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A distributed model of collective creativity in free play

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A group of children engaged in collective free play can spontaneously create new rules, learn to follow them, or find opportunities to break established ones. This rule-playing can be considered as a specific manifestation of the more general phenomenon of collective creativity. In behavioral sciences, collective creativity is often discussed as a collection of individuals each being creative. An alternative perspective views collective creativity as a distributed phenomenon: collective creativity is not a property of individual agents but rather, it emerges from the interactions within a group. Approaching free play as a case of distributed collective creativity, we understand rule-playing in terms of two complementary modes – group exploration and group exploitation-, and the transition between them. Free play is not easily amenable to fine-grained observational analysis. To overcome this, we developed the Grid Game, a new experimental setup which supports detailed empirical investigation while preserving the essence of free play. The Grid Game is a group improvisation game that uses the turn taking logic and spatial organization of typical board games, without any other predefined rules. Small groups of kids (4–5 participants) took turns in freely moving or manipulating a provided set of objects on a large 4 × 4 grid on the floor for 10 min, while being video-recorded. Despite the absence of predefined goals, simple proto-games with *ad hoc* rules often emerge, for example, placing objects on top of each other (create a tower) or an aiming-to-a-target shooting game. We propose an analysis of the emergence of such proto-games in terms of group exploration and exploitation. Building on our previous work on the Creative Foraging Game, we focus on cases of transition from exploration to exploitation underlying the discovery of a new form or rule. Based on Choreographer João Fiadeiro's body of work, we describe these phase shifts as a distributed process composed of three stages: (1) *Suggestion*, (2) *Recognition,* and (3) *Confirmation*. We provide detailed descriptions of game moments according to this model which demonstrate the distributed nature of collective creativity in free play.

KEYWORDS
distributed creativity, collective creativity, free play, interpersonal coordination, exploration-exploitation, improvisation, group improvisation

Introduction

Free play refers to spontaneous activities of children, where they "exert energy in a freely chosen, fun, and unstructured manner" (Truelove et al., 2017), enabling them to develop their motricity, intellectuality, social abilities, imagination, and creativity. Group free play can be considered as a common real-life example of a collective creative process: in different cultures, kids play together, invent play-rules, follow them for a while, break them and then create new ones. Similar dynamics can be observed in other, more structured forms of collective creativity such as group improvisation in music, theater and dance (Noy et al. (2011, 2015), Laroche and Kaddouch (2014, 2015), Himberg et al. (2018)). In fact, it is tempting to assume that group free play is an antecedent of artistic forms such Jazz, dance, and comedy improvisation. Thus, studying the creative processes in group free play might shed light on a wider set of phenomena.

However, group free play tends to resist standard measures of creativity. By its very nature free play is unconstrained, so it is not trivial to analyze and model how it manifests in the wild, and it is not obvious to cast its free form within the logic of lab experiments. Typical experimental approaches for studying creativity are product based: creativity is measured in terms of the quality or quantity of the resulting objects (Kaufman and Sternberg, 2019; Rafner et al., 2022). In contrast, group free play usually does not produce any tangible outcomes. Relatedly, tasks or contexts where creative processes are usually studied are typically goal-oriented (e.g., Fjaellingsdal et al., 2021; Rocca and Tylen, 2022), while free play, almost by definition, lacks a preconceived goal. In addition, most of the work on group or collective creativity focuses on verbal (e.g., brainstorming session) or verbally mediated tasks (e.g., Bjørndahl et al., 2014) while free play also involves important components of gestural, postural and object-mediated communication that can support a creative interaction even in the absence of language. In standard tasks of collective creativity the roles of the different participants or the rules of collaboration are usually pre-specified. Finally, most approaches in studying group creativity simply extend individual models by conceiving collective creativity as a collaboration between multiple creative agents. Here again, free play does not conform to the mold, as roles, rules and ultimately the creative action emerge through the interaction itself.

With these issues in mind, we suggest to approach collective creativity in free play as an enactive process, that is, as the emergence of shared meanings out of the actions and the interactions of participating agents (Di Paolo et al., 2010). We therefore suggest studying collective creativity by: (1) focusing on bodily gestures and object manipulations (as opposed to verbal exchanges), (2) allowing for the absence of explicit goals, and (3) stressing the distributed nature of the creative process across participants and actions.

Aiming to study collective creativity in group freep play from this perspective, we introduce the Grid Game, an experimental setup that constrains the modes of interaction to facilitate the analysis and modeling of their underlying dynamics yet keeps many of the features inherent to free play such as the fun and the spontaneous inventiveness of the participation. Based on an analysis of a number of groups of adolescents playing the Grid Game, we propose a distributed enactive model of a specific aspect of collective creativity, namely the transitions from exploration to exploitation, that can provide useful insights into collective creativity more generally.

The paper starts with an introduction of a distributed enactive perspective on collective creativity, where the very dynamics of interaction between individuals play a role in the creative processes of the group itself. We then turn to present the contrast between two major phases of creative processes, namely exploration and exploitation, along with a theoretical model (the EDEN model) that describes the shifts that occur between them. Next, we situate these two phases within the context of collective distributed processes. This leads us to the work of the choreographer João Fiadeiro on decision-making during collective improvisation, which offers a relevant lens on the distributivity of the exploration and exploitation phases. We then introduce the Grid Game, a simple group improvisation game (GIG, see Himberg et al., 2018) that emulates free play while providing the means to track collective creative processes. After having introduced the setup of the game and the rationale behind its features, we report data collected with five groups of children. We present our observations and analysis in the form of a model (the SuReCo model) developed on the basis of Fiadeiro's work and our observations. Finally, we discuss the results and reflect on the new perspectives they offer.

Creativity as a distributed process

Creativity is often defined as the production of something (e.g., an object, an idea, and a behavior) that is new and useful (Runco and Jaeger, 2012). As such, the majority of creativity literature focuses on the created products, rather than the creative processes themselves. In this context, the evaluation of creativity appeals to socio-cultural norms (Amabile, 1983) such as the impact the created product has on others (Beghetto and Kaufman, 2007). However, a growing field within creativity research has been looking at the creative processes or behavior itself (Jennings, 2010), to which we turn now. While it has been acknowledged that the socio-cultural environment shapes creative behaviors (Amabile, 1983; Csikszentmihalyi, 2014), creative processes have mainly been studied as an individual activity, and more particularly as a psychological, intracranial one (Glaveanu et al., 2013; Glăveanu, 2014; Kupers et al., 2019). Studies have often looked, for instance, at associations between creative behaviors and personality traits or examined cognitive and brain processes that accompany those creative behaviors.

Creativity research that has addressed collective forms of creativity has focused primarily on verbal forms of ideation (such as brainstorming, as pointed out by Kurtzberg and Amabile, 2001; and Lebuda et al., 2016), mirroring the intra-individual view of creativity as a form of disembodied thinking process. In contrast, the embodied dimension of creativity, the fact that we are material bodies moving within a material environment with other bodies (Varela et al., 1991; Sheets-Johnstone, 1999; Manning, 2009), has been neglected (Glăveanu and Beghetto, 2021). Yet, the materiality of the world we are part of is a fundamental dimension of creativity. Gestures and postures play a part in the creative processes (Csikszentmihalyi, 1996; Malinin, 2016, 2019), as do the materials we engage with (Barbot et al., 2019). Starting from infancy, body movements are our primary way to couple with others (Trevarthen, 2012). Though non-verbal collective forms of creative interactions have been studied (in particular in dance improvisation; e.g., Torrents et al., 2010; Kimmel et al., 2018) this issue still occupies a marginal place in creativity research and theory. The prevalent over-emphasis of the individual and the mental and under-emphasis of the corporeal and interactional dimensions of creative processes has led to calls for a paradigmatic change in the way creativity is approached and conceived (Kupers et al., 2019; Malinin, 2019; Glăveanu and Beghetto, 2021).

The bias toward the individual and the mental in creativity research reflects the epistemology of "classical" studies on cognition in general. These studies have most often focused on mental processes and have given a secondary or peripheral role to bodily activity and to the (dynamics of) interactions with the environment such activity allows for. However, over the last decades, a variety of new approaches to cognition have been developed. In particular, the important role that bodily activity in the world plays in the constitution of cognitive experiences has been underscored (Varela et al., 1991; O'Regan and Noë, 2001). In addition, a number of proposals have stressed the distributed nature of cognition, seeing it as an emergent product of the dynamics of interaction between simpler subprocesses, instead of a collection of full-fledged modular functions (Kloos and Van Orden, 2010). In this perspective, rather than being the output of hard-wired or pre-existing structures and functions, cognitive behaviors are thought of as transient patterns within a continuous flow of self-organized dynamics.

