First, the experimenter in the booth, who was blind to the stimulus content and experimental hypotheses, called "ready for x" with x being the number of the trial. This was the signal for the participant to focus his/her eyes on the fixation point. When the subject was ready for the sequence to begin, he/she says "ready." The experimenter outside the booth, who was also blind to the stimulus content, monitored the EEG recordings for possible eye blinking or excessive muscle movement. If the record appeared free of artifacts, the EEG experimenter pushed a button producing a first tone, which preceded the triggering of the sequence. Participants were told to anticipate a sequence of quick presentations of words on the screen that they may or may not be able to see, and that their responses, including their brain responses, would be monitored. The sequence consisted of 1,000 ms fixation point, after which the prime word was presented for 1 ms, followed by the fixation field again for 749 ms; then the target card for 1 ms, again followed by the fixation field for 1,000 ms. After that came a double tone, signaling the end of the sequence and of the data collection period. This was the signal for the subject to relax, move, blink and give his/her answer. Records contaminated with artifacts (determined by online visual inspection; $\leq$ 5% per participant) were rejected and the trial was presented again in the next cycle. Participants were not informed when trials are retaken vs. advancing normally to the next trial. The final source of variability was the time between the double tone and the next single ready tone. Most frequently this was about 5 s, which is the time it took for the experimenter in the booth to change the stimulus cards.

Detection Control Task (Conscious Perception Index)

A 64-item, forced-choice detection task was administered at 1 ms and 5 foot/lamberts luminance (the same conditions as during the experiment) to determine if stimulus presentations met the criteria for the objective detection threshold (Snodgrass et al., 2004; Snodgrass and Shevrin, 2006). The sequence of the cards was the same: a first prime card was presented first and then a second target card with two words, one above and one under the fixation point. In half of the trials the cards with the words (both prime and targets) had been replaced with plain blank cards. The 64 trials were the same for all participants and consisted of 32 blank primes and blank targets and 32 word primes and word targets. The 32 word *primes* consisted of 16 word primes out of each list; the 32 word *targets* consisted of 8 targets to the primes and 8 random targets for each list (see **Table S1**). The subjects' task was to state after each presentation what they believed had been presented, the word or blank cards, and to keep their responses roughly equally divided between the two choices.

Supraliminal Control Experiment

To control for the fact that the participants were able to see the phonological similarity when the stimuli were presented fully consciously, they completed the same tasks as in the main experiment with the same stimuli in the same order, but supraliminally on pen and paper, after the detection task. Participants were simply given the same triads on a paper sheet and circled the choice they thought was most similar to the prime word. (Due to time constraints for the participants' comfort, we could not add a supraliminal part to the tachistoscope-EEG part of the research).

Social Desirability Scale (SDS)

Next, they completed the Personal Reaction Inventory (Crowne and Marlowe, 1960). This 33-item true/false scale is a social desirability scale (SDS) which measures the need for social approval, and the readiness or reluctance to report negative emotional states. It evaluates to what extent people can admit so-called unacceptable but nevertheless quite universal truths about human functioning—e.g., "I have never deliberately said something that hurt someone's feelings."

Physiological Measurement Apparatus

The recording sites were F_{P1}, F_{P2}, F_3, F_Z, F_4, C_Z, T_3, T_4, T_5, T_6, P_Z, P_3, P_4, and EOG according to the International 10–20 Electrode Placement System. Next to the traditional midline electrodes Fz, Cz, Pz, all temporal electrodes (T3, T4, T5, T6) and parietal electrodes P3 and P4 were added, as the research was linguistic in nature; frontal electrodes were of interest since phonology also implies frontal circuits (such as Broca's area). Electrode caps (BIOPAC Systems, Inc.; CAP100C; medium 54–58 cm and large 58–62 cm) were used: this Lycra stretch cap holds 19 imbedded tin electrodes closely to the subject's head; electrodes are pre-positioned in the international 10/20 montage. When the electrode cap is in place, electrode sites were cleaned with a mild abrasive solution and EEG recording gel was injected into each electrode with a blunt-tipped syringe. All electrodes were referenced to linked ears with a mastoid ground. Electrode impedance was <3 kΩ. Eye activity was monitored by electrodes placed on the outer canthus and suborbital ridge of the right eye.

All signals were collected utilizing a Grass Model 8-24D polygraph linked to a Macintosh computer. Signals were digitized at 250 Hz through a National Instruments NB-MIO-16X A-D board controlled by LabVIEW 2.2 (National Instruments) software, then stored in computer files for off-line analysis. Signals were analog filtered online through Grass Model 8A5 AC amplifiers with a low-pass frequency of 100 Hz, and a high-pass frequency of 0.1 Hz. ERPs were sampled for 2,750 ms, including a 1,000-ms prestimulus interval. For the N320 component, the signal was filtered at 9 Hz.

Because the tachistoscopically presented subliminal 1 ms stimuli (black print on a white background) are preceded and followed only by a fixation field (black dot on a white background) of equal luminance, there was very little disturbance in the visual field. This resulted in an ERP waveform which was substantially smaller in amplitude and "noisier" than conventional ERP waveforms to supraliminal stimuli.

Data Reduction

Individual ERP trials were averaged across the experimental and the control trials. Component windows were defined based on grand average ERP wave forms across all presentations and participants (Hoormann et al., 1998). This process was completed within participant and electrode. Component values from the averages in the experimental and control items were then compared statistically. Baselines were calculated as the mean amplitude from 500 to 988 ms prior to prime presentation. The time interval for N320 was 300–372 ms locked to the targets (see introduction). Then an automated computer program was used to find the most negative peak within this window (300–372 ms) for each experimental and control averaged waveform. A similar pattern of results was fond using filters of 25 Hz.

Statistical Analyses

The experimental ERP component-effect is the difference in amplitude between the component in the experimental condition (where one of the targets is the phonological reversed form of the prime) and the component in the control condition (where none of the targets are related to the prime). For the negative N320 component, the literature review (see above) leads us to expect that the experimental component would be smaller than the control component, resulting in a positive difference or experimental effect. A negative difference or effect means that the experimental component is larger in (negative) amplitude than the control component. Due to the relatively low N and the exploratory nature of the ERP analyses, which included other components that are not relevant to the current research question and thus not reported here, we have not adjusted alphas for multiple comparisons leaving significance values at $p < 0.05$.

RESULTS

Behavioral Results

Subliminal and Supraliminal Forced-Choice Tasks

In the subliminal priming condition, the mean number of phonological choices was 13.9 ± 0.4 (± Standard Error of the

Mean) out of 30 in the experimental condition, and 15.0 ± 0.5 out of 30 in the control condition. There was no principal behavioral effect, experimental vs. control, on the number of phonological choices picked by the participants, though there was a tendency to pick the non-related choice ($p = 0.068$; see **Table 1**). In the pen-and-paper supraliminal condition, there was a clear choice for the phonologically similar words in the experimental condition with means of 22.7 ± 0.9 in the experimental vs. 14.8 ± 0.5 in the control condition ($p < 0.001$). Therefore, clearly participants are able to recognize phonological similarities even if in the present research we used phonological reversed forms. A two-way repeated measures ANOVA [condition (experimental, control) by threshold (subliminal, supraliminal)] shows a significant interaction effect of condition x threshold [$F_{(1,30)} = 65.7$; $p < 0.001$; $\eta_p = 0.69$].

