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How does sensitivity influence early executive function? A critical review on hot and cool processes

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ABSTRACT

There is compelling evidence that the quality of caregiver-child interactions during toddlerhood and the preschool years supports the development of executive function (EF) (Bernier et al., 2010; 2015; 2016; Fay-Stammbach et al., 2014; Geeraerts et al., 2021). Based on such findings, we make the case herein that sensitivity may be one of the most important dimensions of parenting contributing to early EF. In the present article, we will review empirical evidence, integrating findings from a wide range of scientific disciplines – cognitive psychology, neuroscience, and developmental psychopathology – and present theoretical ideas about how two contexts of sensitive caregiving – i.e. sensitivity to distress and non-distress cues - may be contributing differently to hot and cool EF development. Implications for future investigations on the environmental contributors of early EF, and its mechanisms, are discussed.

1. Introduction

There is a well-established association between Executive Function (EF) and developmental outcomes in early childhood, for example in academic achievement (Zelazo & Carlson, 2020), social competence (Kochanska et al., 2000), emotion regulation (Carlson & Wang, 2007), or health and wellbeing (Moffitt et al., 2011). While the internal components of the EF construct remain under debate, EF is typically defined as the set of high-order cognitive abilities that supports goal-oriented behavior (Diamond, 2013), including working memory, cognitive flexibility, and inhibitory control (e.g., Blair, 2002; Buss & Spencer, 2014; Diamond, 2013; Miyake et al., 2000). The theoretical question of what processes underlie EF is also a difficulty for developmental studies of EF during the first years of life, despite the evidence that shows the existence of rudimentary inhibitory control and working memory skills in infants as young as 5 and 6 months of age (Cuevas et al., 2012; Holmboe et al., 2018; MacNeill et al., 2018).

Two contrasting perspectives have emerged in the debate on the structure of these abilities: a unitary theory that considers EF as a unitary construct that comprises components loading on a single factor (Duncan et al., 1997), and a multidimensional theory that posits that there is a set of independent components (Stuss & Alexander, 2000). There is also the work of Miyake et al. (2000) with the adult population that has integrated both perspectives into a unified framework ("unity and diversity") and argues that EF components – i.e., working memory, cognitive flexibility, and inhibitory control – contribute differently to the performance in complex EF tasks,

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even though they are interrelated and share common processes. This perspective is not consensual, nonetheless. Evidence from studies that attempted to replicate Miyake et al.'s findings with other populations have contributed to this view, by suggesting that the structure and organization of EF undergoes developmental change, progressing from a single latent EF factor to separate components later, which in turn supports EF specialization (Best & Miller, 2010; Garon et al., 2008). Another group of authors, in a study that tested participants of different ages, found evidence for a two-factor model in preschool years (inhibition + working memory) and a three-factor model clearly demarked by adolescence (Lee et al., 2013). These results corroborated the ones found by Miller and colleagues (2012) with a sample of preschoolers and emphasized that inhibitory and working memory processes might be operating independently as early as the preschool years.

1.1. The hot and cool EF distinction

Another approach to the theoretical question of EF's internal structure is by focusing on a key distinction in the context that engages EF: we argue that the cool and hot EF distinction, proposed by some authors (e.g., Prencipe & Zelazo, 2005), is useful for considering the possible causal pathways for EF development. Cool EF concerns goal-directed behaviors exhibited in non-emotional and strictly analytic contexts, for example in controlled laboratory tasks such as the well-known *Dimensional Change Card Sort* (DCCS; Miyake et al., 2000; Zelazo, 2006). In terms of outcomes, cool EF predicts, for example, academic achievement (Blair & Razza, 2007; Kim et al., 2013; Lan et al., 2011; McClelland et al., 2007). In contrast, hot EF emerges in emotional and motivational eliciting situations (Zelazo & Muller, 2002) and has been linked to other types of developmental outcomes, for instance, prosocial behaviors and positive relations in kindergarten (McIntyre et al., 2006), mental health (Kim et al., 2013; Krueger et al., 1996), and with better-coping strategies in adolescence (Shoda et al., 1990). In a representative study, Zelazo & Muller, 2002 asked 3-year-old children to choose between a large but delayed reward or a smaller immediate one in two distinct conditions: in one, choose between the two rewards for others; in a second, choose between the two rewards for themselves. When asked to choose for others, children were more likely to select the larger and delayed reward – the authors categorized this as cool EF. When asked to choose for themselves, children were more likely to choose the smaller and immediate one – an example of hot EF. Carlson et al. (2005) found that the development of these abilities occurs in distinct developmental periods, perhaps as a result of different developmental trajectories in the underlying neural correlates (for instance, they develop at different rates). Following this line of thinking, there is evidence associating hot EF with the orbitofrontal cortex and other medial regions, while cool EF is usually linked with the lateral prefrontal cortex (Happaney et al., 2004; Zelazo & Muller, 2002. Both these abilities, however, seem to share the right ventrolateral PFC brain area (Aron et al., 2004, 2014).

As mentioned previously, research on EF's internal component structure has found mixed results. On the one hand, a group of studies has demonstrated that these constructs load onto different factors, although correlated between themselves (e.g., Willoughby et al., 2011); on the other hand, researchers found evidence of the opposite (e.g., Allan & Lonigan, 2011, 2014). In a recent study, Moriguchi and Phillips (2023) have examined the usefulness of the hot and cool EF framework in early childhood. They have concluded that according to the current research, the two-factor model is more adequate to assess EF performance than the one-factor model. These authors have stated that researchers who have defended the two-factor approach (e.g., Carlson et al., 2014; Montroy et al., 2019) have employed completely different tasks for the assessment of hot and cool EF, while researchers who found support for a one-factor model (e.g., Allan & Lonigan, 2011) have used more similar tasks. Additional supporting evidence for the cool and hot EF distinction comes from a study in 2-year-olds suggesting that the cool and hot EF domains load onto different factors (Mulder et al., 2014).

Furthermore, in a study of executive control, a construct with close connections with EF (for a detailed review of the conceptual confusion between terms with close connections with EF, please see Nigg, 2016), Conejero and Rueda (2017), have argued that hot and cool processes might have a different developmental course.

If the hot and cool EF distinction can be considered important for our understanding of EF development, a major question is then what factors might be operating on hot and cool EF processes.