The enactive approach has integrated these different strands of non-classical approaches to cognition into a coherent framework where cognition is a sense-making activity that emerges from our bodily interactions with our environment (Di Paolo, 2005). More recently, this approach has been extended to the domain of interpersonal interactions by highlighting the socially distributed nature of cognitive processes (De Jaegher et al., 2010). In effect, if sense-making emerges from our bodily interactions with our surroundings, then, in sensorimotor interactions we couple our very own sensemaking activities by making them contingent on each other (McGann and De Jaegher, 2009). As such, cognitive experiences emerge from the dynamics of our very interactions, that is, from the meshing of our behaviors influencing each other reciprocally over time, and from the way we co-regulate, or negotiate, these very dynamics (De Jaegher and Di Paolo, 2007). Cognitive processes underlying collective behaviors (including the ones underlying creativity) are thus, according to the enactive approach, distributed both intra- and inter-subjectively.

Despite the recent evolution of the epistemological trends discussed above, creativity research has seldom appreciated the extent to which distributed interaction properties play a role in creative processes (Kurtzberg and Amabile, 2001; Lebuda et al., 2016; Almaatouq et al., 2021). Instead, ideas are still most often thought to be born out of individual minds before they reach the world, and therefore others (Wheeler, 2018). Yet, interacting with others brings about specific dynamics that can potentially provoke cognitive and creative changes through the collaborative elaboration and transformation of meaning (De Jaegher and Di Paolo, 2007; Sawyer and DeZutter, 2009).

The process by which individual actions get an interpersonal meaning is particularly visible in group improvisation (Sawyer and DeZutter, 2009). In the context of group improvisation, such as in Jazz, improv comedy and contact dance, improvisers explore together the realm of possibilities by accepting and building on each other "offers." In such contexts the importance of interpersonal contingencies is amplified, and hence the reliance on the explanatory power of individual behaviors is reduced. The context of group improvisation thus makes interaction dynamics more transparent to rigorous analysis. We believe that the same is true for free play, and studying free play also offers an opportunity to study the role of interaction dynamics in distributed creativity processes (Sawyer and DeZutter, 2009). In particular, studying free play should allow us to better highlight the different phases of creative interactions and the transitions between them. In the next section, we provide an overview of two phases (exploration and exploitation) within the creative process that have been mostly studied in the context of individual creativity, and then we discuss their articulation at the collective level.

Exploration and exploitation in creative processes

A common metaphor for creative processes is creativity-as-search, in particular the terminology of exploration and exploitation (Hills et al., 2015). Exploration is the process in which an agent (or group of agents) is opening up new possibilities, whereas exploitation is the process of harvesting a class of similar possibilities. Embedded in these definitions is an implicit assumption that these processes are distinct: the system is either exploring or exploiting at any given moment. The exploration-exploitation distinction is also a spatial metaphor, alluding to an environment where regions of valuable resources (products, solutions, and ideas) exist in spatially separated clusters. For example, David Perkins suggested to view creativity as a search in a Klondike space (Perkins, 1994), echoing the gold rush in Klondike, Canada at the end of the 19th century, where veins of gold in isolated regions needed to be found (exploration phase) and then excavated (exploitation phase).

Exploration and exploitation processes are studied in many domains, including technological innovation, computer science, developmental psychology, and ethology. For example, a prominent theory of technological innovation, the Innovator's Dilemma (Christensen, 2013), describes how successful firms (such as Kodak and IBM) often miss critical technological revolutions (for example, digital photography) as they become too good in exploitation: reacting efficiently to current market needs within the current technological and business paradigm, instead of exploring an emerging technology.

The Innovator's Dilemma is an example of a more general question in mathematical optimization: the exploration-exploitation trade-off. In many situations an agent needs to balance between the more cautious exploitation of local and known solutions, and the riskier exploration for globally optimal solutions. Finding a solution for this trade-off, that is: striking a good balance between exploration and exploitation, is a major topic in current approaches in machine learning and artificial intelligence.

Exploration is also a key topic in developmental psychology, for example in Attachment Theory (Bowlby, 1982). According to Attachment theory human infants seek proximity to supportive others (attachment figures) who can provide protection and care in times of real or perceived threats. This internal representation of a reliable attachment figure can constitute a secure base from which a person can explore the world on their own (Mikulincer and Shaver, 2007). The ability to explore is essential for children's development (Liquin and Gopnik, 2022), in particular at specific sensorimotor and cognitive development steps (Gray, 2011). Children's interactions with their environment are made of explorations and games (Power, 2000): to learn how to use her body, to understand how to grow in her society, the child experiments, tries, fails and tries again with different approaches (Wilkes-Gillan et al., 2016).

In the study of animal behavior the exploration-exploitation trade-off is a central concept in research on foraging, the process by which animals search for spatially distributed resources (Stephens et al., 2008), for example, when a fruit bat alternates between exploiting the current tree it is harvesting or exploring for a new one (Rainho and Palmeirim, 2011). Foraging research describes the behavioral patterns of foraging animals (Kamil et al., 2012) and suggests underlying mathematical models such as the Optimal Foraging Theory (Charnov, 1976; Perry and Pianka, 1997). Recently, this line of work has been extended to cognitive foraging: the patterns in which humans search for information within their mind (Hills et al., 2015).

One of the authors and his colleagues have previously extended the literature on human cognitive foraging to include creative foraging (Hart et al., 2017), and developed a high resolution paradigm for measuring creative foraging of individuals in a well-defined space of geometric shapes (Noy et al., 2012). In the Creative Foraging Game (CFG) participants explore the space of 10-connected squares (∼36°k possible shapes), and are asked to search for shapes they find beautiful and interesting. Upon discovery of an interesting shape participants can save it in their Shapes' Gallery (**Figure 1**, bottom). Participants alternate between exploration along meandering paths and exploitation of categories of similar shapes. Within a category, but not during the exploration phase, people move along optimal paths. The CFG was used to demonstrate the first placebo effect on creative exploration (Rozenkrantz et al., 2017); to develop a computational model of creative exploration (Hart et al., 2018) and as part of a large citizen-science consortium of online creativity studies (Rafner et al., 2020).

A theoretical model, the Explore-Discover-Enjoy-Next (EDEN) model (**Figure 1**), attempts to capture participants' behavior in the CFG. Participants first explore the space of possibilities in the game, then discover a category of similar shape. These shapes can have semantic similarity (e.g., "digits," lower middle), or a more visual similarity ("space invaders," lower right). After exploiting (or, enjoying) this stable pattern for a while, participants then move on, exiting the current pattern and returning to exploration. The same model also explains behavioral patterns in a dyadic movement improvisation task, the mirror game (Noy et al., 2011).

The EDEN model suggests focusing on two specific phase shifts in creative processes. The more familiar one is the shift from exploration to exploitation, that can be termed as the moment of discovery, or the creative leap (Koestler, 1964; Cross, 1997). The second one, which is much less discussed in the literature, is the "move on" (or "next!" below) point (Dahan et al., 2016), the point where the creating agent(s) leaves the current exploitation phase and shifts back to exploration.