Control for Subliminality

Detection d' was 0.044 ± 0.047 with a range from −0.40 to 0.74 (95% confidence-interval: −0.0523 to 0.1408) and was not significantly different from zero ($p = 0.357$). Moreover, the participants were asked at several times during the experiment if they saw something: (1) after each practice trial; (2) halfway the experiment and (3) after the detection experiment. Finally, on debriefing they had to indicate if at any point during the experiment they noticed something. For the 1 ms presentations none of the participants indicated seeing something at any point (except for the excluded participant). Altogether, these data confirm that the energy mask effectively precluded conscious recognition of stimuli at 1 ms exposure.

Note that there was no correlation between the behavioral effect (net number of phonological choices) and the d' ($r = 0.05$; $p = 0.783$; see **Figure S1**).

Social Desirability Scores

The mean SDS-score was 14.3 ± 0.9 (out of 25) with a range from 4 to 25. Subliminally, there is a substantial correlation between the experimental effect (net number of phonological choices) and the social desirability score: the higher the SDS-score, the smaller the experimental effect ($r = -0.51$; $p = 0.004$). Only at low SDS is there a net positive experimental effect with more phonological choices in the experimental than in the control conditions. At mean or high SDS there is a negative experimental effect, i.e., phonological choices in the experimental conditions are significantly less frequently chosen than chance, i.e., they are avoided (see **Figure 1**). Supraliminally, no correlations were found between the net number of phonological choices and SDS ($r = 0.16$; $p = 0.397$).

TABLE 1 | Main behavioral effects: mean number of phonological choices ± SEM (out of 30; $N = 31$).

	Experimental	Control	*p*
Subliminal	13.9 ±.4	15.0 ±.5	0.068
Supraliminal	22.7 ±.9	14.8 ±.5	<0.001

No Difference Between Experimental and Control N320 Parameters

A schematic topographical plot based upon the amplitude values given in **Table S2** shows that N320 is largest at midline electrodes Fz, Cz, and Pz and is also more left than right-lateralized. Based on this, but also relying up on theoretical reasons (Bentin et al., 1999; Proverbio et al., 2004; Simon et al., 2004, 2006; see Discussion) given we measure here ERPs to subliminal stimuli, we regrouped two components, a midleft component (average of electrodes F_{P1}, F_3, F_Z, C_Z, T_3, T_5, P_Z, and P_3; −0.53 ± 0.13 μV) and a right component (average of F_{P2}, F_4, T_4, T_6, and P_4; −0.35 ± 0.14 μV; $p = 0.001$).

A repeated measures ANOVA for the N320 amplitudes (in μV) with localization (midleft vs. right) and condition (experimental vs. control) as factors gave a highly significant localization contrast [$F_{\text{localization }(1,30)} = 14.531$; $p = 0.001$]. However, there was no main effect between experimental and control trials [$F_{\text{condition }(1,30)} = 0.090$; $p = 0.776$] and also no interaction effect. A repeated measures ANOVA for the N320 latencies (in ms) with localization and condition as factors (same as above) gave no localization contrast [$F_{\text{localization }(1,30)} = 0.007$; $p = 0.934$], no main effect between experimental and control trials [$F_{condition\ (1,30)} = 2.714$; $p = 0.110$] and also no interaction effect. As concerns the condition main effect, there is a non-significant tendency for the N320 to come earlier in the control vs. the experimental trials (335 ms ± 4 vs. 343 ms ± 4; 2-tailed). At the midleft electrodes the N320 thus peaked between 304 and 376 ms (with a $\mu = 339 \pm 4$ ms) and with amplitudes between −0.31 and −0.74 μV (with a $\mu = -0.47 \pm 0.12$ μV).

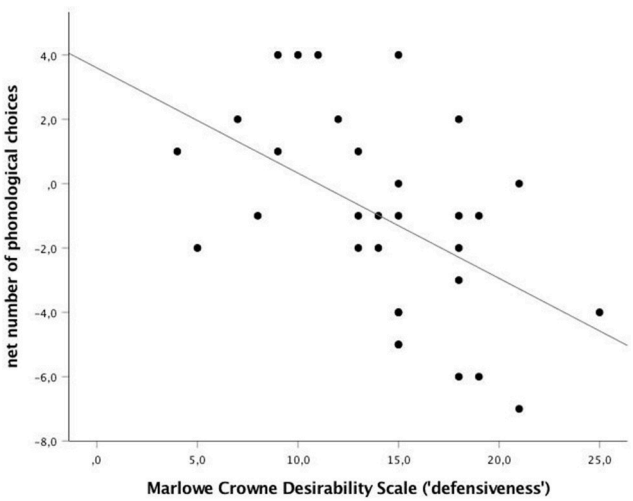


FIGURE 1 | Low defensive participants make phonological choices, high defensive people avoid them. Net number of phonological choices (experimental–control) in function of the Crowne-Marlowe Social Desirability scores ($r = -0.51$; $p = 0.004$; $N = 31$). The less "defensive," the more net phonological choices made by the participant in a fully subliminal priming experiment with tachistoscopic presentation of both prime and target at 1 ms; the participant's task was to pick the target choice which was most similar to the target, choosing between a phonological reversed target (e.g., "DOOR" and "ROAD") and a non-related target (e.g., "LUNG").

The N320 Characteristics Significantly Predict the Behavioral Response Choice

Even if there is no main effect of condition (experimental vs. control), there is an interaction effect between the N320 amplitude difference (experimental minus control) and the behavioral choices the participant picks ca. 1 s later: the larger the N320 amplitude effect at the mid-left of the brain, the more likely the participant will pick the phonological target response ($r = 0.43$; $p = 0.01$). Two ERP traces are shown in **Figure 2**; ERPs may appear unusual due to the extremely brief exposure durations and no backward masking, but Bernat et al. (2001a) have shown that they possess the same component structure as supraliminal ERPs. Note that there is no correlation at the right of the brain ($r = 0.24$; $p = 0.197$).

In other words, the more the N320 amplitude effect is positive (experimental more positive than control), the more the participant chooses the phonological response; the more the N320 amplitude effect becomes negative (experimental less positive than control), the more the participant will pick the non-related target response (see **Figures 3** and **4**). In other words still, the more the participant show electrophysiological signs of recognizing the phonological reversed word subliminally, the higher the probability that he/she will pick that choice (even if to the participant, he/she is just saying "one" or "two").

Note that there is also a significant interaction of the N320 amplitude effects with social desirability. Indeed, the midleft N320-amplitude effect correlates negatively with MC social desirability ($r = -0.49$; $p = 0.005$; see **Figure S2**). The correlation is also significant at the right of the brain ($r = -0.39$; $p = 0.033$). The correlation results are logical since as we have shown that the N320 amplitude effect correlates with the behavioral effect (see **Figure 3**) and that the behavioral effect correlates with the SDS.

