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Early mother-infant interaction and the development of executive functioning during early childhood

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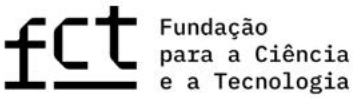
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Resumo

Investigação sobre o funcionamento executivo (FE) tem demonstrado implicações relevantes para o desenvolvimento das crianças. No entanto, na infância, poucos estudos exploraram os potenciais preditores do desenvolvimento do FE, dedicando-se exclusivamente ao estudo de fatores individuais. A presente investigação teve como objetivo examinar a contribuição de fatores ambientais, como a sensibilidade, *mind-mindedness* e o stress tóxico maternos – previamente identificados como preditores do FE em estudos com crianças mais velhas – para as competências executivas precoces. Com este propósito, foram realizados quatro estudos: (i) uma revisão teórica, que analisou a literatura existente e formulou hipóteses sobre como um dos comportamentos parentais mais estudados – a sensibilidade – pode estar a contribuir para o FE precoce; (ii) uma *scoping review* que sintetizou os procedimentos de administração de uma das tarefas mais utilizadas – a tarefa A-not-B; (iii) um estudo empírico quantitativo para compreender as implicações da sensibilidade e *mind-mindedness* maternas, em contextos de interação potencialmente desencadeadores de não-stress ou stress, para o FE no primeiro ano de vida; e (iv) um estudo empírico quantitativo para explorar a validade convergente do Questionário de Funções Executivas Precoces e compreender a potencial contribuição do stresse tóxico para as competências de FE reportadas de crianças com 9-24 meses. A sensibilidade em contextos de stress e a *mind-mindedness* em contexto de não-stress parecem estar associadas ao FE. O stress tóxico emergiu como preditor das competências de regulação. Os presentes resultados contribuem para o desenvolvimento de investigações e intervenções futuras sobre o FE na infância, potencialmente através da intervenção no contexto relacional.

Palavras-chave: Funcionamento executivo; Crianças; Sensibilidade; Mind-mindedness; Stress.

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Abstract

Extensive research on executive functioning (EF) has examined its implications for children's development. However, in infancy, the few studies that have examined the potential predictors contributing to early EF development, examined almost exclusively the study of individual factors. The current investigation aimed to examine the contribution of environmental factors known to be implicated in later EF abilities, namely maternal sensitivity, mind-mindedness, and toxic stress, to early EF. For this purpose, four studies were conducted: (i) a theoretical critical review, which reviewed the existing literature and hypothesized how one of the most studied parental behaviour – sensitivity – may be contributing to early EF; (ii) a scoping review, to synthesize the administration procedures of an important EF task – the A-not-B; (iii) a quantitative empirical study to understand the implications of maternal sensitivity and mind-mindedness in distress and non-distress eliciting contexts of interaction for EF in the first year of life; and (iv) a quantitative empirical study to explore the convergent of the Early Executive Functions Questionnaire and to understand the potential contribution of toxic stress to children's reported EF abilities in children 9-to-24 months. Sensitivity in the distress context and mind-mindedness in the non-distress context appear to be associated with EF. Toxic stress emerged as a predictor of children's regulatory abilities. The present findings help inform future research and interventions on early EF, potentially through the intervention on the relational context.

Keywords: Executive functioning; Children; Sensitivity; Mind-mindedness; Stress.

APA PsycINFO Classification Categories and Codes:

2340 Cognitive Processes

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Introduction

Executive Functioning (EF) has been established as a set of high-order abilities that enable goal-directed behavior, with important implications for later developmental outcomes in several domains (e.g., Caporaso et al., 2019; Kochanska et al., 2000; Kuhn et al., 2014; Zelazo & Carlson, 2020).

These abilities have been extensively studied in preschool years, with research suggesting the important contribution of the quality of caregiver-child interactions and parenting stress to EF development (Baptista et al., 2017; Fay-Stammbach et al., 2014; Hughes & Devine, 2019; Wagner et al., 2016). Far less research has been conducted in infancy, a period of significant developmental changes, particularly in terms of brain development (Fiske & Holmboe, 2019).

The existing and limited research on EF in infancy appears to consist of two bodies of work: (a) the emergence of infants' rudimentary EF abilities during the first year of life (Cuevas et al., 2017; Holmboe et al., 2018), which lends support to the study of EF during this developmental period; and (b) individual predictors of infants´ EF (e.g., Cuevas & Bell, 2014). The latter has specifically explored the role of child factors, such as attention and brain development. Key findings include how attention at 5 months predicts EF at 10 months, and activations in the prefrontal and parietal cortices during inhibitory control tasks are present at 10 months (Blankenship et al., 2019; Fiske et al., 2022; Holmboe et al., 2018). Literature on these individual factors has linked them to the quality of caregiving, specifically to sensitivity and mind-mindedness (Bornstein & Tamis-LeMonda, 2017; Guo et al., 2023; Kok et al., 2015). Nevertheless, research on EF in infancy has not examined the impact of these environmental variables on EF development.