Toward a collective and distributed view of exploration and exploitation

Though exploration and exploitation in human behavior have been primarily studied in the context of single person tasks (e.g., Hart et al., 2017), a growing number of studies, models, and theoretical frameworks have come to address these two phases in the context of dyadic or group creative

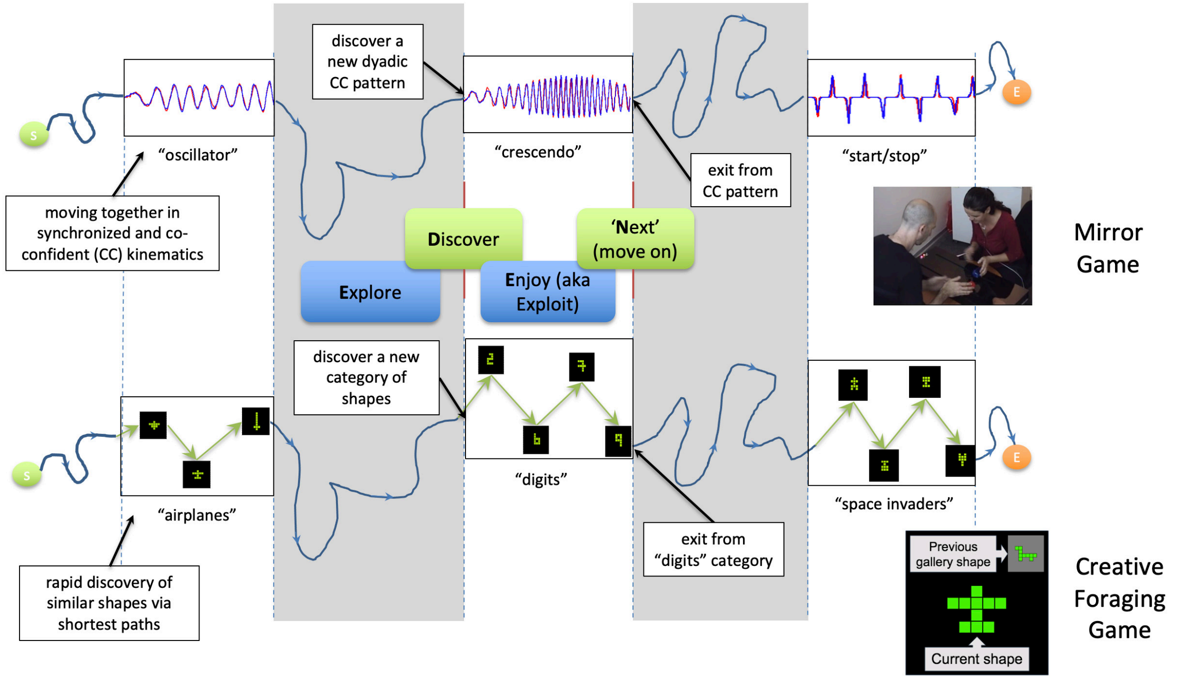

FIGURE 1
The EDEN model. A theoretical model of creative exploration describes participants' behaviors in two empirical paradigms, the mirror game (MG) and the creative foraging game (CFG). In iterative phases, participants first explore the space of possibilities in the game, then discover a stable pattern, exploit/enjoy it for a while, and then move on (next!), leaving the stable pattern and a return to exploration. In the MG (top row), a stable pattern is a specific dynamic of synchronized joint motions, termed co-confident (CC) motions; for example, a simple oscillation (top left), or the more complex "crescendo" (top middle). In the CFG (lower row), a stable pattern is a category of similar shapes that can have semantic similarity (e.g., "digits," lower middle), or a more visual similarity ("space invaders," lower right). A common question raised by the EDEN model is the "next!" point: what promotes participants to exit the current stable pattern and return to exploration? (adapted with permission from Noy, 2018).

activities (Lazer and Friedman, 2007; Toyokawa et al., 2014; Yahosseini et al., 2018; Özcimder et al., 2019). These studies highlight the role of the social context in exploration. For example, Toyokawa et al. (2014), using the classical "multi-arm bandit" decision problem in a group setting, showed how the availability of information concerning the choices made by other group members can improve the efficiency of exploration [but see an alternative view, suggestion how interaction can hinder exploration in Yahosseini et al. (2018)]. Although these studies consider behavior in a social context, they still place the performed tasks and decisions within the individual participants, and in consequence the characterization of exploration and exploitation remains individualized. A recent exception to this perspective can be found in the study of Özcimder et al. (2019) on decision making during a semi-improvised group dance score. The dance score was composed of seven modules the dancers could choose to perform at any moment and a set of six rules. The rules of the score were the following:

(1) any dancer can introduce a new module at any time
(2) a module cannot be chosen if it has come and gone already
(3) only one module can be introduced at a time and the same dancer should not introduce two modules in a row
(4) any dancer can switch to any current module at any time
(5) any dancer can skip a module
(6) no more than two modules can be danced at a given time.

Rules 1, 4, and 5 frame the choice making freedom of every individual dancer while rules 2, 3, and 6 introduce group level constraints on the individual choices.

In line with the literature mentioned above, the authors individualize the choice to explore as the introduction (by one dancer) of a new module, and the choice to exploit as joining an existing module. However, in their quantification, modeling, and interpretation of the behavior at the group level (see figure 4 in Özcimder et al., 2019), the authors highlight the collective states (the distribution of dancers across active modules) that favor either exploration or exploitation. For example, equal distribution of dancers across two modules is the state that maximizes exploitation (when the two modules are both strongly established the introduction of a third module is highly unlikely because of rule 6). In contrast, the collective state that most favors exploration occurs when most or all dancers partake in only one module. In other words, the important collective dimension (rules 2, 3, and 5) of the behavior studied shifts the locus of exploration and exploitation dynamics from individual behavior to the group level. The collective dimension of the creative process is also reflected in the author's evolutionary approach: the dance is developed by the group as dance modules evolve in a generational selection process.

While this aforementioned paper represents an important shift toward a distributed collective view of group exploration-exploitation, it is important to note that exploration is very narrowly constrained (the choice between seven pre-existing modules). In the study reported here, we are interested in creative exploration where new behavior (a new module in the terms of Özcimder et al., 2019) is not predefined but emerges during the interaction itself.

A laboratory task inspired by the theater improvisation exercise commonly referred to as the mirror game (Noy et al., 2011; Hart et al., 2014) provides an interesting context in which emergent collective forms of exploration can be observed. In this task, two players move handles along a bounded line, and are instructed to "to mirror each other, creating interesting motion together, while staying in sync." Experienced players can enter (and exit) a state of synchronized joint motions, termed co-confident (CC) motions (Noy et al., 2011), that can be seen as behavioral signals of a state of togetherness (Hart et al., 2014; Noy et al., 2015). The synchronized joint motions can be simple (a simple oscillation, see **Figure 1**, top left), or more complex (e.g., the "crescendo" pattern, **Figure 1**, top middle). It seems then that players enter and exit stable patterns, or switch between exploration and exploitation through points of discovery (entering an exploitation phase) and exit (leaving exploitation and returning to exploration). Unlike the score used by the Özcimder et al. study, the next stable state is not selected from a predefined menu but emerges spontaneously through the interaction itself.

The mirror game setup allows for a very fine grained tracking of the emergence of new patterns and the unraveling of existing ones. However, it is limited to a dyadic interaction and to a very constrained field of creation (1 dimensional movement). In the task presented here, we were interested to study the dynamics of exploration-exploitation in larger ensembles with a more ecological field of play. Our interest in how exploration and exploitation are negotiated collectively during a creative group process led us to the work of the choreographer João Fiadeiro on decision making during collective improvisation.

João Fiadeiro's com-position

The Portuguese choreographer and dance pedagogue João Fiadeiro has been developing over the last 25 years (in collaboration with multiple artists and scientists like the choreographer Claudia Dias, the economist Antonio Alvarenga or the anthropologist Fernanda Eugenio) an approach to collective improvisation and composition named "Real Time Composition" (Jurgens et al., 2016; Fiadeiro, 2017). Fiadeiro explores, through his practice of collective improvisation, the genesis and dynamics of decision making in a group. Though he does not explicitly refer to creativity or play, the theoretical outlook he has developed seems very pertinent to these two topics and his main pedagogical tool shares many features with the Grid Game we will present soon.

One of Fiadeiro's basic teaching setups includes a table and a collection of objects. The participants take turns adding (or retracting) elements from the table, composing together forms or landscapes without verbal exchange or any prior design. Only two instructions/restrictions guide the players: not doing two moves simultaneously and not correcting the previous move. In his teaching of this form, Fiadeiro reminds us of the etymology of the word composition: with-position (which is quite transparent in Portuguese: "composição": "com"-with, "posição"- position). Fiadeiro suggests thinking about collective composition as positioning-with, a collective distributed process. Individual participants do not compose by themself. Instead, they contribute to positions which, together with positions offered before or after by other actors, bring forth a "com-position." Specifically, Fiadeiro identifies three stages of positioning-with in such a collective composition, and which he names "position −1," "position 0," and "position 1." The model we propose below essentially follows the same tripartite typology with slightly different definitions (focusing on the actions rather than the stages of composition) and a more transparent nomenclature.