Research conducted with toddlers and preschool children has consistently found evidence for the important role of environmental factors in early EF development, namely parenting behaviors. Individual differences in the quality of caregiver-child interactions, in particular sensitivity, measured during toddlerhood and the preschool years, predict early EF outcomes (Bernier et al., 2010; 2015; 2016; Fay-Stammbach et al., 2014; Geeraerts et al., 2021). In this review, based on the conceptual framework of attachment theory, we will discuss potential mechanisms through which sensitivity might be operating in early EF. Findings from research conducted in infancy and preschool from a wide range of scientific disciplines – cognitive psychology, neuroscience, and developmental psychopathology – will contribute to the raised hypotheses and discussed arguments.

1.2. Sensitivity and EF development

Studies with typically developing children in preschool support the prominent role of parental sensitivity in global EF development. Here we used the seminal definition of the sensitivity construct: the caregiver's ability to perceive and interpret accurately the signals and communications of the children's behavior, and to respond to them appropriately and promptly (Ainsworth et al., 1978). According to this definition, sensitivity encompasses different facets, namely the caregiver's responses to the children's both distress and social cues, and has four essential components: (1) awareness of the children's signals, (2) accurate interpretation of those signals, followed by (3) appropriate and (4) contingent responses. Highly sensitive caregivers are able to "see and feel things" from the child's point of view, are insightful towards their own and their child's needs and abilities and respond adequately and promptly. Less sensitive caregivers, in turn, are less aware of their child's behavior, are predominantly governed by their own wishes, and thus their responses tend to be less attuned to the children's needs and mood (Ainsworth et al., 1978; Mills-Koonce et al., 2015).

The positive association between sensitivity and EF outcomes is also supported by studies that measure the quality of parent-child interactions (including sensitivity) and in particular studies of preschool-age children (Baptista et al., 2017; Bernier et al., 2010; Fay-Stammbach et al., 2014; Hughes & Devine, 2019; Moilanen et al., 2010). A review of the effects of parenting on EF development, in early childhood, found that scaffolding, stimulation, control, and sensitivity are the most consistently associated with EF differences (Fay-Stammbach et al., 2014). A more recent meta-analysis has also found evidence of the association between parenting behaviors (responsiveness, warmth, control, scaffolding, negative regard, and autonomy support) and EF skills (Valcan et al., 2018). Here, positive parenting behaviors were associated with a higher global index of EF in preschool children, whereas negative parental behaviors were associated with lower EF skills.

Sensitivity is one of the most studied dimensions of parent-infant interaction (Ilyka et al., 2021), and a growing body of studies has found that this parenting behavior, during infancy, is also predictive of later EF in early childhood (e.g., Bernier et al., 2010; Cuevas et al., 2014; Kraybill & Bell, 2013). In two representative studies of this link, sensitivity and positive affect at 10 and 12 months of age were found to be predictive of later EF at 26 months (Bernier et al., 2010) and at 4 and 6 years of age (Kraybill & Bell, 2013).

Nonetheless, how sensitivity might be operating in EF development remains to be further explored.

1.3. Attachment theory and raised hypotheses

Attachment theory is an important source of knowledge for understanding self-regulation in early life since securely attached children rely on their caregivers to self-regulate and attend to their emotional needs (Cassidy, 1994). Children have immature self-regulatory skills and need the help of others to regulate their emotional and physiological functioning (Ainsworth & Bell, 1974; Sroufe, 1979, 2000). Children also rely heavily on their primary caregivers, with whom they establish a preferential relationship (i.e., attachment), to assist them, acting as co-regulators (Bowlby, 1979; Sroufe, 2000). We briefly discuss next the standard components of the theory with the goal of pointing out where parental sensitivity can contribute to cognitive development outcomes, including EF.

Attachment theory proposes two key components: the attachment and exploratory systems (Bowlby, 1969), which ideally elicit parental support during its activations and transitions between systems (Mercer, 2015). It is noteworthy to mention that caregivers need to be sensitive in order to meet the children's needs in both systems (Bowlby, 1988).

The attachment system is activated when children display attachment-like behaviors, such as crying or calling for the caregiver, seeking the comfort and soothing provided by their attachment figure. In these moments, children require their caregivers to protect them, comfort them, and organize their feelings and behaviors. In this context, when caregivers are sensitive to their children's need for protection in a situation that is perceived as stressful or dangerous to the child, they are allowing children to develop a sense of security, acting as a safe haven (Ainsworth et al., 1978). That is, the consistency of caregivers' behavior will help children learn and rely on their caregivers to feel safe to explore the world (Bowlby, 1979). If children's experiences of interacting with their attachment figure are characterized by being sensitively responded to when in need, they are more likely to learn that their primary caregiver is emotionally available and practice how to down-regulate their emotions in a safe context, gradually developing more self-regulatory abilities themselves (Sroufe, 2000). In addition, when a caregiver is responsive, children also feel they are being understood and that their needs are being attended to (Grossmann et al., 2013), which improves, simultaneously, their feelings of competence and self-worth, fundamental for the development of self-regulation abilities (Sroufe, 2000).

When the need to be regulated is fulfilled, the exploratory system is activated, with the purpose of gathering information from the environment. Caregivers are required to act as a secure base for children to explore – i.e., to watch over their feelings and behaviors and enjoy activities with their children. Here, the child feels motivated to explore their environment - while being aware that their caregiver is close by and ready to offer protection, when necessary (Marvin et al., 2002). This link between caregiving and the promotion of the child's exploration of the environment is fundamental for the development of cognitive abilities (Jacobsen et al., 1994), such as EF.

In the current review, we explore attachment theory's potential role in supporting explanatory hypotheses for the development of EF.

1.3.1. Sensitivity to distress and non-distress cues

Our main hypothesis is that different dimensions of sensitivity – i.e., sensitivity to distress and non-distress cues – may be contributing differentially to hot and cool EF, given that they serve different children's socialization goals (Leerkes et al., 2009). This is consistent with proposals for sensitivity being a multidimensional construct as opposed to a unitary global construct (e.g., Tamis-LeMonda et al., 1996). This is supported by work suggesting that the associations between sensitivity to distress and developmental outcomes are not the same as in the case of sensitivity to non-distress cues. As a representative case, the Attachment and Biobehavioral Catch-up intervention study trained caregivers' sensitivity to distress and non-distress cues (e.g., Dozier et al., 2008, 2013; Dozier & Bernard, 2019; Zajac et al., 2020). Sensitivity to distress was both related to attachment security and early self-regulation, while sensitivity to non-distress cues was only associated with the latter (Dozier & Bernard, 2019).

