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Maternal perinatal depression and child neurocognitive development: A relationship still to be clarified

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Pregnancy frequently is associated with emotional conditions such as anxiety and depression. Perinatal depression has an incidence of around 12%. Only recently researcher put the attention on the effects of pre- and postpartum psychopathology on infant neurocognitive development. Neurobiology studies indicate that perinatal maternal depression can significantly affect the structure and function of children's prefrontal cortex and modulate the development of cognitive abilities from intrauterine life. On the topic, the scientific literature appears ambiguous, reporting mixed results. Some studies have found no significant differences in developmental outcomes between prenatal and postpartum exposure to maternal depression, others have suggested a greater burden of depression in pregnancy than in postpartum, and still others have emphasized the role of chronicity of symptoms rather than the period of onset. Few studies have examined the effects of different developmental trajectories of maternal depression on children's neurocognitive outcomes. The assessment of maternal health has for years been limited to postpartum depression often neglecting the timing of onset, the intensity of symptoms and their chronicity. These aspects have received less attention than they deserve, especially in relation to the effects on children's neurocognitive development. The aim of this Perspective was to highlight inconsistencies and gaps that need to be filled in the approach to the study of this problem. Given the wide heterogeneity of data in the current literature, further studies are needed to clarify these interactions. This Perspective provides an overview of current progress, future directions, and a presentation of the authors' views on the topic.

KEYWORDS

perinatal depression, neurocognitive development, post-partum depression, mother-child relations, maternal depression trajectories

1. Introduction

Motherhood is a period of physical, psychological, and relational transformations that involve a deep reorganization not only of the external reality, but especially of the psychological world of the mother-to-be (1). Pregnancy is associated with changes in women's psychological and relational functioning and can generate certain psychological conditions, such as feelings of anxiety and depression, even after childbirth (2, 3). At the biological level, pregnancy involves hormones (such as estrogen, progesterone, glucocorticoids, prolactin, and oxytocin) that can

alter brain functioning and serve as a substrate to prepare women for the challenge of motherhood (4). After birth, there are not only new hormonal changes, but also other psychological and social factors such as alterations in intimate relationships, confrontation with the physical changes, breastfeeding, lack of social support, in a condition that is already emotionally vulnerable (5). A recent systematic review and meta-analysis showed that the prevalence of postpartum depression among healthy women who have never had depressive episodes stands at 17% (6). Postpartum depression is a mood disorder that usually has onset within the first 4–6 weeks after delivery and lasts up to a year, reaching its maximum intensity within the first 6 months (7). Surprisingly, a recent study by Putnick et al. (8) conducted in a sample of 4,866 women from the general population shows that depressive symptoms can be elevated up to 3 years after childbirth. Very often postpartum depression is a continuation of depressive symptoms already present in the prenatal period and is closely related to the presence of anxiety symptoms during pregnancy (9). More recent research is directing attention to perinatal depression, which considers both depressive manifestations arising during pregnancy and after delivery. In a systematic review and meta-regression of the prevalence of perinatal depression Woody et al. (10) indicate that the global prevalence of perinatal depression has been estimated at 11.9%, although significant differences emerge between high- and low-income countries (6). Perinatal depression is a significant mental and public health problem (11), not only because of its high frequency, but also because it is associated with adverse consequences for future maternal and child health (12). These consequences range from low birth weight or premature birth to the development of insecure attachment, problems in social-emotional, neurocognitive, language, and motor development (12–14). The perinatal period is characterized by special growth and sensitivity. Therefore, intrauterine exposures and early experiences may influence fetal and infant development with long-term consequences (12). While the influences of maternal perinatal psychopathology on children's emotional and relationship development have been extensively investigated (15–18), fewer studies have focused on its effects on neurocognitive development, providing unclear results (19, 20). The purpose of this perspective was to identify weaknesses and aspects that need to be addressed in the approach to the study of these phenomena. Due to the heterogeneity of the data in the current literature, further studies are needed. This perspective gives an overview of current progress, gaps to be filled and future directions, and provides the authors' views on the subject.