The most typical case of "position −1" is the situation after the first object has been placed on the empty table. At this point, although there is a physical element on the table, the com-position is still virtual (Massumi, 2002). A following action is required in order to actualize the potential of the first action. This actualization takes place if a second participant makes an action that stands in a legible relation to the first action. For example, if the first action consisted of placing an object at the corner of the table, placing a second identical object at the opposing corner can be read as a relation of symmetry. Once such action has been performed, the state of the com-position advances to "0." Now that the original action has been actualized, it is the relationship between the two actions (in our example above, symmetry) which is still virtual. An additional action is required to actualize this relationship. If a third participant makes an action that relates (in a legible way) to the relation between the two first actions, the com-position advances to stage "1." An example is adding a third object at the center of the table, recognizing and relating to the symmetry relation of the first two objects. Now we have an established compositional pattern in the common ground that can be exploited. If the following action on the table also relates to the relation between −1/0 and 0/1 (in our example the symmetry relation) the com-position would pass to a 1n state (which essentially means that the emergent operation is reiteration mode). Importantly, when the table com-position is practiced, this three-stage process is often interrupted, aborted or circles back to earlier stages.

As part of a larger research project on collective improvisation (Himberg et al., 2018) we developed an experimental paradigm–the Grid Game (described below)–to look at the emergence of creative ideas and actions through distributed collective discoveries in free play.

We then made use of Fiadeiro's com-position framework to provide a detailed analysis of the emergence of such collective actions or creative activities with particular attention to the shifts from exploration to exploitation. Our central research questions were what triggers such shifts, how these shifts are negotiated non-verbally by the group and, more generally, how novel activities emerge *via* a distributed group process.

Materials and methods

The grid game

The Grid Game setup was developed as an experimental device for the study of interactional dynamics through collective improvisation and free play. The Grid Game opens with a small group of 4 to 6 participants sitting around a 4*4 (16 squares) grid marked on the floor with strips of adhesive tape. Having four participants or more rather than a dyad, allows for a richer pallet of interaction patterns. A set of seven everyday objects are made available for the group. In our corpus, we used two markers, two cups, one tape, and two flat and circular foam objects. The participants are invited to play a game but the rules or the goal of the game are left mostly undefined. The only two constraints are: (1) Only one move can be made at a time (what constitutes a move is left undefined). After she makes a move, a participant must therefore wait for at least one move by another participant before she can make a new one. The order of players' moves is not structured in advance. (2) Verbal communication is discouraged. The experience lasts 10 min and is video-taped.

While the quasi absence of rules or explicit goals emulates free play, the turn taking design, which resonates with improvised theater, lets each of the participants' actions come into focus. Favoring non-verbal communication simplifies the interactions' analysis, and allows us to focus on the role of the bodily activities and interactions with the environment. Moreover, the choice of everyday objects as the main material prevents participants from grasping straightforward affordances that are related to a certain range of known games that players could easily identify. Indeed, the recognition of a traditional type of game by the group could pre-set goals and therefore influence their interactional dynamics and guide the evolution of the collective game, thus limiting the possibilities of experimentation. The setup therefore invites the group of players to collaboratively invent new games and can be considered as a collective creativity task. As in free play the joy and the reward thus lie in shared inventiveness. As such, the set up motivates but does not enforce the interactions, allowing us to observe their spontaneous unfolding.

Participants

Twenty students attending the Doisneau middle school (Paris, 20th arrondissement) took part in the experiments reported here (11–12 years old; 10 girls, 10 boys), and formed five groups. These experiments were part of the ICREA project which aimed at promoting collective attention through improvisation. The project was funded by the Carasso foundation. All participants whose data is used in this paper and their legal guardians signed an informed consent form before the activity in accordance with the norms of the French ministry of education and established in an agreement signed between the CNRS and the Cellule de Recherche of the Académie de Paris.

Protocol

The Grid Game sessions lasted 10 min and had the following structure: the group was sitting on the floor in a small room with minimal distracting stimuli or objects, apart from the game objects. The grid was marked on the floor at the center of the room, and was replaced after each session. Members of the group were sitting around the grid, without preassigned positions. The person giving the rules of the game at the start of the session was the same for each group, and remained throughout the experiment as an observer. She answered questions from group members before the game started, then limited her interactions with the group as much as possible. A camera on a tripod was positioned so that it can capture the actions of each member of the group during the experiment. The rules were stated as follows: "I am going to suggest that you play a simple game, which has very few rules: (i) once you have made a move (for example, moving an object within the game space), you have to wait for at least one other person to make a move before you can do another one yourself (ii) avoid verbal communication. You have 10 minutes to play with each other. Please have at least one object in your hands before the game starts. This camera you can see there is here to record the game and to help us to study it."

Analysis approach: Iterative observation and annotation cycles

The analytical approach we chose followed the general structure of Interaction Analysis (Sawyer and DeZutter, 2009).

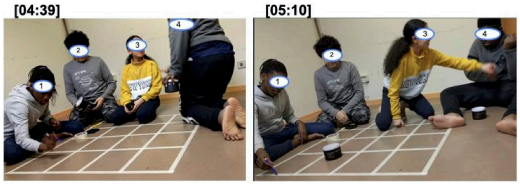

FIGURE 2
Examples of private turns. Participant 1 is engaged in a solitary drawing activity not attended to by the other participants while player 2 is handling the round box also not attended to by other participants.

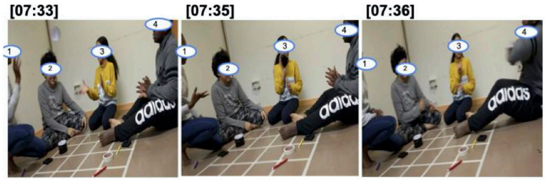

FIGURE 3
Examples of collective turns. All four participants are engaged with the activity of throwing the box (participant 1 throws the box to participant 3 who, in turn, passes it to participant 4). Participant 2 is demonstratively attending the passing of the box.

The annotation of the components of the collective creation process, along the lines of João Fiadeiro's approach (namely *Suggestion*, *Recognition,* and *Confirmation*, see below) stems from an analysis of the video recordings carried in several stages. The segmentation and annotation of the audiovisual recordings of Grid Game sessions was done with ELAN software (version 6.2).

The first step was to segment the interaction into turns (in the spirit of conversation analysis). We defined turns as deliberate attempts, successful or not, to intervene in the game space. A feature that is common to all the games with adolescent participants and that distinguishes them from protocols with adults such as Fiadeiro's table game is the extreme rapidity of turns. Overlapping turns were often observed, though generally the participants respected the sequencing constraints. We quickly came to realize that in order to capture the development of the game we need to pay attention to unintentional (co-)occurrences (accidents, contingencies) and side effects of intentional actions. We then included these moments as turns. The second step of the analysis consisted of naming each turn by each member of the group in terms of newness (or repetition). At the third stage, we distinguished private turns from collective ones. A turn is considered private when a player is engaged in an activity that does not clearly relate to the history of the game and to which other players are not attending. For example, when a player is juggling while having an observation posture, with other players engaged in different activities (**Figure 2**). Collective turns are those which engage multiple participants, either as actors or active audience, for example when a participant throws an object to another (**Figure 3**).

At the fourth stage, we described the development of the game in terms of collective distributed dynamics. We segmented the game into phases (sequences of turns). Applying the EDEN model, we identified two types of collective phases: exploration and exploitation (or proto-games) and phase transitions between them. Finally, we turned to a careful analysis of the transition between the phases. Building on Fiadeiro's framework, we came to elaborate for these transitions the three-stage SuReCo model we describe below.

Results

We will first describe in more details how we came to operationalize the concepts of collective exploration and exploitation phases in our corpus (3.1). We will then turn to our main focus, the transitions between phases and specifically the shifts into new phases of exploitation (3.2) and elaborate the three-stage SuReCo model (3.3).

Distributed collective exploration and exploitation in the grid game

Through the iterative annotation and analysis process described above we came to identify sequences of actions that are organized around a shared rule, goal or constraint. We have named these "proto-games". When a proto-game is maintained for a number of moves by different participants, we consider this to be a phase of collective exploitation– the group "exploits" the implicit shared rule or game. This collective exploitation of a rule, or a proto-game is the equivalent phase to the one described above in the case CFG paradigm when a player produces multiple shapes from the same category.

Importantly, the segmentation of the activity into proto-games and their annotations are based on our visual analysis of the videos and not on the experience of the players themselves (an issue we will get back to in the discussion, see 4.6). In the corpus of games with adolescent participants we analyze here, a certain number of proto-games appear regularly across groups, for example, tower building, aiming game, throw, and catch (see above).