Item Analysis: The Orthographic Similarity Between Prime and Phonological Target Does not Influence Either the Behavioral Choices or the N320 Amplitude

The phonological targets are composed of exactly the same phonemes as the primes but in a reversed order; however they are never totally orthographically similar to the primes and sometimes they are, in fact, quite dissimilar (ex. talk/caught). However, as is shown in the **Table S1**, they are still more orthographically similar to the primes than are the distracter items. Therefore, we do not know if the effect measured is mainly carried by the phonological similarity or by the orthographic similarity between the prime and the phonological target. To disentangle both effects we have calculated an orthographic similarity (OS) index using Weber's graphemic similarity index (see **Table S1**) between prime and phonological target. The orthographic similarity between the prime and any of the targets does not affect the chance of the phonological target to be chosen: there are no correlations between the net number of phonological choices and the orthographic similarity neither subliminally nor ($r = 0.062$; $p = 0.639$) supraliminally ($r = 0.020$; $p = 0.881$). Moreover, **Table S3** shows that correlations between the N320 amplitudes in the experimental condition with the OS between the prime and the phonological target are mostly negative, but we find marginally significant effects at the two prefrontal sites and at F_3 exclusively. In other words, at these electrodes exclusively, orthographic similarity between prime and phonological target might slightly and non-significantly contribute to the N320 reduction upon presentation of the phonological target.

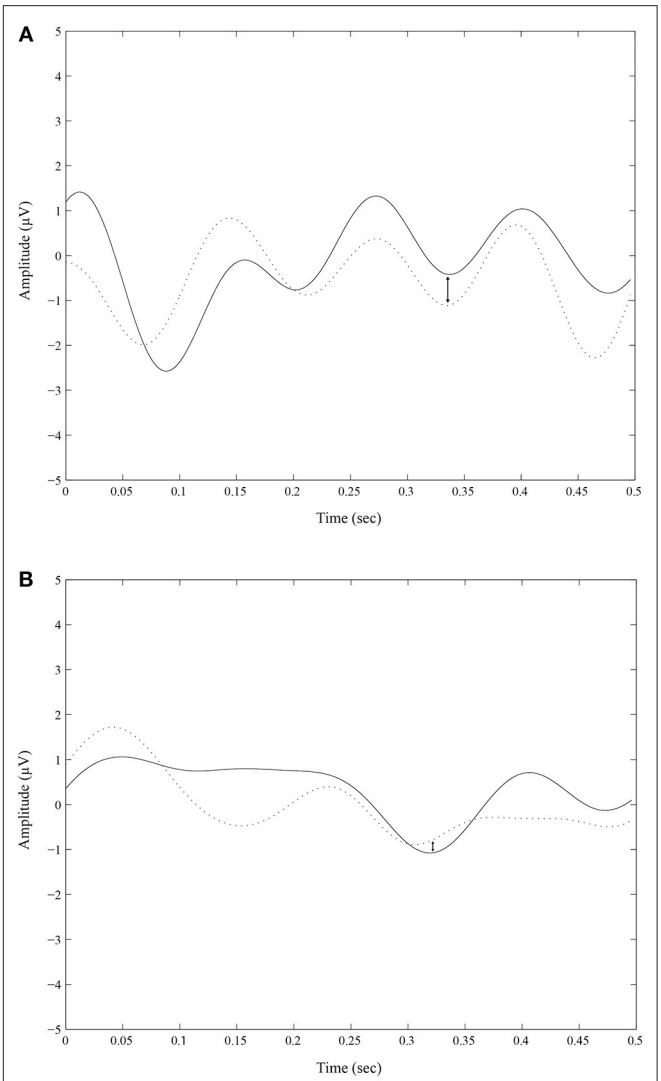


FIGURE 2 | ERP traces for a participant with a high number vs. a low number of phonological choices. Experimental (solid line) vs. control (dotted line) N320 amplitudes at the mid-left of the brain (average of F_{P1}, F_3, F_Z, C_Z, T_3, T_5, P_Z, and P_3 electrodes) **(A)** for a participant with a high net number (4) of phonological choices and **(B)** for a participant with a low net number (−7) of phonological choices (right). The N320 waves are indicated.

DISCUSSION

There Are No Main Effects

No main effects were found: there was no significant behavioral choice for the phonological alternative in the subliminal condition and we did not find a significant difference for

the whole group between experimental N320 and control N320. The 1 ms-tachistoscope presentations were very stringent conditions of subliminality, said to be at the "objective detection threshold" (Snodgrass et al., 2004; Snodgrass and Shevrin, 2006). It might be feared that this stimulus intensity is too low for anything to happen. However, Shevrin and colleagues have repeatedly shown that these kind of subliminal stimuli elicit ERP patterns that are structured similarly to ERP patterns evoked by supraliminal stimuli at all electrodes, be it at a lesser amplitude (e.g., Shevrin and Fritzler, 1968; Shevrin, 1973; Bernat et al., 2001a,b; Silverstein et al., 2015). Moreover, in previous research, it has rarely been possible to observe main effects. For example in the "pop-look" study (see above; Snodgrass et al., 1993), though overall identification was at chance, it was found consistently that poppers and lookers did better than chance in their preferred condition and that lookers performed significantly below chance in the pop condition. In the study by Klein Villa et al. (2006), again, there was no main effect but there was a significant interaction effect with trait anxiety, with facilitation for semantic priming in high trait anxiety and avoidance in low trait anxiety. Because of these bidirectional tendencies operating in function of personality, there is an absence of main effect (for a review on unconscious inhibition, see Bazan and Snodgrass, 2012). To explain the avoidance results, we suggested the implication of defensive operations. For the pop-look study Snodgrass and Shevrin (2006, p. 63) proposed: "when utilizing the strategy congruent with their preference, perhaps participants unconsciously allow this activation to influence their response, elevating performance above chance. In contrast, when utilizing the incongruent strategy, such influences are unconsciously rejected and below-chance performance ensues." The looker inhibition then "might reflect a simple form of unconscious defense [. . .]. Along these lines, lookers consistently expressed a strong preference for activity and control, explaining that they disliked 'doing nothing' as the pop instructions required. Obliging lookers to relinquish conscious control with pop instructions might instantiate a mildly conflictual situation, producing inhibition, whereas more congenial look instructions would not, yielding facilitation." For the Klein Villa et al. (2006) study we proposed that a defensive organization may imply an effective inhibition of word associativity (Freud, 1895/1966, 1900/1958; see also Bazan, 2006). Anxiety interferes with the organization of defense so that people with structurally higher levels of anxiety might not be able to defend as efficiently and show associative facilitation, explaining the results. Alternatively, it might also be that people, who on a paper-and-pen questionnaire claim to be usually less anxious, are more defensive than people who admit more anxiety experience and thereby inhibit associativity better. This is in line with Rapaport (1967) who posited that personality and its use of defensive organization can have a powerful regulating control over cognition.

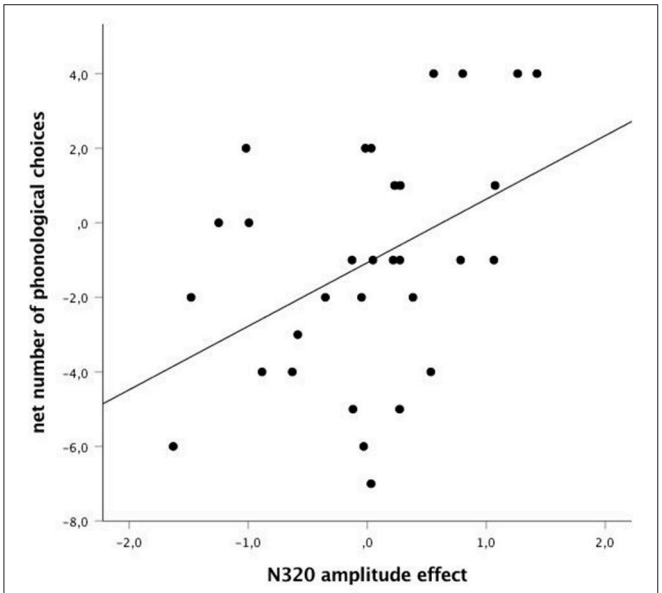


FIGURE 3 | Net number of phonological choices by N320 amplitude effect (experimental−control) at the mid-left of the brain (average of F_{P1}, F_3, F_Z, C_Z, T_3, T_5, P_Z, and P_3); $r = 0.43$; $p = 0.017$); $N = 31$. The more positive the N320 amplitude effect (i.e., the more negative the N320 amplitude in control trials as compared to experimental trials), the more net phonological choices.