2. Search strategy

Even though it was not our goal to conduct a literature review, we tried to provide an overview including reviews, meta-analyses, and recent articles on the subject. We planned two steps in the literature search. First, relevant publications were found by searching the Pubmed electronic databases. The following search strategy was used for the Pubmed database: (((Perinatal[Title/Abstract] OR postnatal[Title/Abstract] OR postpartum[Title/Abstract] OR antenatal[Title/Abstract] OR maternal[Title/Abstract]) AND (child*[Title/Abstract] OR infant*[Title/Abstract])) AND (neurocognit*[Title/Abstract] OR neurodevelopment*[Title/Abstract] OR development[Title/Abstract])) AND (depression[Title/Abstract])). We selected recent literature to identify current advances in the field of interest. Based on

a qualitative assessment, the studies considered most useful in highlighting contradictions in the literature data were selected. In the second phase, the snowballing search method was used to track down related works using the bibliography or reference list at the end of the most interesting articles - especially reviews and meta-analyses - found in the first phase of the search.

3. Perinatal depression and child neurocognitive development

Neurocognitive development refers to the full range of mental activities and abilities, including memory, language, learning, problem solving, perception, and higher abilities such as executive functions involving attention and behavioral control, which are important for self-regulation (21). Specifically, executive functions refer to a set of cognitive and self-regulatory processes such as working memory, inhibitory control, and flexibility of attention necessary to plan future behaviors, make predictions, enact goal-oriented behaviors, and adapt to novelty (22, 23). In close correspondence with the rapid maturation of the brain and prefrontal cortex (24), neurocognitive development accelerates in the second half of the first year, leading to improvements in executive performance between 8 and 12 months. Importantly, these abilities are particularly flexible (15, 25) because the prefrontal cortex, which underlies the development of executive functions, shows plasticity and sensitivity to early care and experiences. In addition, maturation of the prefrontal cortex and other involved brain structures occurs over a long period of time, making cognitive functioning open to positive environmental input, but at the same time vulnerable to early adversity (20, 24). Alterations in executive function have been shown to cause lifelong effects, such as problem behavior in preschool (26), higher incidence of specific learning disorders (27), internalizing and externalizing disorders in childhood (28), school dropout (29), and lower academic achievement (30). Prenatal stress has been related to higher anxiety, depression, larger amygdala volume, and altered neural connectivity in girls (31–34) and to higher frequency of disturbances or delays in neuromuscular and cognitive development in general (34, 35). Assessments conducted on children's nonverbal communication skills at age 14 months also indicate that maternal depressive symptomatology is associated with an increased risk of developmental delay (36). The cognitive development of 6- to 8-week-old infants (37) and the cognitive, language, and motor development of 4- and 13-month-olds (38) with depressed mothers is also lower when measured with the Bayley Scales of Infant and Toddler Development. Children of depressed mothers are six times more likely to be at risk for delayed emotional development (39) and five times more likely to be at risk for delayed language development with negative impact also on cognitive development at 6 months and 12 months and on motor development at 12 months and 18 months (39). Longitudinal studies indicate that maternal perinatal depression is associated with alterations in executive functions such as inhibition, shifting ability, cognitive flexibility, and working memory (12, 19, 20), but also with decreased thickness of the right frontal cortex (40, 41). In a study by Park et al. (42), the neurodevelopment outcomes of children of women with partially improved depressive symptoms in the first 3 years after delivery were comparable to those of children of mothers