We also identified sequences of actions or time-spans that we considered to be collective exploration. We define collective exploration as an epoch where players make moves that do not seem to consist of a single shared stable proto-game. During certain phases of collective exploration, it appears that each player is "doing her own thing" without taking into consideration what the other players are doing (see **Figure 4**).

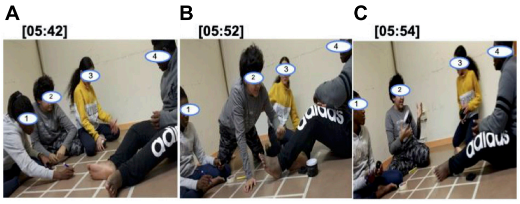

FIGURE 4
Example of shared exploration **(A–C)**. **(A)** Participant 1 is focused on her (non-shared) graphical activity. Participant 2 is paying attention to what participant 4 is doing, who is himself trying to get into interaction with participant 3. The latter seems to enjoy exploring, and no personal or shared game is elaborated enough to be identifiable. **(B)** Participant 1 didn't cease her non-shared activity. Participant 2 intervenes in the interaction between 3 and 4, reaching for the round box. **(C)** Participant 1 ceases her private activity. All 4 participants are in a moment of joint attention.

We consider this to be a distributed form of exploration: each individual is not necessarily visibly exploring but exploration takes place at the group level. During other phases of collective exploration, players do respond to each other's moves but no proto-game seems to emerge. We consider this case to be a form of shared/joint exploration as individuals intentionally engage together in a common task of exploration (**Figure 4**). For the purpose of the current paper we group these two forms of exploration together. However, this distinction should be addressed in future research.

Distributed phase transitions

Identifiable phases of exploitation (proto-games) or exploration (distributed or shared) were generally short, lasting only a few turns before some transition took place. In addition, it was often difficult to determine the phase for the whole group (where all four participants are collectively exploring or collectively exploiting). Instead, we often observed only two or three participants commonly exploring or exploiting. The upshot of these short and complex phases is that it allowed us to observe multiple and different phase transitions and aborted transitions, to which we now turn.

Proto-games are emergent patterns of coordination and are not verbally proposed, accepted, modified, or terminated. As such, one can observe the emergence of a new proto-game either through a transformation of an ongoing game or appearing from a phase of exploration. With respect to the notion of distributed creativity discussed above, we observed that in our corpus such phase transitions were generally not accomplished by a single move of one player but were mostly negotiated or elaborated in a sequence of moves by different players. Taking as a point of departure Fiadeiro's conceptual framework discussed above, we outline a three-step model of moving from exploration to exploitation (in other words, the emergence of new proto-games): the *Suggestion*, *Recognition,* and *Confirmation* (SuReCo) model.

The SuReCo model for the emergence of new proto-games

Schematically, one can describe the phase transition from exploration into the exploitation of a new proto-game as a sequence of three questions addressed to the collective of participants:

Q1: "Can you see this?" (suggestion): Something is signaled to the collective attention of the group.
Q2: "Did you mean this?" (recognition): A move that reifies the act of suggestion and attempts to disambiguate its content or intention.
Q3: "Are we playing this?" (confirmation): A move that established the new proto-game in the common ground.

We will now discuss and provide specific examples for each of these stages.

Suggestion

Suggestion is an occurence (something happens: a gesture, an action, an accident or a natural event such as gust of wind) that indicates (literally: points our attention to) an affordance. Affordance (from Gibson, 2000) is a virtual action made possible (invited) by a feature of the environment. In the games we have analyzed, suggestions are often intentional propositions by one of the players (**Figure 5**), or unintended, "accidental" events (**Figure 6**):

I. In **Figure 5A** player 4 puts one object on top of the other. Her action "points" toward the affordance of the objects to be stacked up. Before this suggestion, objects were always placed directly on the floor. This action thus opens a new dimension of possibilities in the game.
II. In **Figure 6B** player 4 knocks down a construction (part of an earlier established game, 6A) and in doing so, turns the roll of adhesive tape on its side (until that moment the tape was only placed on its flat base). This "accidental" suggestion points to the affordance of the tape to support construction also on its side, as well as that of rolling.

Recognition

Recognition is an intentional action or gesture through which a player (or players) actualizes the affordance they came to notice through the suggestion. By actualizing the affordance they integrate this new possibility into the game. An act of recognition stands in a particular relationship to a specific suggestion. Moreover, as one suggestion could contain multiple

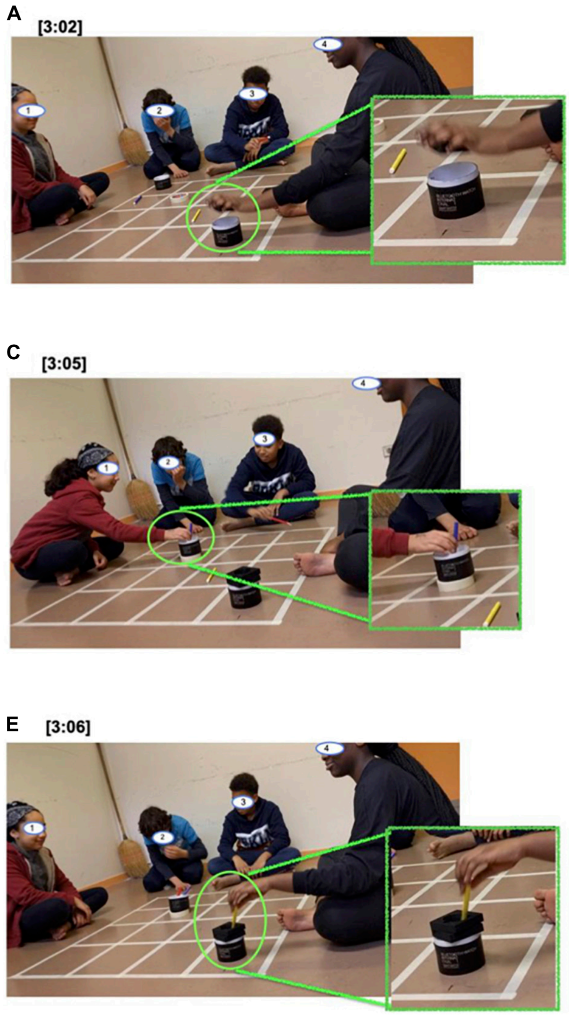

FIGURE 5
Example of an intentional suggestion. **(A)** Player 4 places the flat square on top of one of the round boxes. **(B)** Player 3 places the other round box on top of the roll of tape. **(C)** Player 1 places a pen inside the round box. **(D)** Player 3 puts a second pen in the same box. **(E)** Player 4 places the last pen in the other round box.

affordances (as above: the affordance of the tape both to support and to roll), the act of recognition might actualize a specific affordance of a specific suggestion.

For example:

III. In **Figure 5B** participant 3 puts a box on top of the tape, thus recognizing the affordance suggested by player 4 (as in I above). This is a simple form of recognition as he seems to simply repeat her move. However, note that he puts the box on top of the tape. This is different in two aspects from the suggestion: in the suggestion the box is on the bottom and the second element is the black frame. By repeating only a specific aspect of the suggestion, the player recognizes a more general property of stacking-up-ness rather than one specific to the black box and black frame.

IV. In **Figure 6C** participant 2 responds to suggestion II above by stacking a black frame on the tape roll (now standing on its side). Stacking (and undoing the stack) had been the ongoing game when the suggestion II happened, and so the recognition here is performed by integrating the new dimension–having things on their side–into the ongoing game.