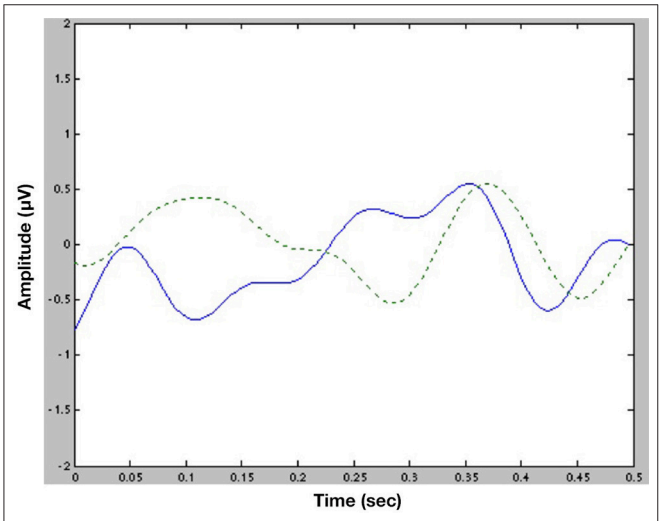


FIGURE 4 | Average ERP traces (experimental minus control) at Cz for subjects with a positive behavioral effect ($\mu = 2.5$; $N = 10$; solid line) vs. for subjects with a negative behavioral effect ($\mu = -3.1$; $N = 19$; dotted line). The higher the difference between experimental and control at N320, the more phonological choices ca. 1 s after the N320.

N320 Amplitude Predicts Behavioral Choices

Our main finding, then, is that the behavior of a negative wave, peaking around 340 ms at midleft locations, correlates with the behavioral choice of the participant more or less 1 s later. In other words, the more the amplitude effect is positive (experimental more positive than control), the more the subject chooses the phonological target; the more the amplitude effect is negative (experimental more negative than control), the more

the subject chooses the non-related target. Because of this behavior we propose that this negativity could correspond to the N320. Indeed, this N320 has been described as being mobilized specifically when phonological decoding is at stake: the N320 component would represent the allocation of resources to areas specific to phonological decoding of written words (Grossi et al., 2001) or recoding of written words to phonemic representations (Bentin et al., 1999; Simon et al., 2006). This, then, is especially needed when the targets are phonologically different from the prime, i.e., more for the control than for the experimental targets. The more positive the difference between experimental and control N320 amplitude i.e., the more the participant recognizes the phonological similarity, the more he chooses the phonological target. Note that orthographic similarity does not influence the behavioral choices and that there is no significant contribution of orthographic similarity to the behavior of the experimental N320.

As concerns the spatial localization of this negativity over the scalp, it is best observed at the midline and left of the brain and the correlations with subsequent behavioral choices are especially high at midleft electrode sites. These results make sense with the phonologic linguistic decoding needed for the task. These results are also in some aspects comparable to e.g., those of Bentin et al. (1999) where the N320 was most evident over the temporal and temporo-parietal regions bilaterally but significantly larger over the left than over the right hemisphere and with those of Simon et al. (2004, 2006) who found a left occipito-temporal scalp distribution. In the present study there is no shift toward the back of the brain for the N320 (see **Table S2**). Proverbio et al. (2004) had shown that there is an antero-posterior topographic dissociation for N320 whereby access to the phonemic representation of letter strings would activate the left occipito-temporal regions for reading words and pseudowords and frontal regions for reading letter strings. In the present research, participants read both distinct words (e.g., the prime word and the non-related target) and words which share phoneme strings even if in reversed orders (the prime and the phonological target). This would fit well with our observations that N320 appears in a comparable way at frontal and parietal recording sides.

It thus appears that a phonological mismatch negativity, the N320, characterized for (visually presented) words in supraliminal conditions, also plays a comparable role in subliminal conditions. The subliminal conditions in the present experiment are very rigorous: the d' is at zero for the whole prime-target sequence and there is no correlation between the behavioral choices and the d', excluding any contribution of conscious detection to the results (see Snodgrass et al., 2004; Snodgrass and Shevrin, 2006).

Moreover, it appears that unbeknownst to the participants themselves, who are convinced that they are making arbitrary choices, saying "one" or "two" randomly, nevertheless a pattern can be seen in their behavioral responses, as those can be significantly predicted by their N320 waves. The amplitude of the N320 happening at the mid-left of the brain ± 340 ms after subliminal target presentation can significantly contribute to predicting the behavioral target choice the participant will make, ± 1,000 ms after target presentation, i.e., at the earliest ± 650 ms later than the N320 wave, while all the same the participant is having the experience of a totally arbitrary choice. Hence, we believe evidence is given for the association of physiologically measurable unconscious processes with subsequent conscious behavioral choices.

High SDS-Scorers Avoid Ambiguous Choices Unconsciously

While in the supraliminal experiment, participants clearly recognized and choose the phonological target, a majority (19 out of 32) of the participants choose a majority of non-related targets in subliminal conditions. In fact, the number of phonological choices is almost significantly less-than-chance level in the experimental condition ($p = .068$). Moreover, when we regress these results with the level of social desirability, measured with the Personal Reaction Inventory (Crowne and Marlowe, 1960) we find that there is an inverse relationship between this social desirability and the participants' responses: participants with low SDS give more phonological responses while participants with high SDS give more distracter responses. As these distracter items have no systematic relationship with the prime, neither phonological nor semantic, it must be assumed that a positive choice for the distracter is, in fact, a negative choice for the phonological choice, i.e., people with high SDS *avoid* the phonological target. How comes participants choose the non-related item when there is a phonologically similar choice?

In fact, their behavior is in average "logical" with their electrophysiology: the experimental N320 is more negative than the control N320, which, on the basis of the literature in supraliminal research, is indicative for the detection of more phonological dissimilarity in the experimental targets than in the control targets, hence the non-related target is picked. It is strange, though, that the phonologically similar target could behave subliminally as less similar than the control target. However, if we remember that the N320 component represents the allocation of resources to phonological decoding of written words, we must infer that these participants, who "avoid" the phonological target, mobilize a phonological recoding pathway more for the prime-phonological target pair than for the prime-non-related target pair. The phonological target, though, is not a straightforward phonological equivalent; it is, in fact, a phonologically reversed form of the target. Therefore, the phonological target might be particularly ambiguous for these participants, bearing both signs of similarity and of difference. Indeed, psycholinguistic research has shown that visually presented codes mandatorily activate a phonological code (e.g., Frost, 1998) and that, moreover, there can be a large variability of visual codes (partially) activating the same phonological code, including e.g., heterographic homophones (soule/sole; e.g., Van Orden, 1987), pseudohomophones (lace/lais; Martin, 1981) but also so-called neighborwords (fruit/flute) and even transposed-letter nonwords (jugde/judge, Perea and Lupker, 2003). There is less research on phonological reversion, though the fact that brain processes for mirror-writing generally remain immature even in adolescents who no longer produce letter reversals (Blackburne

et al., 2014) and commonly makes a usually transient return following stroke (e.g., Gottfried et al., 2003), shows the probably easy access to reversed language reading and processing in general. This is confirmed by a study by Saberi and Perrott (1999) who showed that artificially reversing auditory speech segments did not or minimally damage intelligibility.