Therefore, this dissertation aimed to address the following research question: *To what extent do environmental factors, such as sensitivity, mind-mindedness, and parental toxic stress – previously associated with EF in older children - contribute to the development of EF already in infancy?*

To provide evidence to respond to this research question, four studies were conducted based on Attachment Theory (Bowlby, 1969/1979) and Blair & Ursache's bidirectional model for EF and self-regulation (Blair & Ursache, 2011). Attachment theory provides an important framework for understanding the development of self-regulation in early childhood. Since children rely heavily on their caregivers to help them manage their emotions and physiological states due to their immature regulatory abilities, it is crucial that caregivers act as co-regulators

and respond consistently and sensitively to their infants' needs. This promotes a secure attachment, whereby children turn to their caregivers when they are distressed (Ainsworth & Bell, 1974; Bowlby, 1979; Sroufe, 1979; Sroufe, 2000). Complementarily, Blair and Ursache (2011) propose that the inverted U-shaped relationship between EF and self-regulation is dynamic and feedback-based, in which moderate levels of arousal optimize this feedback loop, promoting EF abilities (Arnsten & Goldman-Rakic, 1998); perhaps through the influence of experience (e.g., sensitive environments) on brain systems (Kok et al., 2015; Sethna et al., 2017).

Grounded in these theoretical frameworks, this dissertation is divided into seven chapters, each designed to address the proposed research question.

Chapter I (Theoretical Background) presents the current debate on the structural organization of EF abilities in detail. This is followed by an overview of the development of these abilities in the first year of life, along with arguments supporting the relevance of examining EF abilities during this period (e.g., implications of EF for development, stability in individual differences, and EF malleability). The chapter also discusses the theoretical frameworks underlying EF development, the challenges associated with the assessment of rudimentary EF abilities, and the empirical evidence supporting the influence of individual and environmental predictors on EF is outlined.

Chapter II outlines the research problems and objectives of the present study.

Chapter III focuses on the first study of the dissertation: a critical review that aims to examine empirical evidence, integrate findings from various scientific disciplines, and present theoretical ideas about how different contexts of sensitive caregiving may contribute differently to the development of hot and cool EF. Based on existing literature on early attention and attachment studies, this study hypothesises that different contexts of sensitivity (i.e., non-distress and distress-eliciting interactions) may affect distinct EF outcomes. This critical review and the theoretical arguments concerning the development of EF during this period supported the subsequent studies.

The above study highlighted the challenges associated with assessing EF in early childhood, prompting us to conduct a second study: a scoping review aimed to map the procedures used in studies employing the A-not-B task to assess EF in children up to 24 months (**Chapter IV**). A total of 53 reports were included in the review. The majority of these were found to use the A-not-B task to make a general assessment of EF, followed by an assessment of working memory and inhibitory control. This involved using the standard two-location task with fixed delays or delays that varied according to the children's performance. Two

consecutive correct trials were used to switch locations, and accuracy was measured as the main outcome. These findings informed the design of the subsequent empirical studies, particularly Study 3, for which the A-not-B task procedures were derived. This work is also relevant, as it provides clear insights into current EF assessment practices and clarifies the usefulness of the A-not-B task for EF evaluation.

The third study (**Chapter V**) was a quantitative, cross-sectional, empirical study of children aged 9 to 13 months and their mothers. The study aimed to examine the associations between maternal sensitivity and mind-mindedness in non-distress (free-play) and distress-eliciting interaction contexts (play with no toys, play with a challenging toy, and a reunion episode after a brief mother-infant separation), and infants' EF within the first year of life. Maternal sensitivity was measured using the Ainsworth Sensitivity-Insensitivity scale (Ainsworth et al., 1978), while mind-mindedness was assessed using the coding scheme of Meins and Fernyhough (2015). The A-not-B task was employed to evaluate children's EF performance. This study found that maternal sensitivity in the distress context and mind-mindedness in the non-distress context were both associated with EF, but only mind-mindedness predicted EF performance.