Confirmation

Confirmation is a recognition of the relation between a suggestion and a recognition: not of the individual actions themselves but of a specific relationship between the action of recognition and the suggestion. The same sequence of suggestion-recognition can be confirmed multiple times, with

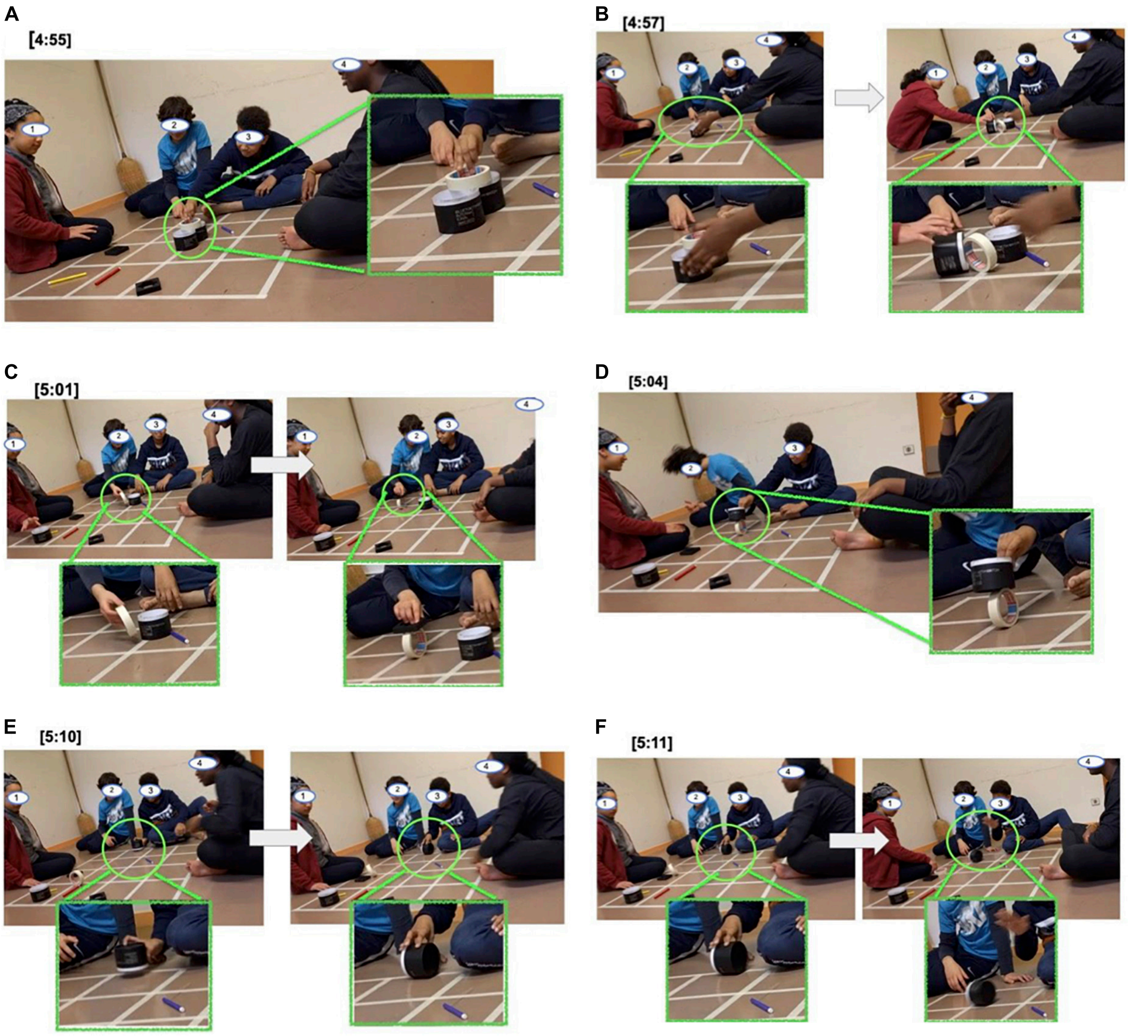

FIGURE 6
Example of an accidental suggestion. **(A)** The players are engaged in a collective "tower building" proto-game. **(B)** Player 4 knocks down a construction but in doing so turns the roll of adhesive tape on its side (until that moment the tape was only placed on its flat base). **(C)** Player 2 stacks a black frame on the tape roll (now standing on its side). **(D)** Player 3 stacks a different object on top of the tape. **(E)** Player 3 turns the black box on its side. **(F)** Player 3 rolls the black box.

a different relationship recognized each time. In addition, a confirmation can be iterated.

For example:

V. In Figure 5C participant 1 puts a pen into the box. This action recognizes a specific relation that holds between the suggestion I and the recognition III, that of stacking, or gathering together (but not layering). This confirmation is then iterated in the next two moves in the game, until all objects have been gathered into two heaps and the proto-game has been exhausted (Figures 5D,E).

VI. In Figure 6E player 3 turns the black box on its side. This can be considered a form of confirmation as it generalizes the aspect of flipping to the narrow edge (in II and IV that of the tape). By transferring this manipulation to a different object, the player confirms that it was this particular manipulation, and not any other aspect of the tape or its handling, that was recognized in IV.

The SuReCo model can operate in a non-linear manner

The SuReCO model does not necessarily describe a linear or deterministic process. Suggestions can remain un-recognized and suggestion-recognition sequences are not always confirmed.

Furthermore, suggestions can be recognized multiple times, when each such recognition highlights a different affordance.

For example:

VII. In **Figure 6F** player 3 rolls the black box. This can be considered a form of a second recognition of II as it now highlights a different affordance of the tape/black box once on their side: the affordance of rolling.

A recognition can also become a suggestion, if it is recognized by another player rather than confirmed:

VIII. In **Figure 6D** player 3 stacks a different object on top of the tape. This action repeats the action in IV but uses a different element and so recognizes it. However, it does not confirm the II-IV relation, so it is not a confirmation.

A suggestion-recognition-confirmation sequence does not necessarily entail the end of a proto-game or the beginning of a new one. Depending on the situation, a new game can arise or an existing game can evolve to integrate the new dimension (for example compare AC and BD).

Here is an example of a SuReCo process that evolves in an ongoing proto-game:

IX. In **Figure 7** player 3 places the black box on his own head (a suggestion, A). Player 2 adds a second box on top of it (recognition, B). Player 1 adds the roll of tape to the construction (C), which can be considered as a second recognition or a confirmation. The proto-game itself is not new: the participants have been engaging in tower building throughout the session. What is new is the extension of the playing field outside the grid (a transgression of an implicit rule) and specifically onto the body of the participants. This is an activation of a latent dimension: the body is implicated in the game not only as an effector but also as a territory. A little later (D), player 2 hangs the sponge on the ear of player 3 while player 4 puts one of the boxes on her own head. These two actions can be considered as two parallel confirmations. Both actions extend the field of play from the top of the head of player 3.

Discussion

Recap of the paper

The main contribution of the current paper is providing evidence for cases of distributed collective creativity in the context of free play, in particular specific moments of phase shifts from collective exploration to collective exploitation. In order to do so we put together three building blocks. First, we developed the Grid Game, a new experimental setup to study free play. Second, we presented a general model describing creative exploration and exploitation, the EDEN model, stemming from previous experimental work on creative behavior in individuals (Hart et al., 2017) and dyads (Noy et al., 2011). Third, we make use of a system for teaching and performing collective improvisation from the choreographer João Fiadeiro.

We recorded five sessions of four children playing the Grid Game and analyzed them *via* the two aforementioned prisms. Following this process we developed the SuReCo model – a specific labeling scheme that delineates distributed shifts from collective exploration to collective exploitation in the Grid Game. We provide detailed sequences of actions that demonstrate the utility of the SuReCo model for analyzing distributed phase shifts in the Grid Game.

The grid game as a distributed collective creative process

Analysis of the Grid Game sessions provided us with a perspective on the setup itself, on which we reflect below. First, we have confirmed the relevance of focusing on non-verbal communication channels. The absence of verbal communication requires all communication to be carried by the actions themselves. This highlights the importance of eye contact, posture, and body orientation in the interaction process. Secondly, because of the preferential recourse to verbal communication in education and professional settings, the use of non-verbal communication to interact with others puts the group in a higher attentional state. Relatedly, the recourse to non-verbal communication slows down the interaction dynamics, and highlights the shifts between the phases of the collective creative process. New proto-games require multiple actions by multiple participants in order to be clearly communicated and agreed upon (which could have been achieved in a single speech act using language). The longer sequences of actions facilitate the traceability of the collaborative interactions that can bring about new games. In particular, it clarifies the occurrences of the sequences described by the SuReCo model.

Second, we noticed the importance of the "observer" role in the distributed process of collective creativity. To achieve a collective creation, collaboration between players is needed. However, collective does not necessarily mean that all participants are jointly active. For instance, even if the observer does not play back, her presence and her attention (i.e., *via* gaze direction) to the action gives it more importance and enhances its collective force.