Hence, high SDS-scorers physiologically react as if they are particularly puzzled by the experimental stimulus and as if they were in some ways double-checking its phonology, i.e., double-checking the ambiguity arisen between e.g., "name" and "main." This exacerbation of the phonological pathway would then explain the experimental pairs eliciting a more negative N320 than the control pairs. Indication for such a perplexity induced by ambiguity was found before in supraliminal research, as evidence from eye-tracking studies has shown that for homophones the absence of a clue to the contextually appropriate meaning, leads to longer fixation times (Binder and Morris, 1995). For the "non-avoidant" participants, once the target arrives its phonological decoding is facilitated since the phonological code of the prime is still active, and this fact does not seem to be double-checked. As a consequence, there seems to be no big need for them to mobilize the phonologic recoding pathway, and therefore the experimental N320 is smaller (more positive) than the control N320. This hypothesis is corroborated by the finding that the social desirability measure also correlates directly with the N320 amplitude effect: the higher the SDS, the more negative the N320 amplitude effect.

Language Ambiguity and Defense

The Marlowe-Crowne Social Desirability Scale (Crowne and Marlowe, 1960) was originally intended to be a measure of response bias. Representative items ask participants to respond to typical shortcomings (e.g., "I'm always willing to admit it when I make a mistake"). But the scale was later considered to measure a substantive personality dimension in its own right (Crowne, 1991; Paulhus and Reid, 1991) indexing defensiveness (Crowne and Marlowe, 1964; Weinberger, 1990; Crowne, 1991 p. 18; Paulhus et al., 1998). High scorers are people who deny anything unacceptable about themselves. Weinberger et al. (1979) consider that high SDS scorers resort to defensive inhibition in the face of anxiety when being confronted with unacceptable truths about themselves. In the present study as in others (e.g., Furnham et al., 2002) SDS are interpreted as indexing defensiveness and high vs. low SDS scorers are therefore called high, respectively low defensive participants.

Summarizing our findings, low SDS-scorers or low defensive participants have a more positive N320 upon phonological similarity than upon control and proportionally pick more phonological targets while high defensive participants display a more negative N320 upon phonological similarity than upon control and pick more distracter targets proportionally—and all this is happening unbeknownst to the participant. As the phonological target reveals another way of understanding the prime, maintaining open or opening up its interpretation possibilities, this phonological target elicits ambiguity as concerns the understanding of the prime (and, at the same time, as concerns its proper understanding). Avoiding the phonological target choice unconsciously by the high defensive participants might hence be understood as a way of avoiding ambiguity.

Why would one avoid, or even "defend" against ambiguity? Research from various fields in psychology has shown that ambiguity—defined as "the fact of something having more than one possible meaning and therefore possibly causing confusion" (Cambridge online dictionary)—is more or less aversive depending on personality. For example, the "Intolerance of Uncertainty Scale" (IUS; Freeston et al., 1994) assesses reactions to ambiguous situations and people with high IU are more likely to interpret ambiguous information as threatening (Heydayati et al., 2003) and experience anxiety when engaging in situations with uncertain outcomes (Dugas et al., 2001). A related concept, Tolerance of Ambiguity (TA), measures the tendency to perceive ambiguous situations as sources of threat (for review see Furnham and Marks, 2013). For those with low TA there is an aversive reaction to ambiguous situations including stress, avoidance, delay, suppression, or denial (e.g., Furnham and Ribchester, 1995). Psycholinguistic research in particular, shows that anxious individuals tend to interpret ambiguous information in words or texts in more threatening ways than do non-anxious individuals (e.g., see review in Blanchette et al., 2007).

But apart from being threatening from a content point of view, psycholinguistic research shows ample evidence that phonological ambiguity asks for more mental work as it slows down its processing and makes it less accurate both in visual and auditory paradigms. For a beautiful example, Van Orden (1987) reported that participants made significantly more false positive errors when the homophone mate of the target word was a member of the pre-specified category (e.g., is "rows" a flower?), compared to orthographic controls (is "robs" a flower?). Similar observations are found with other paradigms in heterographic homophones (e.g., Lukatela et al., 1999), with pseudohomophones (e.g., Martin, 1981) and with words with many phonological neighbors (e.g., Gahl and Strand, 2016).

Actually, independently of homophonic effects, language has an inherently ambiguous structure as intermediate or embedded words in sentences are thought to be transiently activated as well (such as the intermediate word "east" and the embedded word "egg" in e.g., "We stop begging," see Cutler et al., 2002). Therefore, correct decoding of language continually requires an efficient inhibitory mechanism for on-line disambiguation and normal language understanding (e.g., Chiarello, 1985; Burgess and Simpson, 1988; Atchley et al., 1999; Poldrack et al., 1999; Chee et al., 2000). When there is ambiguity, there is an even greater appeal to this energy-consuming inhibitory process (Gernsbacher and Robertson, 1995). Already from this economic point of view, language ambiguity might be considered as aversive. It makes sense to consider that less mental energy is available for allocation to this surplus of mental work, all the more when mental resources are scarce—such as e.g., in case they are needed for defense against socially undesirable judgments. In fact, it has been proposed before that this online inhibitory mechanism that allows for correct disambiguation is a possible

neurophysiological correlate of Freudian repression (Bazan, 2012). Both disambiguation from a psycholinguistic point of view (Gernsbacher and Robertson, 1995) and repression from a psychodynamic point of view (Freud, 1915/1957), are considered costly in mental energy. This would fit well with an interpretation of the current results proposing that high SDS-scorers, deemed defensive by us and others, seem indeed physiologically overreactive to ambiguity (i.e., invest a lot in this putative mechanism of repression) while showing behavioral reactions of avoidance (which is the observable defensive counterpart of repression).

Language Ambiguity and Psychoanalysis

Allowing ourselves for a digression into psychoanalysis at the end of this paper, not only is there more cognitive work required by an ambiguous stimulus but when there is an uncertain interpretation, there is by definition more chance for it to harbor a revealing and potentially threatening interpretation. Listen to how the American physician and poet Oliver Wendell Holmes (1891, p. 11) says it: "People that make puns are like wanton boys that put coppers on the railroad tracks.… They amuse themselves… but their little trick may upset a freight train of conversation for the sake of a battered witticism." Indeed, confronted with the ambiguous situation of a slip of the tongue—and by extension by any kind of language ambiguity—two reactions are possible: either we acknowledge some recognition of the ambiguous version, and even engage in an interpretation or we might deny any value to the sudden ambiguity and quickly close the ambiguous moment. Listening to potential language ambiguity is, in fact, a working principle for the clinical psychoanalytic work from a Lacanian point of view. To illustrate this principle, we refer to a telling example by the Lacanian analyst Patrick Gauthier-Lafaye (2017, p. 80) who hears an unusual pause in a sentence of a patient. Indeed, in the French sentence: "Ma mère n'était pas parvenue..." ("My mother did not succeed in…"), she pauses in the middle of the word "par-venue" ("succeed"). This slight pause isolates for a suspended moment the embedded phrase "papa revenue," "daddy has come back." The analyst does not interpret his patient's sayings but simply repeats "pas par'venue," opening up a new world of meanings. It appeared that the patient's father left the family without explanation. It had always seemed the minimal duty of the then young woman to be loyal to her mother and to her outrage. Thereby she could never express her own longings for her father to come back, save for this moment in her analysis 40 years later. We have previously proposed an extensive theoretical framework (e.g., Bazan, 2007, 2011, 2012) to understand these psychodynamic logics—the unconscious being structured as a language—in coherence with modern neuroscience and psycholinguitics.