Leerkes et al. (2012) proposed that sensitivity to distress and to non-distress cues corresponds to two distinct dimensions of sensitivity, given that: (1) there is evidence for different caregiver neurological and physiological response activations when children are in distress (negative affect), compared to non-distress cues (Groh & Roisman, 2009); and (2) results from past research show that sensitivity to distress and to non-distress cues, although moderately correlated, have more unshared than shared variance (Leerkes et al., 2009; Leerkes, 2011). Sensitivity to distress can be defined as the sensitive caregiving behaviors when responding to a child's distress cues (e.g., fear, sadness) or in emotional contexts that could likely cause distress (Leerkes et al., 2012); this involves the recognition of these distress signs on the child, such as pain, sadness, fear, and anxiety. Sensitivity to distress cues can be assessed with emotional-eliciting tasks, such as the widely used Still-Face Paradigm (SFP; Tronick et al.,1978).

Complementary, sensitivity to non-distress refers to the sensitive behaviors in response to neutral or positive affect cues, in typically non-distress-like emotion-eliciting contexts (e.g., free play) (Leerkes et al., 2012). Here, caregivers are required to be aware of the child's interests and needs during neutral or positive emotional states. In summary, sensitivity to distress concerns comfort and protection, while sensitivity to non-distress concerns reciprocity and learning (Grusec & Davidov, 2010). The discrimination of these contexts of sensitivity is important because children's distress and non-distress cues may evoke different caregivers' behaviors and feelings (Leerkes et al., 2010).

A similar distinction is proposed by Bernard and colleagues (2013) that refers to the same phenomenon as: (1) nurturance, concerning caregivers' sensitivity to distress cues, and (2) synchrony, when attending to children's social signals. These authors describe nurturance behaviors as when caregivers show children in distress that they are concerned and available, responding to the children's needs by communicating comfort. These behaviors can combine verbal statements or physical behaviors (i.e., picking a child up, rocking a baby). Synchronous behaviors are described as caregivers responding contingently to their children's gestures, and vocalizations while keeping their interactions child-oriented. This set of behaviors could include, for example, responding to a direct request (e.g., receiving a toy the child is handing them) or commenting on what the child is doing (Bernard et al., 2013).

During these moments of sensitive responding, caregivers can provide two different types of input in response to children's bids: emotional input, defined by affective information provided by caregivers, and cognitive input, described as the stimulation offered by the caregiver (King et al., 2019). Nonetheless, both inputs must be expressed in a way that is considered sensitive to the child's needs and mood. A sensitive emotional input can be characterized as a contingent child-centered manifestation of affection that recognizes children's distress and intends to regulate their arousal. Parental input can be coded as both cognitive and sensitive when it is synchronous and the stimulation is appropriate, therefore providing opportunities for scaffolding children's learning and exploration activities (King et al., 2019). There is, however, no strict separation between these two forms of parental input that can arise in distress and non-distress contexts; nonetheless, emotional input responses are more likely to take place following children's distress cues (King et al., 2019).

We propose that the distinction between sensitivity to distress and sensitivity to non-distress cues could help researchers understand EF development in infancy, in particular in the context of the hot and cool EF distinction. This follows the line of thinking that hot and cool EF possibly may have different developmental courses, specifically distinct predictors and outcomes (Conejero & Rueda, 2017; Zelazo & Carlson, 2012). Finally, there is evidence that suggests that hot and cool EF are linked to distinctive brain regions (Happaney et al., 2004; Zelazo & Muller, 2002).

1.3.2. A developmental pathway from parental sensitivity to EF development

A more specific two-part hypothesis can now be introduced: (H1) early hot EF should be most strongly associated with sensitivity to distress, while (H2) early cool EF should be most strongly associated with sensitivity to non-distress. Supporting this hypothesis is evidence suggesting that, e.g., sensitivity to distress cues appears to be strongly associated with attachment security (Del Carmen et al., 1993; Leerkes, 2011; McElwain & Booth-LaForce, 2006), while sensitivity to non-distress cues has been found to be associated with cognitive abilities (i.e., attention and symbolic play) (Bornstein & Tamis-LeMonda, 1997). These findings inform our arguments that infants' attachment quality and attentional abilities are the mechanisms through which sensitivity to distress and non-distress cues operate in hot and cool EF development, respectively.

Our conjecture also finds support in attachment theory's differentiation of systems, with the activation of: a) the attachment system, eliciting more sensitive to distress behaviors in response to children's attachment behaviors – to fulfill children's needs to connect and establish an affective bond with a primary caregiver; and b) the exploratory system, in which children's exploratory-like behaviors elicit more caregiver behaviors that promote learning (and thus can be seen as sensitive to non-distress behaviors).

2. How is sensitivity operating on early executive function?

Despite the evidence pointing to the contribution of parental sensitivity in EF development, much remains to be explained about the possible mechanisms underlying such relationships. Arguments for each of the hypotheses are presented below.

2.1. Hypothesis 1. Parental sensitivity to distress is associated with the development of early hot executive function

Support for our hypothesis that hot EF is more strongly linked to sensitivity to distress comes from research that found associations between caregivers' sensitivity to distress and attachment security or self-regulation abilities and the link between attachment quality and children's hot EF (e.g., Conradt & Ablow, 2010; Jacobsen et al., 1997; Leerkes, 2011).

Attachment security has emerged as being significantly associated with caregivers' sensitivity to distress cues (Del Carmen et al., 1993; Leerkes, 2011; McElwain & Booth-LaForce, 2006). This makes sense since being able to perceive, interpret, and respond promptly and appropriately to a child's distress signals helps the child gradually internalize that their caregiver is accessible and able to meet their needs. By doing this, children are building expectations of how the caregivers will respond in the future, guiding their behaviors (Ainsworth et al., 1978; Bowlby, 1951).

Research on caregivers' responses to infants' distress cues has also found that mothers who were considered more sensitive to their infants' needs had infants who evidenced more attention-seeking behaviors when in distress and were less resistant to their mothers' attempts at soothing and regulating their distress (Haley & Stansbury, 2003; Kogan & Carter, 1996). Interestingly, Conradt and Ablow

(2010) added that children were more physiologically and behaviorally regulated since they relied on their mothers as an external regulation source. In line with this reasoning, several authors (e.g., Perry et al., 2017; Sroufe, 2000) have argued that attachment serves as a model for physiological and behavioral self-regulation learning.