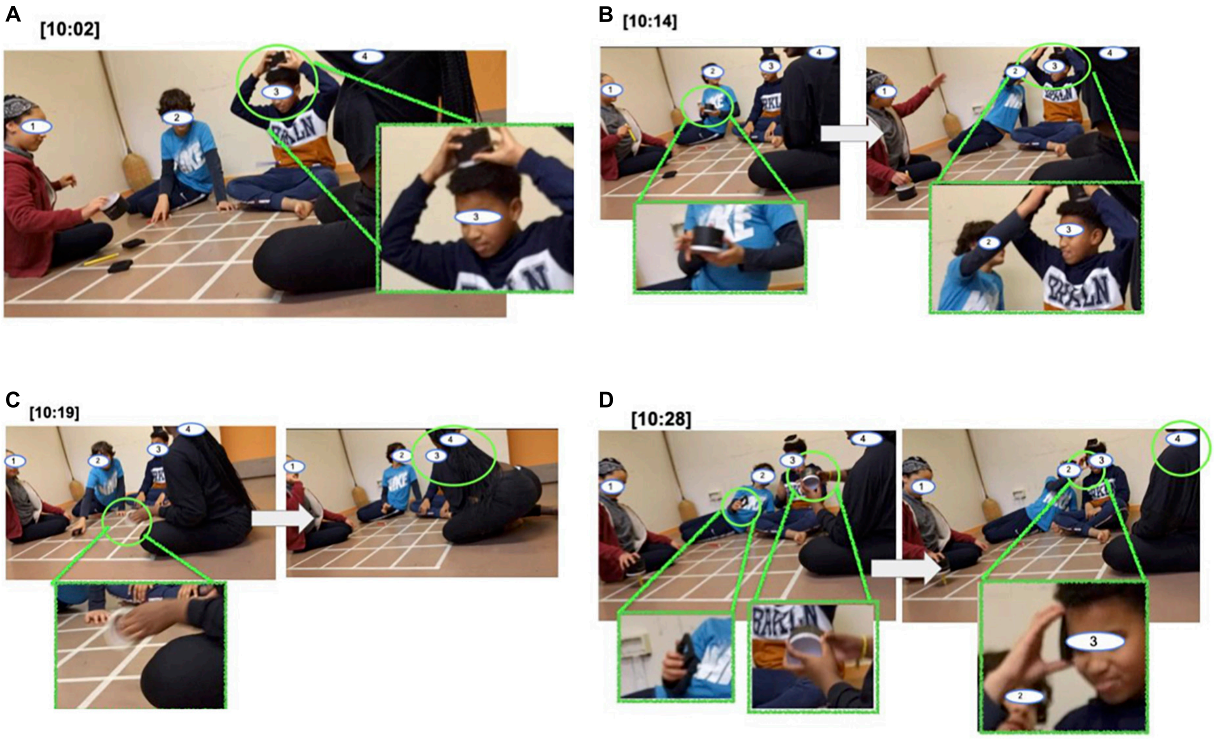

FIGURE 7
Example of the activation of a dimension. **(A)** Player 3 places a round box on his head. **(B)** Player 2 places a second box on top of the first one. **(C)** Player 4 places the roll of tape on top of the two boxes. **(D)** Player 2 hangs the flat square on the ear of player 3 while player 4 places a box on top of her own head.

Third, as for the way distributed creativity plays out in the Grid Game, we have come to appreciate how the dynamics of creative interactions can become more visible in the context of free play. In effect, previous behavioral outputs become inputs to the ongoing development of individual and collective action (Sawyer et al., 2003; Sawyer, 2006). Moreover, the lack of pre-specified purpose or behavioral guidelines (instructions or rules) opens the space of "adjacent possibilities" (Kauffman, 2019) and makes the exploration of that space more contingent on the unfolding of the interactions themselves. Amplifying the role of interpersonal contingencies at the expense of isolated individual behaviors and pre-given rules or goals makes interaction dynamics more transparent. Indeed, a large amount of the participants' activity is materialized in their observable contribution to the ongoing flow of interactions. The interaction happens out there in the world, and hence the underlying creative processes can be observed in real-time. Specifically, this gave us an opportunity to describe different phases of creative interactions and the transitions between them.

Finally, beyond mere contingencies between successive actions taken, the present work allowed us to notice that certain phase shifts require a specific sequence of more than one or two actions to be completed (in our case three: suggestion, recognition and confirmation). This can be obscured in the study of dyadic interactions and becomes more visible when we look at the detailed interactions of larger groups.

Expanding the EDEN model: Distributed phase shifts in creative processes beyond the grid game

The EDEN model describes apparently abrupt shifts that occur between phases of exploration and exploitation. Here, in the context of a specific free play setup, we zoomed in on these shifts in a collective creative process and described their micro-structure or inter-subjective "choreography" we named the SuReCo sequence.

Existing accounts of distributed creativity, while sharing many epistemological and methodological features with our approach, fall short in providing a detailed account of the phase shifts that distributed creativity entails. For instance, we agree with Glaveanu's broad view of creativity as materially, socially, and temporally distributed processes (Glăveanu, 2014). However, his account doesn't go into the detailed structure of the interactive process, while we look at the micro-level of coordination of interpersonal actions.

Our epistemic perspective on distributed group creativity is also in line with Sawyer's work on collaborative emergence (Sawyer and DeZutter, 2009), and in particular their focus on online interaction among group members in the creative process (in this case, improvised theater). However, Sawyer and De Zutter's approach is purely descriptive and they end up organizing the analysis around produced repeated patterns ("bits" of scripted dialogs) rather than the interactional dynamics that shape them. As such, they fall short at providing a formalized model of the interaction processes at work.

While the SuReCo model proposed here was developed in the specific context of the Grid Game, we believe it embodies a number of important components required to describe qualitative shifts in other unscripted creative processes. As such, it can both include and expand previous models. We turn below to a discussion of three specific insights the SuReCo model offers into the nature and dynamics of distributed phase shifts.

First, Sawyer and Dezutter suggested that distributed phase shifts rely on "moment-to-moment contingency" (Sawyer and DeZutter, 2009, p. 82) between successive actions, stressing the need for actions carried by group members to be dependent on preceding ones. Our findings here agree with the principle of contingency, however in the SuReCo model contingency is defined not only between the actions themselves, but also between an action and the contextual relation between previous actions. For example, the confirmation stage in the model addresses the relation between a specific relation that holds between a suggestion and its recognition.

Also, note that if the recognition component highlights the contingency on previous actions and their relationships, the suggestion component, when corresponding to an intentional action, leans into the future by inviting certain behaviors to happen next, and constitutes actions that are interpersonal in nature as they invite the complementarity of others' actions.

Second, Sawyer and DeZutter put forward that the effect on the interaction of any given action "can be changed by the subsequent actions of other participants" (Sawyer and DeZutter, 2009, p. 82). The SuReCo model embodies this logic, but goes further in proposing that certain actions have the explicit role of actualizing some previous actions, or even transforming the framework of the play that was taken for granted (see next section).

Third, our results expand on the importance of materiality of the interactions individual creators have with their environment, where what is already there acts as an enabling constraint (Glăveanu, 2014; Baber et al., 2019). We suggest that in creative group processes, non-human actors can become "full-fledged" participants, or catalytic factors in phase shifts, rather than a mere contextual environment. Our vignette in **Figure 6** where an accidental flip of the tape becomes fundamental in the progression of the SuReCo is one such example.

We think that a dynamical approach based on distributed processes integrating the insights pointed to above is necessary to capture, formalize and provide a general theoretical framework for the phase shifts that occur during unscripted creative interactions (Laroche and Kaddouch, 2014).

Creative leaps within free play

One question regarding the EDEN model that arose during our analysis process was to what extent shifts in collective dynamics always correspond to new exploration phases. With the SuReCo model at hand we are also able to reverse the logic of discovery. Rather than recognize proto-games and then attend to their distributed micro-genesis, we can now look for sequences of actions that conform to the SuReCo model (or parts of it) even in the absence of a proto-game (that we recognize as observers). Viewing the different games with the SuReCo model as a reading tool, we indeed observed other changes or shifts in the game that did not seem to us to be fully-fledged phase shifts from exploration to exploitation. Specifically, we came to notice "remarkable" or "surprising" sequences which seemed to modify or enrich the ongoing game. These sequences involve the activation of a dimension of the game that was previously latent, or a transgression of an implicit rule (a rule that was not explicitly provided by the experimenter but that was assumed by the participants).