In the present study, we therefore might also propose that high defensive participants shy away from the phonological targets because they potentially harbor threatening ambiguity. What is remarkable is that this pattern is shown to happen unconsciously and totally unbeknownst to the subjects themselves, who are convinced that they make completely arbitrary choices. The results are backed up by the additionally finding that not only do the behavioral responses correlate highly with defensiveness, but also the brain N320 amplitude-effects. High defensive subjects show both different brain and behavior patterns when confronted with phonological ambiguity as compared to low defensive subjects, with a N320 not signaling the phonological closeness between prime and phonological target, but seemingly testifying of some perplexity in decoding the signal. For this reason, we suggest these results are revealing aspects of how personality dispositions, such as defensiveness, interact with elementary mental processes, such as the unconscious resolution of language ambiguity.

Limitations

A first limitation of the present study is the complexity of the results. First, in the experimental condition, one target is phonologically similar and the other is non-related. We nevertheless take the difference between the N320 reaction upon the experimental trials (one phonologically related and one non-related target) with the N320 reaction upon the control trials (none of the targets is related to the prime), as indicative of its reaction upon the phonological target in the experimental trials specifically. We feel this is justified because it is in fact the only difference between experimental and control trials. Moreover, this complex experimental paradigm allows us to correlate brain waves with behavioral choices in a subliminal paradigm. Second, we do not simply find a N320 reduction indicative of the recognition, and subsequently, the positive choice for the phonological target, we also find a more negative experimental N320, associated with "a negative choice" for (or "avoidance" of) the phonological target. This we interpret as the result of a perplexity in the face of phonological ambiguity, leading to a stronger activation of the phonological recoding pathway.

A second limitation of the study is that indeed no main effects were found. We found a correlation between an ERP and a behavioral effect, but we did not find a significant difference for the whole group between experimental N320 and control N320. In some ways, the present results are similar to the Snodgrass et al. (1993) study: there seems to be, in the total pool of participants, two groups with opposite behavior: one group in which the recognition of the phonological similarity leads to lesser mobilization of the phonological recoding pathway and therefore a relative N320 reduction; these participants tend to pick the phonological targets; and another group in which the detection of the phonological ambiguity leads to over-mobilization of the phonological recoding pathway and therefore a relative N320 increase; these participants tend to avoid the phonological target. These bidirectional effects, then, neutralize the main effects.

CONCLUSION

In conclusion, the amplitude of a subliminally induced mid-left brain N320 wave, known to react upon supraliminal phonological mismatch, relative to its behavior in a control condition, significantly predicts the behavioral choices of the

participant more than half a second later, while the subjective experience of the participants is one of complete arbitrariness. Moreover, social desirability, as measured by Crowne and Marlowe's Personal Reaction Inventory, significantly correlates with both the behavioral and the N320 brain responses of the participants. It is proposed that in participants with low social desirability scores the phonological target induces a normal N320 reduction that increases their probability to pick this target, while participants with high social desirability scores have a perplexed brain reaction upon the phonological target with a negatively peaking N320 that more often leads them to avoid this target. Social desirability, which is understood as reflecting defensiveness, might also manifest itself as a defense against the (energy-consuming) ambiguity of language. The specificity of this study is that all of this is happening totally out of awareness and at the level of very elementary linguistic distinctions.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the Institutional Review Board of the University of Michigan (Department of Psychiatry) with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Institutional Review Board.

AUTHOR CONTRIBUTIONS

AB had the idea for the research, did the experiments, the data-analysis, and the write-up. RK did the ERP measurements and ERP data analyses. EW helped with the preparation and the administration of the experiments. JS taught and supervised the subliminal priming method and supervised the data analyses. LB helped with the rationale of the research and the interpretation of the results. HS supervised the whole process at all stages. All authors discussed preparation, running, data-analyses and interpretation of the study during the Shevlab-meetings.

ACKNOWLEDGMENTS

AB thanks HS for his inspiration, his teaching and his mentorship. AB was funded by a Fellowship of the Belgian American Educational Foundation (BAEF) and by support from HS at the University of Michigan. AB was able to finish the manuscript thanks to a summer stay at the Stellenbosch Institute for Advanced Study, Wallenberg Research Center at Stellenbosch University, Stellenbosch, South Africa.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnhum.2019.00077/full#supplementary-material

REFERENCES

Atchley, R. A., Keeney, M., and Burgess, C. (1999). Cerebral hemispheric mechanisms linking ambiguous word meaning retrieval and creativity. *Brain Cogn.* 40, 479–499. doi: 10.1006/brcg.1999.1080

Bazan, A. (2006). Primary process language. *Neuro-Psychoanalysis* 8, 2157–159. doi: 10.1080/15294145.2006.10773526

Bazan, A. (2007). *Des Fantômes Dans la Voix. Une Hypothèse Neuropsychanalytique sur la Structure de l'inconscient*. Montréal, QC: Liber.

Bazan, A. (2011). Phantoms in the voice. A neuropsychoanalytic hypothesis on the structure of the unconscious. *Neuro Psychoanal.* 13, 161–176. doi: 10.1080/15294145.2011.10773672

Bazan, A. (2012). From sensorimotor inhibition to Freudian repression: insights from psychosis applied to neurosis. *Front. Psychol.* 3:452. doi: 10.3389/fpsyg.2012.00452

Bazan, A., and Snodgrass, M. (2012). "On unconscious inhibition: instantiating repression in the brain," in *Trends in Neuropsychoanalysis: Psychology, Psychoanalysis and Cognitive Neuroscience in Dialogue*, eds. A. Fotopoulou, D. W. Pfaff, and E. M. Conway (Oxford: Oxford University Press), 307–337.

Bentin, S., Mouchetant-Rostaing, Y., Giard, M. H., Echallier, J. F., and Pernier, J. (1999). ERP manifestations of processing printed words at different psycholinguistic levels: time course and scalp distribution. *J. Cogn. Neurosci.* 11, 35–60. doi: 10.1162/089892999563373

Bernat, E., Bunce, S., and Shevrin, H. (2001a). Event-related brain potentials differentiate positive and negative mood adjectives during both supraliminal and subliminal visual processing. *Int. J. Psychophysiol.* 42, 11–34. doi: 10.1016/S0167-8760(01)00133-7

Bernat, E., Shevrin, H., and Snodgrass, M. (2001b). Subliminal visual oddball stimuli evoke a P300 component. *Clin. Neurophysiol.* 112, 159–171. doi: 10.1016/S1388-2457(00)00445-4

Binder, K. S., and Morris, R. K. (1995). Eye movements and lexical ambiguity resolution: effects of prior encounter and discourse topic. *J. Exp. Psychol. Learn. Memory Cogn.* 21, 1186–1196. doi: 10.1037/0278-7393.21.5.1186

Blackburne, L. K., Eddy, M. D., Kalra, P., Yee, D., Sinha, P., and Gabrieli, J. D. E. (2014). Neural correlates of letter reversal in children and adults. *PLoS ONE* 9:e98386. doi: 10.1371/journal.pone.0098386

Blanchette, I., Richards, A., and Cross, A. (2007). Anxiety and the interpretation of ambiguous facial expressions: the influence of contextual cues. *Q. J. Exp. Psychol.* 60, 1101–1115. doi: 10.1080/17470210600890511

Breuer, J., and Freud, S. (1893-95/1955). "On the psychical mechanism of hysterical phenomena: preliminary communication," in *Studies on Hysteria*. *Standard Edition II,* 3–305. ed. J. Stratchey (London: The Hogarth Press), p. 183–252.