who consistently reported low levels of depressive symptomatology. In contrast, in women who continued to have more severe and longer-lasting depressive symptoms, children had greater neurocognitive impairments. This would suggest that an improvement in the mothers' symptomatology in the first 3 years would reduce, or even reverse, the impact of maternal psychopathology on the children. Moreover, Faleschini et al. (43) found that exposure to prenatal maternal depressive symptoms predicts in children poorer executive functions related to planning, organization, working memory, inhibition of inappropriate impulses, emotional control, and ability to reevaluate and modify responses. At the same time, the authors, after accounting for influential factors including depressive symptoms in the prenatal period, identified poor associations between maternal depressive symptoms at six and 12 months postpartum and development in middle childhood. A recent meta-analysis (20) found no significant differences in neurocognitive developmental outcomes between prenatal and postpartum exposure to maternal depression, highlighting the need for further studies measuring depression over a longer time frame and emphasizing the importance of assessing chronicity of depressive symptomatology. Ibanez et al. (44) found that prenatal maternal depression is not associated with child development except when prenatal maternal anxiety is also present, while postpartum maternal depression would appear to play a mediating role in the relationship between prenatal maternal anxiety and children's cognitive development. Evaluations conducted on the outcomes of prenatal, postpartum depression and their combination suggest that only prenatal depression is a significant predictor of cognitive development in children (45), thus the impact of prenatal depression cannot be explained by postpartum depressive symptoms. Indeed, in a very large study of 3,379 mother-infant pairs, prenatal maternal depression was associated with less optimal early neurodevelopment of the child, including social-emotional, cognitive, and motor skills in the first 2 years, which were not observed for postpartum depression (46). Also, in low- and middle-income countries has been shown up a direct association between prenatal depression and child cognitive development to the second and third years, even independent of the presence of postpartum depression (19). In a study by Urizar (47) maternal depression was assessed during pregnancy and 6 months after delivery, while infant development was assessed up to 5 years after delivery. The results showed that maternal depression experienced during pregnancy was associated with less cognitive development of the child. However, both the onset in pregnancy and early postpartum and the severity and chronicity of depression were associated with lower social-emotional development. Although few studies have examined the effects of severity and chronicity of maternal depressive symptoms beyond the perinatal period on child outcomes, research shows that depressive symptoms can persist long after birth (8), meaning many children in early childhood are exposed to maternal depression. As early as 2000, a study by Brennan et al. (48) suggested that the interaction between the severity and chronicity of maternal depressive symptoms are related to more behavioral problems and worse language performance in children, concluding that greater severity of depressive symptoms is likely to be accompanied by worse infant developmental outcomes. Interestingly, one study has explored and identified three developmental trajectories of maternal depressive symptoms from pregnancy to 4 years after delivery (49)

describing them as follows: (1) no or few symptoms (61%), (2) persistent subclinical symptoms (30%) and (3) persistently elevated escalating symptoms (9%). Specifically, the authors found that children of mothers with subclinical, escalating, and persistently elevated symptoms were at least twice as likely to experience emotional and relationship difficulties than the others, even after accounting for other risk factors. Despite this, studies still seem to overlook the importance and interaction between severity, chronicity, and time of onset of maternal depression in predicting children's outcomes. Similarly, there is little clarity on the role of childhood age of exposure to maternal depression. Overall, as argued in the discussion section, these results highlight the need to prospectively examine the developmental trajectories of maternal depression, giving greater relevance to the times of onset of depression (prenatal or postpartum), to the chronicity and severity of depressive symptoms and paying more attention to their effect on subsequent outcomes of the child's neurocognitive development.

4. Mechanisms underlying the interaction between maternal perinatal depression and child neurocognitive development

There are multiple mechanisms that might underlie the interactions mentioned above. First, mothers with depressive symptoms might initiate with greater difficulty a dyadic interaction within which to maintain joint attention with their child. Consistent with other authors, we consider it is possible that these women are more distracted and less attuned to their children's demands for interaction (50). Indeed, postpartum depression has been associated with maternal disengagement (12). Mothers who exhibit depressive symptoms perform less verbal repetition, give fewer explanations and suggestions, and thus have reduced lexical input (50). They also appear more withdrawn and less attuned, showing a narrow range of emotional expressions and being emotionally unpredictable (15, 51). Although the biological aspects underlying these influences are not yet entirely identified, they could involve changes in hormone regulation and gene expression in the placenta (52). Among other mechanisms, studies suggest that prenatal depression might lead to epigenetic dysregulation in offspring through alterations in the hypothalamic-pituitary-adrenal axis and serotonergic transmission (12). Neurobiology studies indicate that prenatal maternal stress can significantly affect the structure and function of the prefrontal cortex due to the rapid brain development during pregnancy and due to the high density of glucocorticoid receptors in the prefrontal cortex (40, 53). Alterations in white matter of 2-3-year-old children with prenatal exposure to depression could explain functional impact on cognitive development (54), moreover other structural and microstructural changes have also been described in the neonatal period (55). Scientific evidence suggests that exposure to maternal depression, both prenatal and postpartum, influences children's lifelong health and illness pathways. Continued exposure to maternal depression in early life seems an independent risk factor for poorer cognitive, behavioral, and emotional development during childhood and adolescence (12). Notably, these effects appear to persist even when controlling for other risk variables such as obstetric complications or psychosocial conditions (42).