Sensitive behaviors, which include caregivers' ability to adapt to the children's mood and needs mostly by learning from their past experiences, presumably will allow caregivers to support them in stabilizing their arousal more easily (Bretherton, 2013; Voorthuis et al., 2013). Children's self-regulation processes will benefit from these past experiences, which will provide strategies for interpreting and managing negative emotions (Beebe & Steele, 2013). This evidence supports the central role of the attachment figure in the process of children's emotion regulation. Noteworthy, primary caregivers constitute the first models of self-regulation, which helps children progressively incorporate and generalize that knowledge, training those competencies in a safe place created by the dyadic interaction (Sroufe, 2000).

We assume that this sense of security is transmitted in part during moments with parental sensitivity to distress behaviors, which also play a role in children's physiological regulation (Conradt & Ablow, 2010). In fact, sensitive behaviors are thought to be critical for the development of the children's stress response system (Gunnar & Cheatham, 2003). The Hypothalamic-Pituitary-Adrenal (HPA) axis is one of the main mechanisms responsible for regulating stress response and maintaining the homeostasis of the organism (Shenk et al., 2012). Longer activations of the HPA axis are associated with the dysregulation of the stress response system (see Flannery et al., 2017, and Papadimitriou & Priftis, 2009, for reviews), and with less developed self-regulatory and cognitive abilities (Blair et al., 2005; Lupien et al., 2005; Wagner et al., 2016).

The HPA axis is immature in the early postnatal period and labile to external influences. Early sensitive caregiving is known to be associated with less prolonged activations of children's HPA axis (Gunnar & Donzella, 2002), children's improved responses to stress (Hostinar et al., 2014), and shields the child from frequent exposure to stressful situations (Albers et al., 2008); for instance, insensitive behavior may constitute a source of continuous and harmful stress (Atkinson et al., 2013), which may disrupt brain development (Lupien et al., 2009).

The above-reviewed evidence contributes to the argument that sensitivity to distress is particularly relevant to the development of hot EF. However, discriminating parental sensitivity to distress behaviors in a natural environment during the early years of life tends to be challenging since the signals of distress are typically less frequent in everyday interactions, with the majority of the studies being conducted in controlled lab environments. Despite this, research has found that both attachment and regulatory abilities (both associated with parental sensitivity to distress), have been linked to the domain of hot EF (Jacobsen et al., 1997; Kochanska et al., 2000; Mittal et al., 2013; Rothbart et al., 2006). Our conjecture is for one of several developmental pathways likely at work, that is, for instance, we are not disregarding the role of the child's own regulatory abilities in hot EF. Yet, we argue that attachment is a key mechanism responsible for the development of this domain, through which sensitivity to distress operates. In fact, attachment has also been linked to regulatory abilities. Securely attached children display less significant HPA axis activation when assessed in the Strange Situation Procedure (Spangler & Grossmann, 1993; Spangler & Schieche, 1998). Furthermore, in a recent review, Brumariu (2015) presented studies that found that securely attached children are more competent in emotional regulation than insecurely attached children.

Studies of the contribution of attachment security to the development of hot EF (Jacobsen et al., 1997; Mittal et al., 2013) have used the delay-gratification task similar to the Toy Prohibition (Friedman et al., 2011), one of the few tasks used to elicit more emotional-cognitive abilities, in which infants seated on their mothers' laps are asked not to touch an attractive toy seizing their attention. Their conclusions linked secure attachment quality to children's ability to sustain a delay. In Jacobsen and colleagues (1997), attachment security was measured at three-time points (12 and 18 months, and 6 years of age), and the relation between this variable and children's hot EF was assessed longitudinally and concurrently. Results from this research suggest that the predictive role of attachment depends on the time of its assessment, with the overall (from infancy to childhood) and concurrent attachment (at 12 and 18 months of age) being the strongest predictors. However, attachment quality at 6 years did not predict children's ability to wait, when considering cognitive functioning. The difference in results given the timing of attachment quality measurement may be due to the smaller sample size ($n = 12$ children) when considering the three assessment moments. Mittal et al. (2013) only measured attachment quality concurrently, so predictive conclusions could not be withdrawn.

Attachment theory provides some clues on how caregivers' sensitivity aids young children in delaying gratification. When caregivers are sensitive to their children's needs, they are helping them develop a sense of security and trust, modeling their emotion regulation strategies. These strategies promote children's ability to manage their impulses and emotions. Interestingly, this sense of trust in one's ability to control their impulses is strengthened with the development of positive working models within the context of a secure attachment (Bowlby, 1951; Sroufe, 2000). The studies we just introduced advance some explanations for this phenomenon, suggesting that mothers of secure children may be facilitating their delayed behaviors by being more available and responsive, which in turn improves their ability to rely on parental resources, supporting children to take control of their behaviors. Of relevance, Jacobsen et al. (1997) proposed that children's ability to sustain a delay of gratification could be linked to choice. In recent work, Carlson (2023) claims that parents providing children with a choice is fueling EF development, by helping children reflect on their behavioral options, and not act purely on reflexes. This could be because children can understand they have a choice; this is evidenced in a study by Sullivan and Lewis (2003). In this study, 4-month-old infants experienced distress-like emotions when perceiving the loss of choice over the movement of an external object (a baby mobile) and therefore loss of control over the environment. In these cases, in which the infants are not allowed to choose, they act on reflex and do not ponder over their behaviors, and this could impair the practice of EF abilities and its development.

On another note, emotional input, most frequently used in distress moments, is considered relevant for the functioning of children's stress response system (Gunnar et al., 2015). For instance, touch – considered a manifestation of affection – attenuated infants' cortisol reactivity during the SFP (Feldman et al., 2010). This provides support for the contribution of nurturance behaviors for the regulation of children's arousal, closely related to the development of hot EF.

The discussed effect of infants' attachment style is not restricted to hot EF. Although less reported in the literature, seems to also be related to cool EF, measured as inhibitory control (Kamza & Putko, 2021). Attachment security allows children to feel secure to explore and learn, which in turn improves children's cognitive abilities, namely EF. This argument is also linked to caregivers helping children regulate their arousal to optimal states, which provides children with the necessary conditions and opportunities to develop their cognitive abilities while exploring (Bell et al., 2019). When children exhibit negative emotions, they tend to be less efficient in directing and focusing their attention on a specific task (Bell & Calkins, 2012). Neurobiological studies have strengthened this assumption with evidence that non-optimal levels of arousal decrease PFC functioning (McEwen & Morrison, 2013). Another complementary explanation refers to the possible mixed use by caregivers of both cognitive and emotional input when regulating children's arousal (King et al., 2019). This can then elicit more cognitive responses from children.