Burgess, C., and Simpson, G. B. (1988). Cerebral hemispheric mechanisms in the retrieval of ambiguous word meanings. *Brain Lang.* 33, 86–103. doi: 10.1016/0093-934X(88)90056-9

Chee, M. W. L., Sriram, N., Soon, C. S., and Lee, K. M. (2000). Dorsolateral prefrontal cortex and the implicit association of concepts and attributes. *NeuroReport* 11, 135–140. doi: 10.1097/00001756-200001170-00027

Chiarello, C. (1985). Hemispheric dynamics in lexical access: automatic and controlled priming. *Brain Lang.* 26, 146–172. doi: 10.1016/0093-934X(85)90034-3

Connolly, J. F., Phillips, N. A., and Forbes, K. A. (1995). The effects of phonological and semantic features of sentence-ending words on visual event-related brain potentials. *Electroencephalogr. Clin. Neurophysiol.* 94, 276–287. doi: 10.1016/0013-4694(95)98479-R

Connolly, J. F., Service, E., D'Arcy, R.C. N., Kujala, A., and Alho, K. (2001). Phonological aspects of word recognition as revealed by high-resolution spatio-temporal brain mapping. *NeuroReport* 12, 237–243. doi: 10.1097/00001756-200102120-00012

Crowne, D., and Marlowe, D. (1960). A new scale of social desirability independent of psychopathology. *J. Consul. Psychol.* 24, 349–354. doi: 10.1037/h0047358

Crowne, D. P. (1991). From response style to motive. *Curr. Contents* 30:18.

Crowne, D. P., and Marlowe, D. (1964). *The Approval Motive: Studies in Evaluative Dependence*. New York, NY: Wiley.

Cutler, A., Demuth, K., and McQueen, J. (2002). Universality versus language-specificity in listening to running speech. *Psychol. Sci.* 13, 258–262. doi: 10.1111/1467-9280.00447

D'Arcy, R. C. N., Connolly, J. F., and Crocker, S. F. (2000). Latency shifts in the N2b component track phonological deviations in spoken words. *Clin. Neurophysiol.* 111, 40–44. doi: 10.1016/S1388-2457(99)00210-2

Dehaene-Lambertz, G., Dupoux, E., and Gout, A. (2000). Electrophysiological correlates of phonological processing: a cross-linguistic study. *J. Cogn. Neurosci.* 12, 635–647. doi: 10.1162/089892900562390

Dugas, M., Gosselin, P., and Ladouceur, R. (2001). Intolerance of Uncertainty and Worry: investigating Specificity in a Nonclinical Sample. *Cogn. Ther. Res.* 25, 551–558. doi: 10.1023/A:1005553414688

Freeston, M., Rhéaume, J., Letarte, H., Dugas, M. J., and Ladouceur, R. (1994). Why do people worry? *Personal. Indiv. Differ.* 17, 791–802. doi: 10.1016/0191-8869(94)90048-5

Freud, S. (1895/1966). "Project for a scientific psychology," in *Standard Edition I,* ed J. Stratchey (London: The Hogarth Press), 281–397.

Freud, S. (1900/1958). "The interpretation of dreams," in *Standard Edition IV-V,* ed J. Stratchey (London: The Hogarth Press), 339–627.

Freud, S. (1901/1953). *Psychopathologie de la vie quotidienne, trad. S. Jankélévitch,* Paris:Payot.

Freud, S. (1901/1974). "The psychopathology of everyday life," in *Standard Edition VI,* ed. J. Stratchey (London: The Hogarth Press), 1–310.

Freud, S. (1915/1957). "The unconscious," in *Standard Edition XIV,* ed. J. Stratchey (London: The Hogarth Press), 159–215.

Frost, R. (1998). Toward a strong phonological theory of visual word recognition: true issues and false trails. *Psychol. Bull.* 123, 71–99. doi: 10.1037/0033-2909.123.1.71

Furnham, A., and Marks, J. (2013). Tolerance of ambiguity: a review of the recent literature. *Psychology* 4, 717–728. doi: 10.4236/psych.2013.49102

Furnham, A., Petrides, K. V., and Spencer-Bowdage, S. (2002). The effects of different types of social desirability on the identification of repressors. *Personal. Indiv. Differ.* 33, 119–130. doi: 10.1016/S0191-8869(01)00139-8

Furnham, A., and Ribchester, T. (1995). Tolerance of ambiguity: a review of the concept, its measurement and applications. *Curr. Psychol.* 14, 179–199. doi: 10.1007/BF02686907

Gahl, S., and Strand, J. (2016). Many neighborhoods: phonological and perceptual neighborhood density in lexical production and perception. *J. Memory Lang.* 89, 162–178. doi: 10.1016/j.jml.2015.12.006

Gauthier-Lafaye, P. (2017). *Conversations Psychanalytiques: Pour les Curieux de Tous Âges*. Montréal, QC: Liber.

Gernsbacher, M. A., and Robertson, R. R. W. (1995). Reading skill and suppression revisited. *Psychol. Sci.* 6, 165–169. doi: 10.1111/j.1467-9280.1995.tb00326.x

Gottfried, J. A., Sancar, F., and Chatterjee, A. (2003). Acquired mirror writing and reading: evidence for reflected graphemic representations. *Neuropsychologia* 41, 96–107. doi: 10.1016/S0028-3932(02)00130-6

Grossi, G., Coch, D., Coffey-Corina, S., Holcomb, P. J., and Neville, H. J. (2001). Phonological processing in visual rhyming: a developmental ERP study. *J. Cogn. Neurosci.* 13, 610–625. doi: 10.1162/089892901750363190

Heydayati, M., Dugas, M. J., Buhr, K., and Francis, K. (2003). "The relationship between intolerance of uncertainty and the interpretation of ambiguous and unambiguous information," in *Paper presented at the Annual Convention of the Association for Advancement of Behaviour Therapy*, (Boston, MA).

Hoormann, J., Falkenstein, M., Schwarzenau, P., and Hohnsbein, J. (1998). Methods for the quantification and statistical testing of ERP differences across conditions. *Behav. Res. Methods Instruments Comp.* 30, 103–109. doi: 10.3758/BF03209420

Klein Villa, K., Shevrin, H., Snodgrass, M., Bazan, A., and Brakel, L. A. W. (2006). Testing Freud's hypothesis that word forms and word meanings are functionally distinct in the unconscious: subliminal primary process cognition and its links to personality. *Neuro Psychoanal.* 8, 117–138. doi: 10.1080/15294145.2006.10773521

Lukatela, G., Frost, S. J., and Turvey, M. T. (1999). Identity priming in English is compromised by phonological ambiguity. *J. Exp. Psychol. Hum. Percept. Perform.* 25, 775–790. doi: 10.1037/0096-1523.25.3.775

Martin, R.C. (1981). The pseudohomophone effect: the role of visual similarity in non-word decisions. *Q. J. Exp. Psychol.* 34A, 395–409.