5. The role of psychological and psychosocial factors

Recently, maternal stress and anxiety have been recognized as important as depressive states. The prevalence of anxiety disorders during pregnancy is around 10% in developed countries and about 25% in developing countries (56). Buss et al. (57) report that pregnancy-specific anxiety is associated with lower visual-spatial working memory in both sexes and lower inhibitory control in girls. A recent review by Fitzgerald et al. (58) suggests that changes in DNA methylation are present in the umbilical cord blood and in the blood of children of mothers affected by prenatal stress. Similarly, inflammatory mechanisms and processes are also powerful modifiers of neurodevelopment and infant behavior. Other factors are also important and should be considered. For instance, Gonzalez et al. (59) found that economic, psychosocial, physiological and perinatal well-being were associated with better cognitive performance and greater total cortical surface area in children. Regarding socioeconomic status, lower maternal socioeconomic status has been found to negatively influence cognitive and behavioral outcomes at age 24 months (60) as well as the brain structure of children and their language performance. Few studies have examined these issues in low- and middle-income settings, where children are generally exposed to a greater number and range of adversities. A systematic review by Fisher et al. (61) highlighted socioeconomic disadvantage, unwanted pregnancy, young age, being unmarried, lack of empathy and support from partner, the presence of hostile in-laws, experience of violence by an intimate partner, insufficient emotional and practical support, and a history of mental health problems are among the most important risk factors for perinatal mental disorders in women from low- and middle-income countries. The authors concluded that perinatal mental disorders are more prevalent in low- and middle-income countries, particularly among poorer women with gender risk or psychiatric history. According to Bluett-Duncan et al. (19), the co-presence of additional risk factors in low- and middle-income settings may result in more impaired development than observed in middle- and upper-income socio-cultural settings. This suggests that socioeconomic adversity within low-income countries plays a significant role in determining the burden of perinatal depression on child development, making opportunities to recover from any developmental alterations less frequent. More studies are needed in low- to middle-development areas. Among other factors, pre and postnatal exposure to tobacco may also influence children neurocognitive development. For example, children of mothers who smoked during pregnancy may show delays in motor function and may exhibit less cognitive abilities in attention and response inhibition (62). Moreover, child smoking exposure *in utero* is associated with lower total brain volume and brain gray matter volume in preadolescence (63). Furthermore, maternal exposure to drugs revealed pronounced effects on executive functions and mild impairment of spatial memory in children (64). Alcohol, nicotine, cocaine, amphetamine, ecstasy, and opioids have been shown to produce alterations in neurodevelopmental trajectories (65). A recent systematic review has shown that prenatal alcohol exposure impacts motor skills, cognition, language, school achievement, attention, and affect regulation (66). However, further studies examining substances consumption and subsequent neurodevelopmental outcomes are needed (67). We could argue that health services should consider

implementing maternal-perinatal health screening programs, collecting more timely and accurate information on sometimes overlooked risk factors. In addition, more in-depth assessment programs would be important for children most exposed *in utero* to the above risk factors.

6. Discussion

According to other authors (19, 42), we consider that the existing literature is insufficient to distinguish the effect of prenatal versus postpartum maternal depressive symptoms on children's development. It is possible that it is the intensity and chronicity of maternal depression, rather than the timing of exposure (pre or postpartum) that plays a critical role in influencing children's mental health and development. Although several studies indicate an association between pre- and postnatal depression and infant neurodevelopmental outcomes, there is currently limited agreement on the period most susceptible to this influence. Several studies have shown that maternal depression during pregnancy, but not after birth, predicts adverse effects in child (45, 46, 68). Exposure to prenatal maternal depressive symptoms predicts in children poorer executive functions related to planning, organization, working memory, inhibition of inappropriate impulses and emotional control (43). However, poor associations were identified between maternal depressive symptoms at six and 12 months postpartum and neurodevelopment in middle childhood (43). Evaluations conducted on the outcomes of prenatal, postpartum depression and their combination suggest that only prenatal depression is a significant predictor of cognitive development in children (19, 20, 45). Therefore, the evidence for the direct influence of postpartum depression on cognitive development is more equivocal (19, 43, 44). To explain this inconsistency in results, we could argue how difficult it is to quantify and circumscribe the onset and duration of depressive symptoms using self-report instruments, usually administered at one time. The Edinburg Postnatal Depression Scale by Cox et al. (69), a validated and reliable instrument, is widely used in maternal depression research, but still a self-report scale that does not allow for diagnosis. EPDS also neglects intensity and stability of symptoms over time. As a result, most studies rely on the level of depressive symptoms and not on diagnoses of depressive disorders to assess the impact of maternal depression on child development. Moreover, in past decades, maternal mental health screenings were mostly done in the postpartum period, not discriminating the period of onset of the disorder. In addition, women are often unable to precisely detect the period of occurrence because they are long-standing disorders. Assessments of maternal mood based only on one or two assessments in the first year after delivery or on retrospective assessments thereafter are subject to recall bias. This type of assessment also makes it difficult to distinguish the effect of depressive symptoms developed in the first few weeks after birth from those developed several months after the child's birth. The method in which the child's development is assessed, either with standardized instruments or with parent-reported assessments, could also influence the results of a study. Furthermore, many studies tend to assess children's neurocognitive development at only one follow-up, resulting in a serious loss of information. There is considerable heterogeneity in the measurement of child neurocognitive development. The most widely used instruments for neurocognitive assessment include the Bayley