2.2. *Hypothesis 2. Parental sensitivity to non-distress cues is associated with the development of early cool executive function*

Sensitivity to non-distress cues is typically assessed in free-play contexts, which do not usually elicit stressful emotions in children (Bernard et al., 2013). Raters of these interactions are interested in understanding if parents are responding contingently to their children's neutral or positive signals, keeping the child's interests in mind (Bernard et al., 2013; Leerkes et al., 2012). Carlson (2023) adds that parent insensitivity occurs when parents are not able to follow children's behaviors and provide choices for them. During early caregiver-child interactions, caregivers and their children adjust to one another's characteristics, by mutually regulating their behaviors (Beebe & Steele, 2013; Lourenço et al., 2021a). Cognitive stimulation is possible when caregivers consider their children as partners in the interaction (King et al., 2019).

In a recent review, Wass (2021) suggested that EF can be expressed in the interactive relationship between the children and their environment. For children to adjust to their environment physiologically and behaviorally, they need to make predictions, anticipate events, and eventually change their behaviors to maintain stability if this environment happens to change. Caregivers' unpredictable behaviors have been associated with worse EF outcomes (Glynn & Baram, 2019). When the environment is unpredictable, children are required to adapt their behaviors more often (Wass, 2021) and must invest more resources in these unexpected scenarios (Peters et al., 2017), which may impair EF development and expression. This illustrates the need for caregivers to be predictable in order to support children's learning of how to anticipate caregivers and their behaviors. A possible explanation for this phenomenon includes attention allocation. Children may need to allocate their attention to their caregivers' behaviors more often, monitoring them with the purpose of constantly readapting to the adult. While doing so, children are not directing their attention to stimulating objects or behaviors and thus miss opportunities to explore the environment and develop their own cool EF competencies. This is consistent with all the evidence supporting an association between the development of attention and development of cool EF development (e.g., Reck & Hund, 2011; Wiebe et al., 2008; Willoughby et al., 2011).

In infancy, attention has been found to predict the development of EF. Johansson et al. (2015) found that sustained attention at 12 months, rated on a scale from 1 – minimal play-directed attention to 5 - play-directed attention for a substantial period of time, was predictive of EF at 36 months, a finding corroborated by other studies (Hendry et al., 2016; Kochanska et al., 2000). It is further supported by the observation that a key transitional phase in the development of attention, that we see around 9 months, coincides with important improvements in working memory and inhibitory control at the same age (Colombo & Cheatham, 2006; Diamond, 2002). More recently, research has identified that attention earlier in infancy is also predictive of EF capacities. Blankenship et al. (2019) found that infant attention measured as peak look duration (i.e., longest look at the video) and shift rate (i.e., number of looks at the video) towards a brief video clip, as early as 5 months, is predictive of cool EF at 10 months, measured with the A-not-B task.

The potential explanation for this relation may rely on the fact that attention plays a prominent role in the development of EF due to its link with information processing (Garon et al., 2008). Improved attention helps control information processing, which in turn aids the development of top-down regulated (goal-directed) behavior and higher self-regulatory functions (such as EF). Further support for the intrinsic link between attention and EF development comes from research that demonstrates that higher cognitive self-regulatory processes rely on cortical networks related to attention (Posner & Rothbart, 2009; Rothbart et al., 2011; Rueda et al., 2004). Thus, for basic forms of early EF to develop properly, healthy development of attentional control can be considered vital.

Furthermore, literature on attention has shown that, at first, infants are dominated by exogenous control of attention but as they progressively develop, infants are more equipped to detect patterns that may help them in processing information (Ruff & Rothbart, 1996). Contingent responsiveness (i.e., relational predictability) and temporal regularities guide individuals in detecting these patterns and how to redirect behavior to maintain stability when faced with change (Wass, 2021). Contingent responsiveness is one of the ways the environment can be predictable, supporting children's exploration of the behavioral consequences of their actions. This helps infants gather information and generalize about how they can influence the environment. These environmental responses (in this scenario, the caregivers) can be more responsive than others (Wass, 2021). Caregivers' contingent responses to infants' social cues increase the quantity and quality of the infants' attention toward an object (Mason, 2018; Mason et al., 2019). The Mason and colleagues' findings were obtained in a free-play context, with researchers comparing caregivers' sensitive and redirective (i.e., caregivers' attempts to distract infants' focus from their object of interest) responses to infants' bids. Besides predicting infant attention, caregivers' contingency in infancy predicts EF development in toddlerhood (Feldman et al., 1999). Response predictability helps infants anticipate behaviors, which improves their learning ability (Pereira et al., 2019) and increases their neural responsivity (Rayson et al., 2019; Wass, 2021). The ability to predict and anticipate events is also associated with behavioral chain reactions, since children and caregivers can already predict others and their behaviors, promoting a developmental richer interaction.

Another source of information for building predictive models of the behavior of others is by using temporal regularities in social interactions (across multiple timescales). One common example of temporal regularities in the home environment is daily routines (Feldman, 2006), where something is expected to happen in a determined time interval. Environments characterized by consistent periodic activity patterns facilitate children's prediction and rhythmic coupling between children's intrinsic patterns with caregivers (Wass, 2021). During the moment-to-moment of social interaction, oscillatory entrainment between caregiver and child is thought to ease sensory processing (Haegens & Golumbic, 2018), by eliciting bottom-up processing (Sauseng et al., 2007) and effectively providing an external source of top-down processing. This is particularly helpful for infants given their yet immature and slow-developing top-down processing abilities (Wass, 2021).

Endogenous oscillatory activity is ubiquitous in the brain and is responsible for timing-related functions, included in several cognitive processes, such as attention (Buzsáki & Draguhn, 2004). Infants who exhibit more periodic internal rhythms (e.g., heart rate and sleep cycles) display more executive control (Feldman et al., 2002; Thayer & Lane, 2000). Evidence also suggests a positive association between periodic attention patterns and faster learning (Feldman & Mayes, 1999).

Caregivers (i.e., exogenous oscillators to the child's endogenous oscillators) can act as timing devices that encode these signal periodicities, assisting children in anticipation and predicting certain events or behaviors. Nonetheless, these signal periodicities must be displayed in the form of behaviors for children to acknowledge them and integrate them into their patterns (Wass et al., 2021; Wilson & Wilson, 2005). When these signals are displayed periodically, caregivers accentuate those signals instead of others that are less predictable, directing children's attention (Wass, 2022). This conjecture seems directly related to the relevance of temporal regularities for EF development (Marsh et al., 2020).