Newman, R. L., Forbes, K., and Connolly, J. F. (2012). "Event-related potentials and magnetic fields associated with spoken word recognition," in *Cambridge Handbook of Psycholinguistics,* eds. M. Spivey, M. Joanisse, and K. McRae (Cambridge: Cambridge University Press), 127–156.

Paulhus, D., Fridhandler, B., and Hayes, S. (1998). "Psychological defense: contemporary theory and research," in *Handbook of Personality Psychology*, eds. R. Hogan, J. Johnson, and S. Briggs (San Diego: Academic Press), 543–579.

Paulhus, D., and Reid, D. (1991). Attribution and denial in socially desirable responding. *J. Personal. Soc. Psychol.* 60, 307–317. doi: 10.1037/0022-3514.60.2.307

Perea, M., and Lupker, S.J. (2003). Does jugde activate COURT? Transposed-letter similarity effects in masked associative priming. *Memory Cogn.* 31, 829–841. doi: 10.3758/BF03196438

Poldrack, R. A., Wagner, A. D., Prull, M. W., Desmond, J. E., Glover, G. H., and Gabrieli, J. D. (1999). Functional specialization for semantic and phonological processing in the left inferior prefrontal cortex. *NeuroImage* 10, 15–35. doi: 10.1006/nimg.1999.0441

Proverbio, A. M., Vecchi, L., and Zani, A. (2004). From orthography to phonetics: ERP measures of grapheme-to-phoneme conversion mechanisms in reading. *J. Cogn. Neurosci.* 16, 301–317. doi: 10.1162/0898929043229 84580

Rapaport, D. (1967). *The Collected Papers of David Rapaport*. New York, NY: Basic Books.

Saberi, K., and Perrott, D.R. (1999). Cognitive restoration of reversed speech. *Nature* 398:760. doi: 10.1038/19652

Shevrin, H. (1973). Brain wave correlates of subliminal stimulation, unconscious attention, primary- and secondary-process thinking, and repressiveness. *Psychol. Issues* 8, 56–87.

Shevrin, H. (1992). "Subliminal perception, memory and consciousness: cognitive and dynamic perspectives," in *Perception Without Awareness,* eds. R. F. Bornstein and T. S. Pittman (New York, NY: Guilford), 123–142.

Shevrin, H., and Fritzler, D. E. (1968). Visual evoked response correlates of unconscious mental processes. *Science* 161, 295–298. doi: 10.1126/science.161.3838.295

Shevrin, H., Snodgrass, M., Abelson, J., Brakel, L., Kushwaha, R., Briggs, H., et al. (2010). Evidence for unconscious, perceptual avoidance in phobic fear. *Biol. Psychiatry* 67, 33S. doi: 10.1016/j.biopsych.2010.03.007

Shevrin, H., Snodgrass, M., Brakel, L.A. W., Kushwaha, R., Kalaida, N. L., and Bazan, A. (2013). Subliminal unconscious conflict alpha power inhibits supraliminal conscious symptom experience. *Front. Hum. Neurosci.* 7: 544. doi: 10.3389/fnhum.2013.00544

Shevrin, H., Williams, W. J., Marshall, R. E., Hertel, R. K., Bond, J. A., and Brakel, L. A. (1992). Event-related potential indicators of the dynamic unconscious. *Consc. Cogn.* 1, 340–366. doi: 10.1016/1053-8100(92)90068-L

Silverstein, B. H., Snodgrass, M., Shevrin, H., and Kushwaha, R. (2015). P3b, Consciousness, and complex unconscious processing. *Cortex* 73, 216–227. doi: 10.1016/j.cortex.2015.09.004

Simon, G., Bernard, C., Lalonde, R., and Reba,ï, M. (2006). Orthographic transparency and grapheme-phoneme conversion: an ERP study in Arabic and French readers. *Brain Res.* 1104, 141–152. doi: 10.1016/j.brainres.2006.05.071

Simon, G., Bernard, C., Largy, P., Lalonde, R., and Rebaï, M. (2004). Chronometry of visual word recognition during passive and lexical decision tasks: an ERP investigation. *Int. J. Neurosci.* 114, 1401–1432. doi: 10.1080/00207450490476057

Snodgrass, M., Bernat, E., and Shevrin, H. (2004). Unconscious perception: a model-based approach to method and evidence. *Percept. Psychophys.* 66, 846–867. doi: 10.3758/BF03194978

Snodgrass, M., and Shevrin, H. (2006). Unconscious inhibition and facilitation at the objective detection threshold: replicable and qualitatively different unconscious perceptual effects. *Cognition* 101, 43–79. doi: 10.1016/j.cognition.2005.06.006

Snodgrass, M., Shevrin, H., and Kopka, M. (1993). The mediation of intentional judgments by unconscious perceptions: the influences of task strategy,

task preference, word meaning and motivation. *Consc. Cogn.* 2, 169–193. doi: 10.1006/ccog.1993.1017

Van Orden, G.C. (1987). A ROWS is a ROSE: Spelling, sound and reading. *Memory Cogn.* 15, 181–198. doi: 10.3758/BF03197716

Van Selst, M., and Merikle, P. (1993). Perception below the objective threshold? *Consc. Cogn.* 2, 194–203. doi: 10.1006/ccog.1993.1018

Weber, M. R. (1970). "First-graders' use of grammatical context in reading," in *Basic Studies on Reading,* eds. H. Levin, and J. P. Williams (New York, NY: Basic Books). 147–163.

Weinberger, D. (1990). "The construct validity of the repressive style," in *Repression and Dissociation: Implications for Personality Theory, Psychopathology, and Health,* ed. J. Singer (Chicago: University of Chicago Press), 337–386.

Weinberger, D. A., Schwartz, G. E., and Davidson, R. J. (1979). Low-anxious, high-anxious, and repressive coping styles: psychometric patterns and behavioral and physiological responses to stress. *J. Abnormal Psychol.* 88, 369–380. doi: 10.1037/0021-843X.88.4.369

Wendell Holmes, O. (1891). *The Autocrat of the Breakfast Table*. London: Walter Scott Ltd.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Advantages of publishing in Frontiers

OPEN ACCESS
Articles are free to read for greatest visibility and readership

FAST PUBLICATION
Around 90 days from submission to decision

HIGH QUALITY PEER-REVIEW
Rigorous, collaborative, and constructive peer-review

TRANSPARENT PEER-REVIEW
Editors and reviewers acknowledged by name on published articles

Frontiers
Avenue du Tribunal-Fédéral 34
1005 Lausanne | Switzerland

Visit us: www.frontiersin.org
Contact us: info@frontiersin.org | +41 21 510 17 00

REPRODUCIBILITY OF RESEARCH
Support open data and methods to enhance research reproducibility

DIGITAL PUBLISHING
Articles designed for optimal readership across devices

FOLLOW US
@frontiersin

IMPACT METRICS
Advanced article metrics track visibility across digital media

EXTENSIVE PROMOTION
Marketing and promotion of impactful research

LOOP RESEARCH NETWORK
Our network increases your article's readership