Scales of Infant and Toddler Development-Third Edition (BSID-III; 70), the Wechsler Intelligence Scale for Children (WISC, 71), various cognitive tasks (e.g., sequential memory tests, working memory tasks, inhibition tasks, etc.), heterogeneous neuropsychological batteries to assess executive functions or data collected from parents (e.g., Behavior Rating Inventory of Executive Function - Preschool version, BRIEF-P, 72). The BSID-III (70) is the most widely used standardized assessment of cognitive, language and motor development in infants aged 6 to 42 months. This instrument has good cross-cultural validity and has greater sensitivity to changes in development. However, it is an expensive and time-consuming instrument to administer. Several studies have used parent self-report assessments of child development. Although self-report measures have the advantage of providing information based on the natural life context at a reduced cost, the exclusive use of self-report measures could lead to bias in conclusions about child development (19). Indeed, maternal self-report measures are likely to be biased by mood, making ratings more negative due to negative cognitive biases common in depression. Given that the heterogeneity of data in the literature suggests that measured effects may be sensitive to instrument choice, an important step will be the selection or development of feasible and culturally sensitive measures of cognitive development (19). Future studies would benefit from the use of both physician-administered diagnostic interviews and developmental assessment and observation batteries, which, on the other hand, are more time-consuming. In addition, most of the research to date has focused primarily on early child development, single assessments or very limited time follow-ups. Future research could explore a longer time frame to strengthen the evidence about different developmental stages (12). However, mothers with higher depressive symptoms may be less likely to participate in longer follow-ups over time, with increased risk of drop out. Many studies base their assessments solely on childhood executive functions. Several authors have argued that executive functions might reflect an ability distinct from other measures of neuropsychological development (73). Therefore, it can be hypothesized that the effects of maternal depression on executive functions might be independent of overall cognitive development. This observation underscores the need to use of instruments that investigate the relationship of maternal depression with overall cognitive development and not just executive functions. The absence of clinical information on the characteristics and history of depressive symptoms and the relative paucity of longitudinal studies on children of depressed mothers make it difficult to characterize the nature of depression and its outcomes. In our opinion, although some studies have investigated the relationship between maternal depression in the postpartum period and children's neurocognitive development, few studies have really focused on the effect of different trajectories of maternal depression from the prenatal period to the postpartum period. Similarly, research differs in terms of the timing of assessments in the gestational period or postpartum period, and consequently it is difficult to compare them. In addition, the sample sizes of longitudinal studies on cohorts of mothers and children are probably insufficient to represent the magnitude of the phenomenon in the population examined. Further research is needed to clarify these issues. Depression in women is a serious public health problem, and in past years the focus has been mainly on depression in the postpartum period. Putting light on the trajectories of influence of prenatal and postpartum depression both combined and independently could be of crucial importance in identifying