In these temporal regularities, social partners (in this case, caregivers and children) are attuned to the interactional rhythms of each other and follow contingently each other's behaviors. For behavior to be well-coordinated, social partners are required to recurrently alternate their communicational cues. An example of smooth and precise coordination is predicting each other's beginning and ending transition timings during turn-taking in speech (e.g., Levinson & Torreira, 2015; Lourenço et al., 2021b). For instance, infants as young as 1.5 months can already engage in proto-conversations with their mothers (through vocalizations), communicative exchanges that exhibit turn-taking properties (Bateson, 1975; Beebe et al., 2010). Besides interaction with only their caregivers, children can also integrate their object exploration into these interactional exchanges and are progressively more involved in co-constructing their exploration mechanisms (Schneider et al., 2022). Research has evidenced parents' role in facilitating these processes.

Recent developmental work has demonstrated the role of caregiver-infant joint attention in the infants' in-the-moment sustained attention, in comparison with infants playing alone (Wass et al., 2018; Yu & Smith, 2016). Wass and colleagues (2018) have used two cameras to capture infants' and caregivers' frontal head and shoulder's view; while Yu and Smith (2016) have opted for the head-mounted eye-tracking technology to assess caregiver-infant joint attention and infants' attentional abilities. Both studies have used a within-subjects design, comparing infants' playing alone vs. with the caregiver. Despite these contributions, these studies have assessed in-the-moment effects on the duration of attention and cannot attest to the long-term development of attentional abilities. However, Yu and Smith (2016) highlight that in-the-moment effects may be contributing to the training of the networks accountable for attention regulation development. In another study, Suarez-Rivera et al. (2019) found more evidence for parent's multimodal behavior: besides looking at objects and their infants, parents may be signaling infants their interest by engaging in multimodal behaviors, such as handling or talking about the objects (Suarez-Rivera et al., 2019). In this work, caregivers were asked to play with their children using three toys and to name them during the interaction; later, the researchers would code for the duration and overlapping of those behaviors. These findings add to the literature regarding temporal regularities, suggesting that the difference between the onset of parent touch, gaze, or talk and the onset of infant visual attention was almost null, showing the role of temporal coordination in the development of attention (Suarez-Rivera et al., 2019). Interestingly, infants' longer sustained attention may provide caregivers with opportunities to stimulate infants' development through, for example, object naming (Pereira et al., 2014; Yu & Smith, 2012). This research has provided clues on how sensitivity in free play context may be shaping infants' preferential-looking behaviors, by testing infants' name comprehension after caregivers were asked to name novel toys while engaging the infant in free play. These parental multimodal behaviors serve as possible cues about parents' interests, which, when repeated, may entrain children's internal mechanisms implicated in the development of attention regulation (Yu & Smith, 2016).

Nonetheless, children and caregivers must be coordinated for those moments to be successful. Parents must be sensitive to children's signals to assure their response is adequate (Ainsworth et al., 1974). Supporting this claim, infants whose parents were more responsive (vs. more directed parents or infants playing alone) were more likely to direct their attention to an object for a longer period of time (McQuillan et al., 2020; Tamis-LeMonda et al., 2017). Indeed, caregivers can adjust their behavior in important ways when observing their children exploring. For instance, if the infant grabs a toy and plays with it, caregivers may introduce some information about the toy, assisting their exploration (e.g., McQuillan et al., 2020).

A recent study of parent-infant interactions has suggested that differences emerged in parent-infant coordination and infant-sustained attention concerning the amount of talk provided by parents: infants whose parents talked less exhibited longer periods of sustained attention. Researchers stated that these less talkative parents could be more sensitive to the appropriate moments to intervene and stimulate infants (Schroer et al., 2019), which resembles the definition provided by King and colleagues (2019) concerning cognitive input, and strengthens the arguments raised by the latter group of authors, establishing that quality of input matters most, in comparison to quantity. This underscores the importance of caregivers' sensitivity to children's social signals.

The reviewed research provides pertinent examples of how parents' sensitivity to social signals, through the use of cognitive input in the right amount considering their children's needs, contributes to the children's ability to predict and anticipate events and, consequently, adapt to one's environment. Moreover, longer sustained attention, one of the outcomes of sensitivity to non-distress, might emerge also as a result of contingent responsiveness and temporal regularities (e.g., Yu & Smith, 2016). Noteworthy, infants' attentional skills (besides contributing to learning) are a predictor of EF in the early years of life (Blankenship et al., 2019; Colombo & Cheatham, 2006; Colombo & Richman, 2002; Cuevas & Bell, 2014; Reck & Hund, 2011; Ruff, 1986). This suggests attention might serve as a mechanism for cool EF development.

Finally, factors associated with hot EF can also be at play in cool EF. Attachment security may also be contributing to cool EF– as noted in the previous section – given that caregivers, when providing a safe haven for children to be soothed and comforted, are equipping them with a sense of security that allows them to explore the environment, which is linked with the development of cognitive abilities.

3. Discussion

Despite the well-consolidated evidence of the important role of caregivers' sensitivity to EF development (Baptista et al., 2017; Bernier et al., 2010; Fay-Stammbach et al., 2014; Hughes & Devine, 2019; Moilanen et al., 2010), our understanding of the underlying mechanisms is still limited.

In this review, motivated by the attachment theory framework, we argued that sensitivity to distress and sensitivity to non-distress cues might contribute differently to distinct components of EF: sensitivity to distress cues to hot EF, i.e. to more emotional abilities elicited in emotional contexts; and sensitivity to non-distress cues to cool EF, i.e. to more cognitive abilities assessed in abstract contexts (Prencipe & Zelazo, 2005). Our conjecture, when considering hot and cool EF, is one that predicts a relative importance of sensitivity to distress vs. sensitivity to non-distress cues, not a strict separation. In both moments with or without distress, adults can respond with two types of behaviors: emotional, characterized by a more affective response, or cognitive, when stimulation is provided by the caregiver (King et al., 2019). In recent studies, researchers found significant differences in caregivers' elicited responses when comparing moments of distress and non-distress in the infant (Leerkes, 2011; Leerkes et al., 2009, 2012, 2015).