We take these shifts to belong to the creativity class Boden (1998) named "transformative": "the transformation of some (one or more) dimension of the space, so that new structures can be generated which could not have arisen before" (Boden, 1998, p. 348). Boden notes that transformative creativity brings about "shock of amazement . . . much greater than the surprise occasioned by mere improbabilities, however unexpected they may be." For the purpose of the current paper we suggest to name such moments of transformative creativity as creative leaps.

For example, the coming into play of the narrow round side of the tape (sequence B-D-F-H) can be considered as a creative leap (leading eventually to a new proto-game) as it activated a latent dimension (playing with the orientation of objects). In the case of the sequence described in J, the action of using one's head as part of the playing field, "breaks" an implicit rule that the playing field is limited to the grid on the floor (a rule that was never explicitly stated).

These observations within the specific context of the Grid Game might provide insight into creative leaps more generally.

Specifically, it highlights the importance of interaction in the development of play and invites us to consider the importance of implicit rules that govern free play, and how they evolve through a distributed negotiation process.

In particular, the definition of creative leaps here is different from the one proposed in the EDEN model (based on the CFG protocol). In the EDEN model creative leaps are defined computationally using a similarity distance function comparing the similarity across shapes within a category compared to the similarity across categories, see details in Hart et al. (2017). Here creative leaps are identified experientially by the annotator (an experience of surprise or "shock" as in Boden) and are explained as a transformative change in the game. Future research can address whether these two definitions are extensionally equivalent or if we need to think of creative leaps as an heterogeneous set of phenomena.

What does the SuReCo model bring to the understanding of the creative process between and within individuals?

The observations we reported demonstrate the extent to which creative behaviors stem from the entanglement of multiple processes and sources of information distributed across persons and actions. In effect, rather than a centralized process, creative behavior is seen as emerging from the contingencies between partners' various actions, perception and re-actions. We foresee two domains in which these observations and the developed SuReCo model could be useful. First, since the open-endedness of creative tasks such as the Grid Game increases the role of interpersonal contingencies in cognitive behaviors, they should help to highlight properties of interaction processes in general: how cognitive behaviors and experiences of interacting participants build on each other. In particular, our observations directly relate to the enactive concept of participatory sense-making, a process whereby interacting partners actively and mutually regulate their interaction in order to bring forth new and shared meaning. Such meaning could not be construed if it wasn't for the way actions contingently relate to each other. Second, the pluri-personal, non-verbal and interactive nature of tasks such as the Grid Game forces the externalization of processes at play. Such processes include motor acts, attention, perception, and imitation. Consider for example how one participant might use his attention toward the motricity of another, which is influenced by the latter's perception of a third person, while all influences the behavior of a fourth member. As such, this sort of task shines light on the interactions that take place between body and cognitive processes that are necessary for creativity to manifest. Such studies could therefore inform us on processes happening within individuals as well, processes that are not easily observable from a third person perspective, revealing the sort of cognitive and bodily combinations that favors the discovery of new outcomes. In sum, free play and, in particular, tasks such as the Grid Game could open a window into the distributiveness of body and mind processes–whether they happen within individual or collective settings.

Future experimental directions with the grid game

We consider the current paper as a "proof of concept" for the validity of the Grid Game as an experimental paradigm. An obvious limitation of the current paper is the small number of groups we analyzed and our focus on very specific moments in the rich pallet of group behaviors. The Grid Game itself has limits when it comes to the study of collective creativity, as it is limited in time and reduces the sphere of possible actions. Notwithstanding these limitations, we suggest that the Grid Game strikes a good balance between being both ecological (in the sense of adhering to real life phenomena such as free play and group improvisation) and amenable to rigorous analysis as demonstrated in the current paper.

We propose below several possible future experimental directions with the current approach (and even data we have already collected) that we find intriguing.

First, previous experimental paradigms to study creative exploration, in particular the CFG (Hart et al., 2017) benefited from the existence of a well-defined and enumerated space of creative products. Studying creative exploration in an enumerated space enables the detection of recurrent patterns (Hart et al., 2017), experimental manipulations (Rozenkrantz et al., 2017), and mathematical modeling (Hart et al., 2018). While the Grid Game search space is far more complex, we believe it might also be amenable to some kind of typology. For example, we often observe in our dataset recurring "discoveries" of new proto-games, for example, using the body as part of the game (e.g., placing an object on its own head) or using the fact that the grid is marked with tape to change the game by adding or removing cells from the grid. Interestingly, we see the same discoveries both in the data reported here (collected with young participants), and in data we collected with adult groups that blended experienced improvisers and novices who played the Grid Game (unpublished pilot data).

An important line of study can therefore try to automatically identify specific actions in the Grid Game (such as placing an object on the head or adding cells to the grid) using recent advances in machine learning and automatic action detection. Such automatic detection can convert videos of groups playing the Grid Game to a string of actions, allowing for the detection of recurring patterns. For example, is there an order for the discoveries in the Grid Game? Do different groups first find "using the body" and only then "changing the grid"?

Other measures than those concerning the content of the players' moves could be used. Whether extracted automatically or annotated manually, the timing between successive turns or the distribution of actions and type of actions across players, for instance, could shed light on the group game dynamics at play. In general, the recourse to time series would open new possibilities in the study of the dynamics at play. In particular, temporal patterns could be extracted to identify recurrent structures in the succession of turns e.g., using recurrence analysis (Coco et al., 2017; Walton et al., 2018; Kodama et al., 2021) or t-patterns (Torrents et al., 2011). This could help pinpointing the group dynamics that are more prone to bring forth creative leaps.

Another promising line of investigation concerns the relation between socio-affective variables and the occurrences of SuReCo sequences. Indeed, research using group improvisation games has shown that psychological measures such as secure attachment tendencies (Feniger-Schaal et al., 2018) or empathy (Himberg et al., 2018) correlates with the dynamics of interpersonal coordination in group improvisation. For instance, Himberg et al. (2018) used a four-person version of the mirror game and found that those participants scoring higher on empathy scales were more prompt to respond to movement propositions made by others. It would be interesting to gage the extent to which such variables factor in the distributed processes at play in the Grid Game. For example, are players with a higher social status more prompt at suggesting? How do those with less dominant status allow themselves and are allowed by others to participate? Are those with higher empathy scores more inclined to recognize, or to confirm? This type of investigation could also go beyond mere correlations between psycho-social variables measured individually and use network analysis instead. For instance, a cartography of socio-affective relations (Oztop et al., 2018) could be established by interrogating the feelings of affiliation players have with each other. We could then look into potential mappings between the structure of socio-affiliative networks and the structure of the SuReCo sequences. Are there preferential SuReCo patterns between certain members–does one person differentially recognize the actions of other members of the group? On the contrary, does experiencing the game change the socio-affective cartography?

First-person experiences could more generally be an alternative point of departure of our analysis schemes, which we have so far conducted from an observer, non-participating point of view. While annotations such as those which led us to detect SuReCo sequences are likely beyond children capacities, they could report during retrospective analysis (and post-test video auto-confrontation) when they felt that something special did happen (e.g., a creative leap, defined in non-conceptual terms), when they felt a new game has started, or when they felt they made or responded to a suggestion. A promising avenue for this line of research is using micro-phenomenology, a systematic paradigm for accessing first person perspective (Heimann and Roepstorff, 2018). Similarities and differences between first and third person perception could enrich our understanding of the dynamics at play and give more hints into the intention of the players.

Overall, the Grid Game holds the potential to generate a myriad of questions and ways to address them. We suggest that this new setup strikes a good balance between being ecological on the one hand, allowing for the spontaneous emergence and development of proto-games in free play, while being, on the other hand, simple enough to allow for detailed analysis of the micro-dynamics of collective creativity. In the current work we attempt to demonstrate this balance by providing new evidence for distributed collective creativity in free play. In doing so, we borrowed freely from a range of domains, including a previous reductionist setup for studying creative exploration and João Fiadeiro's system for describing com-position in dance improvisation. By freely borrowing and re-combining these elements the current paper attempts to "walk the talk," engaging in the process of free play as a technique to study it as an external object.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

JK collected the data and executed the analysis of the videos in dialog with the other authors. All authors contributed equally to the development of the model and the writing of the article, share authorship, contributed to the article, and approved the submitted version.

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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.

Publisher's note

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