mother-child dyads at higher developmental risk and in developing early intervention programs from the earliest stages of pregnancy. If prenatal depression persists after childbirth, it may affect the quality of parental functions and parental care, as well as the woman's perception of the newborn itself. Thus, an inconsistent style of care might undermine the relational foundations that should promote the maturation of self-regulation and higher-order cognitive skills in child. These effects may be even more pronounced among the offspring of chronically depressed mothers. It seems clear that screening for perinatal depression should be an important goal to support maternal and child mental health. Unfortunately, perinatal depression is often undiagnosed or untreated. The results from a systematic literature review on detection and treatment rates of perinatal depression indicate that approximately 50% of women with prenatal depression are identified in the clinical setting, of these 14% receive treatment and only 8.6% receive adequate treatment (58). For women with postpartum depression, about 31% are identified, 16% receive treatment and only 6.3% receive adequate treatment (74). Clinically, these data suggest that it would be wrong to focus psychological interventions exclusively on depressed mothers in the early postpartum weeks. Early intervention during pregnancy could have important clinical implications reducing the impact of psychopathology on maternal and child health. Even if the possible efficacy of different interventions has yet to be explored, a very recent study indicates that cognitive-behavioral psychotherapy interventions on depression during pregnancy were shown to be effective in indirectly improving infant motor development during the first 18 months after birth (75). Understanding the prenatal and postpartum mechanisms underlying these relationships would help design more appropriate timing of successful prenatal and/or postpartum interventions, as well as identifying a gestational age of increased vulnerability would change the direction of research in clinical practice. The Authors of this perspective consider that it is not the presence of depressive symptoms *per se* at a given stage of pregnancy or postpartum that influences the outcome of child neurodevelopment. We argue that it is the pervasiveness and intensity of this symptomatology over a long period of time that determines the negative effects on neurodevelopment. We also believe that future investigations should consider a broader time window capable of discerning the exerted influences of pre- and postpartum depression, using not only self-report instruments but also clinical interviews. In addition, future research should more accurately consider the influence of psychosocial risk factors, such as maternal stress, perceived social support, socioeconomic status, parental educational level, presence of a supportive partner, substance use and abuse (from tobacco to drugs) or the presence of stressful events in the past year on the child's neurocognitive development, not just using them as control variables. In addition, more data should be collected on low and middle developing countries. Further studies should also consider other confounding factors, e.g., maternal IQ, being primipara, gender of the child, sociocultural background of the woman, and the presence of additional ongoing psychological symptomatology. In our idea, chronicity and intensity of maternal depression have greater negative effects on child neurodevelopment than a single depressive episode pre- and/or postpartum. Although a literature review was not within our objectives for this perspective, we tried to include data from a wide range of studies (including literature reviews and recent and original articles on the topic). This allowed us to outline the state of

the art on the topic covered in this perspective, as well as to highlight inconsistencies and gaps that need to be filled in the approach to the study of this issue. Systematic reviews and meta-analyses on the topic have shown unclear results, therefore, a continuous evolution of research is needed in order to carry out a more careful analysis of the overall results in the literature. In this perspective, we pointed out that the assessment of maternal health has for years been limited to postpartum depression (and mostly to its influences on infant emotional and affective development), often neglecting the timing of its onset, the intensity of symptoms and their chronicity. In our idea, these aspects have received less attention than they deserve, considering the decisive role these factors might play in delineating the impact of maternal depression on childhood neurocognitive development. Certainly, as mentioned above, some aspects are very difficult to assess, thus they are less considered in the literature. However, recent studies have opened this discussion by highlighting the gaps and inconsistencies among the various data available in the literature. These considerations should be integrated in the evaluation and development of screening and treatment activities for the pregnant population, especially considering the actual burden in terms of health and disease development pathways.

7. Conclusion

Maternal depression represents a public health problem related to serious difficulties for the establishment of a good mother–child relationship. Maternal depression is also capable of directly and indirectly altering infant brain and neurocognitive development. Few prospective studies have examined the effects of perinatal depression on cognitive development with seemingly contradictory results. These inconsistencies may reflect methodological differences, but also the neglect of aspects such as the time of onset of depressive symptoms, their intensity and their duration. Further studies are needed to clarify these interactions. Understanding the prenatal and postpartum mechanisms underlying these relationships, as well as identifying a gestational age of increased vulnerability would help design more appropriate interventions. There is a clear need for clinicians to design early intervention pathways to be implemented already during

pregnancy. These could have important clinical implications for mother–child dyads who are candidates for individualized psychological treatment aimed at reducing the impact of maternal psychopathology on child development.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MS developed the theoretical formalism. All authors 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.

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