The role of attachment security in hot EF

In moments of distress, caregivers' sensitive behaviors have been associated with children's attachment security and regulatory abilities (e.g., Leerkes, 2011), which in turn are known predictors of hot EF (Jacobsen et al., 1997; Kochanska et al., 2000; Mittal et al., 2013). Attachment security and regulatory abilities on their own may elicit more emotional input from caregivers (King et al., 2019). We advance that the mechanism through which nurturance behaviors promote the development of more emotional abilities of EF is attachment security, which helps physiological and emotional regulation (Ainsworth & Bell, 1974; Brumariu, 2015; Spangler & Grossmann, 1993; Spangler & Schieche, 1998; Sroufe, 2000). The children's immature self-regulation abilities are supported by caregivers that both provide exogenous input but also serve as a primary model for these abilities. When children feel that their needs are being met by sensitive caregivers, they develop a sense of security that their caregivers are emotionally available to assist them in these complex processes of regulation. Given the links between self-regulation and hot EF abilities (Kochanska et al., 2000), caregivers may be contributing to these competencies by providing the sensitive behaviors that children require when in distress, through which an attachment security pattern is developed. Furthermore, these parenting to distress behaviors, and attachment security as well, operate on the development of stress response systems (e.g., HPA axis; Gunnar & Cheatham, 2003; Gunnar & Donzella, 2002). Emotional input conveyed through facial expressions, vocalizations, touch, etc., is likely to be present in distress-eliciting responses (King et al., 2019) and is associated with this complex system of regulation (Feldman et al., 2010).

The role of attention abilities in cool EF

In general, regarding social cues (i.e., when engaging in smooth, well-coordinated interactions that show high levels of synchrony), children are progressively more capable of detecting environmental patterns that assist them in information processing. Two possible ways of improving an individual's pattern detection are (1) contingent responsiveness (if-then sequence or more complex behavioral sequences) and (2) temporal regularities (at different time scales). Contingent-responsive caregivers help children gather and generalize information about how they are influencing the environment and how to be a partner in behavioral chain reactions, which occur when both caregivers and children are able to anticipate and predict one's behaviors (Beebe & Lanchmann, 2014; Wass, 2021). These are also responsible for children's growing learning abilities (Pereira et al., 2019) and neural responsivity (Rayson et al., 2019; Wass, 2021). Temporal regularities (consistent periodic activity patterns at multiple timescales) are thought to promote sensory processing (Haegens & Golumbic, 2018). Caregivers, acting as timing devices, are effectively assisting children by replacing their immature top-down processing (Sauseng et al., 2007; Wass, 2021) by providing the timing signal externally. When periodic, these sensitive behaviors are highlighting those signals instead of more aperiodic ones and, therefore, can also orient children's attention (Wass, 2022). Conclusions of a growing body of studies have linked longer sustained attention (Bornstein & Tamis-LeMonda, 1997) to caregivers' interactive behaviors that are contingent and exhibit temporal regularities (Mason et al., 2019; Wass et al., 2018; Yu & Smith, 2016). This supports the hypothesis that sensitive to non-distress behaviors may be contributing to cool EF, given that attentional skills are a known predictor of differences in later EF (Reck & Hund, 2011; Ruff, 1986). These responses to children's non-distress cues may elicit both emotional and cognitive input from caregivers since these moments are characterized by children's positive or neutral affect.

Partial separation of hot and cool EF

Our hypothesis is not that sensitivity to distress and to non-distress are necessarily operating exclusively on hot and cool EF, respectively. Instead, we propose that there is a predominant contribution of these moments of sensitive parenting to EF development. The caregivers' use of both emotional and cognitive input may provide some explanation for why attachment security is also contributing to the cool domain of EF, given that these types of inputs are not used exclusively in one context (i.e., sensitivity to distress or non-distress moments). In fact, attachment security theory itself provides support for this possibility: a) a secure environment helps infants feel safe to explore, practice, and develop their own cognitive abilities (Sroufe, 2000), and b) it helps down-regulate their arousal, which in turn provides the appropriate conditions to explore the environment (Bell et al., 2019). In both moments, caregiver sensitive behaviors must be consistent enough to allow infants to anticipate and generate models, models that can be used for generalization to other social contexts. This is supported by attachment studies: insecure-ambivalent children are more likely to be exposed to unpredictable and inconsistent caregiver responsiveness (Cassidy & Berlin, 1994), leading to hypervigilance, reduced exploration, and more emotional regulation difficulties (Weinfield et al., 1999).

The role of infants' characteristics

To promote children's development, caregivers must be sensitive in enough moments of distress – i.e., responding promptly and adequately to children's distress signals – to also allow for more non-distress moments to occur – that is, support more frequent episodes of positive or neutral mood where exploration of the environment is more probable. Most likely, this also depends on children's characteristics that change how often caregivers must be sensitive in distress moments, and others during non-distress periods. For instance, children's temperamental characteristics may influence the balance between sensitivity to distress and to non-distress.

More temperament-reactive children are harder to soothe and are easily distressed (Rothbart & Bates, 1998). Although these characteristics do not seem to moderate the relationship between maternal sensitivity to distress cues, behavioral problems, and social competence (Leerkes et al., 2009) – i.e., maternal sensitivity to children's distress has the same effect on more and less temperamentally reactive children when considering behavioral problems and social competence – maternal sensitivity to distress appears to be related to less affect dysregulation, among children who are more temperamentally reactive (Leerkes et al., 2009). Furthermore, maternal sensitivity to distress was also linked to more affect dysregulation among children who were less temperamentally reactive. Additional results demonstrated that maternal sensitivity to non-distress cues was not relevant for affect dysregulation by itself, only predicting affect dysregulation when maternal sensitivity to distress was considered (Leerkes et al., 2009). According to the authors' interpretation, these findings do not entirely support the differential susceptibility theory, as temperamentally reactive children do not display higher susceptibility to the influence of maternal sensitivity to distress, compared to less temperamentally reactive children. Instead, what varies between the two groups of children is how sensitivity to distress is influencing affect regulation. Nonetheless, these results suggest that more temperamentally reactive children may benefit more from sensitivity to distress moments than less temperamental children, who may find higher sensitivity to be intrusive (Leerkes et al., 2009). This is corroborated by the vantage sensitivity model (Pluess & Belsky, 2013), which posits that children temperament is a vantage-sensitivity factor, in which children with more difficult temperaments may benefit from early sensitive parenting in later social competence and social skills; but also, in higher extension than children with less difficult temperaments (Roisman et al., 2012; Stright et al., 2008). Nonetheless, Bosquet-Enlow and colleagues (2019), in a study of inhibitory control and working memory, found that maternal caregiving in infancy that is emotionally supportive was a predictor of inhibitory control in preschool years, independently of infant temperament, whereas maternal behaviors that are supportive of the infant's cognition were predictive of working memory abilities. Future studies could contribute to this literature and clarify the potential moderator role of infant temperament on the relationship between maternal sensitivity and EF development in infancy.

In addition to children's temperament interaction on the relationship between sensitivity to distress/non-distress and hot/cool processes, genetics may also play a role. A limited but growing body of studies has brought to light that EF abilities in young children are heritable (e.g., Groot et al., 2004; Polderman et al., 2007). Friedman et al. (2008) found similar results in a study carried out with young adults but concluded that this does not mean that the environment cannot influence the development of EF. Petrill and Deater-Deckard (2004) contribute to this line of thinking. In a large sample study of same-sex identical twin pairs, assessed from 3 years 6 months to 3 years 9 months, these researchers examined the potential associations between task orientation, parental warmth, socioeconomic status, and cognitive ability, controlling for genetic influences. Cognitive ability was associated with maternal warm behavior, assessed during home visits, over and beyond genetics, in which twin similarity was estimated. Finally, Taylor et al. (2010) argued that interactions between genetics and the environment are also contributing to EF individual differences.

On another line of evidence, a study with a full-adoption design raised an important research question regarding genetic influences on hot and cool EF development, suggesting that there could be partially distinctive pathways given that there were no genetic effects on hot EF (measured with a delay of gratification task) – only on cool EF (Leve et al., 2013). Future research could approach this possibility and further study its implications for hot and cool EF development, and also for sensitivity to distress and to non-distress cues.

The role of caregivers' characteristics

Adding to the complexity of the assessment of caregiver-child interaction behaviors, caregivers' individual differences shape the use of emotional and cognitive input in social exchanges, independently of the distress vs. non-distress context (King et al., 2019).

Adaptive emotional regulation seems to be related to the use of emotional input, while the ability to take into perspective children's thoughts and interests stimulates cognitive input. Understanding children's needs may inform the amount and quality of the input. Caregivers who do not accurately understand children's developmental needs may be non-responsive or perhaps more problematic, be intrusive. Interestingly, according to biological sensitivity and differential susceptibility theories, children may be more sensitive to one input relative to another (King et al., 2019; Leerkes et al., 2009). This assumption indicated the need to assess these different dimensions of input in children's development. For emotional input, King et al. (2019) used the SFP and then calculated the mean proportion of the time mothers spent touching the infant. For cognitive input, they asked mother-infant dyads to use audio recording devices to assess infants' exposure to linguistic stimulation. Nonetheless, despite the amount of input provided for the child, these behaviors must be sensitive and provided according to the child's needs (King et al., 2019). Another recent study corroborates this, as findings showed infants whose parents talked less, exhibit longer sustained attention (Schroer et al., 2019).

3.1. Questions for future research

Considering the issues previously addressed, the above-reviewed evidence also motivates us to reflect on certain questions that require further research.

The first concerns the role of the frequency of sensitivity to distress and to non-distress moments to EF development: *Could it be the case that* sensitivity to distress *contributes more than* sensitivity to non-distress *for overall EF development (or* vice versa*)?* Further reflection upon these arguments could be useful to understand if sensitivity to distress contributes indirectly to this ability, for instance, by removing the interference effect of negative affect in the development of cognitive processes.

Another important issue refers to the importance of caregivers' multimodal behaviors. The majority of studies regarding caregivers' sensitivity contribution to EF development have been assessed considering sensitivity as a global construct, not giving enough details to sensitivity's multimodal behaviors, which include touch, mind-mindedness, and mental-state talk, among many others. Nonetheless, one study did address maternal mental-state talk and the development of EF components in preschool children (Baptista et al., 2017). The authors found that maternal mental-state talk predicted cognitive flexibility development, but not other EF components. This raises an important question in the literature: *could multimodal sensitivity behaviors be contributing differently to distinct components of EF? And what about overall EF during the early years of life?* There is not enough evidence to allow researchers to conclude what specific sensitive behavior could be contributing the most to EF emergence and development in the early years. We believe this is an important gap in the literature and that further research is needed.

Finally, research with at-risk populations is also needed. Developmentalists concerned with psychopathology have long defended that research about normative development is needed to allow for later comparisons with atypical populations to determine possible strengths and difficulties and inform effective interventions (Rutter & Sroufe, 2000), which upholds the relevance of further studying the role of sensitive behaviors on early EF development. Regarding atypical populations, for instance, assessing prematurity is relevant since this is an increasing population at risk, and studies about parenting and EF development are still lacking (Doellinger et al., 2017). Children born preterm exhibit poorer performance in cognitive tasks and in joint attention compared to full-term samples during the first year of life (Brummelte et al., 2011; Landry, 1986). Specifically, premature children have shown EF deficits (Aarnoudse-Moens et al., 2009). The differential susceptibility model (Belsky et al., 2007) has found support from a group of studies with children born preterm: when exposed to high maternal stress at the age of 6 months preterm infants exhibited lower social competence compared to preterm peers exposed to low maternal stress, with the latter demonstrating more positive results even than full-term infants (Gueron-Sela et al., 2015). This might imply that children born preterm could be more susceptible to the quality of the environment. Further research on this topic is needed to understand if sensitive parenting behaviors could be playing a prominent role in EF development among children at risk. This would strengthen our knowledge about risk and protective factors that contribute to early EF development.

3.2. Limitations and contributions

The present review aimed to explore the possible contributions of caregivers' sensitive to distress and to non-distress behaviors to early EF development. In this work, we advanced arguments from a wide range of scientific disciplines and presented theoretical ideas about how sensitivity could be operating in early EF abilities, and raised some research questions that are yet to be explored.

Besides the relevance of this work, it is centered on a more classical view that considers mostly the maternal role in children's development. Literature has been presenting evidence of potential differences in mother-child and father-child interaction styles, yet these studies are scarce, which hampers their inclusion and discussion in review studies. Future reviews should also include reflections on how sociodemographic factors might influence the relationship between sensitivity and early EF outcomes.

Despite these limitations, this review raises important questions not yet explored, introducing that different contexts of sensitivity may be working differently on distinct EF outcomes. To our knowledge, no other work has explored potential mechanisms for the relation of caregivers' sensitivity to the development of hot and cool executive function domains. Importantly, we raise two grounded hypotheses to be discussed in the scientific community. Future studies should research these assumptions so targeted interventions could be developed and validated for the early years of life, to prevent difficulties in executive functioning.

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CRediT authorship contribution statement

Cláudia Ramos: Conceptualization, Writing – original draft. **Alfredo F. Pereira:** Conceptualization, Writing – review & editing, Project administration. **Amber Feher:** Writing – review & editing; **Joana Baptista:** Conceptualization, Writing – review & editing, Project administration.

Data Availability

No data was used for the research described in the article.

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