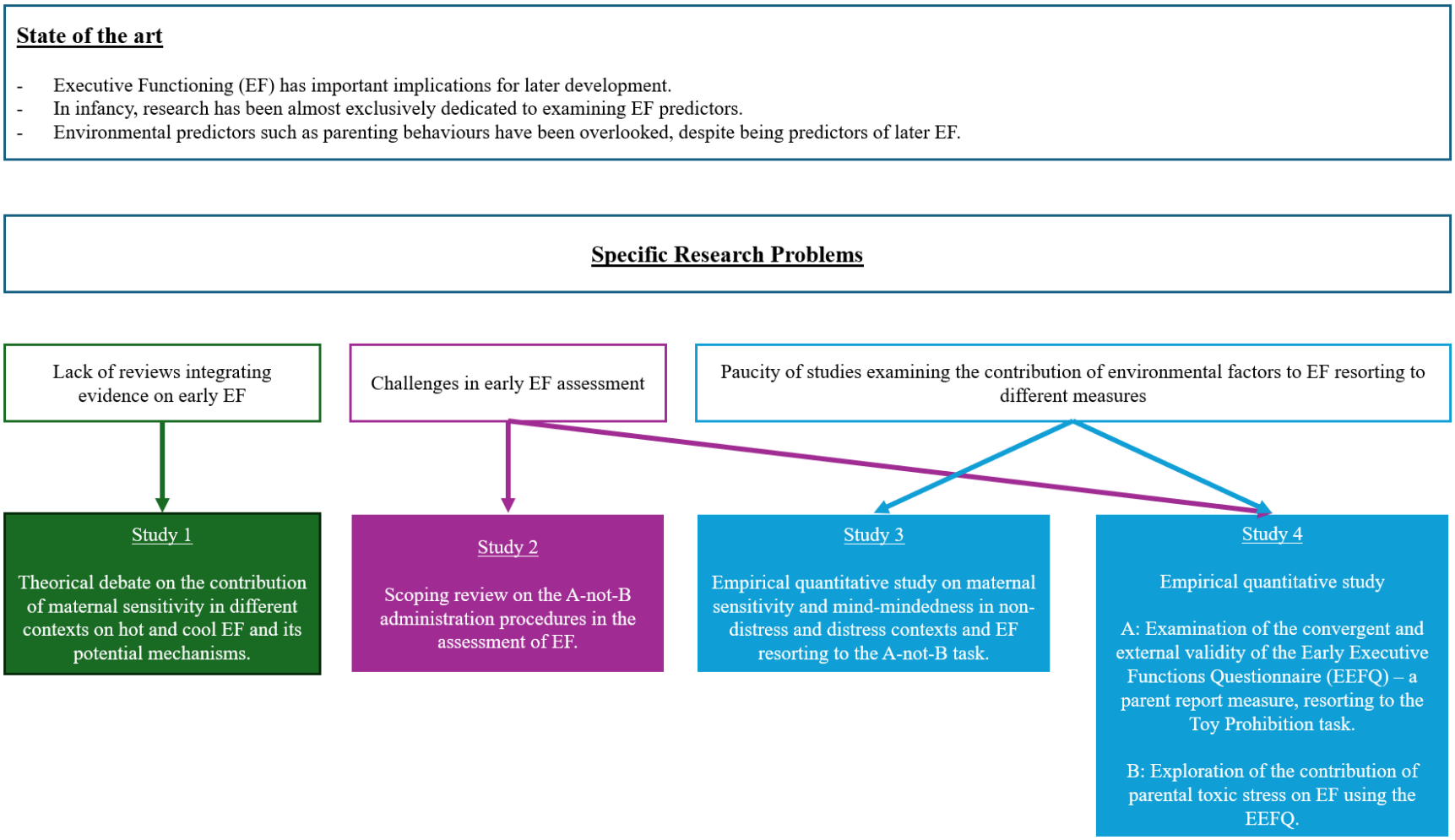
Although the use of performance-based measures is essential, reports are equally important for understanding children's behaviours in everyday situations. However, there are no EF report measures available for infants and toddlers. To address this, Hendry & Holmboe (2021) have designed a parent-report questionnaire on children's early EF – the Early Executive Functions Questionnaire (EEFQ). One of the objectives of the fourth study (**Chapter VI**) was to examine the convergent and external validity of this measure in 9 to 13-month-old children. This study concluded that the inhibitory subscale of the EEFQ was associated with Toy Prohibition performance (Friedman et al., 2011), a widely used measure of inhibitory control. Building on previous research that has highlighted the impact of parenting stress on both parent-child interactions and children's EF (e.g., Dai et al., 2019; de Cock et al., 2017; Demers et al., 2010; Hutchinson et al., 2016; Landry et al., 2006; McMahon & Meins, 2012), this study also aimed to investigate whether parental toxic stress is associated with early EF in children aged 9 to 24 months, over and above sociodemographic factors. This study found that parental toxic stress concerning the behavioural domain was related to the regulation subscale of the EEFQ.

Finally, **Chapter VII** (General Discussion) provides an overview of the four aforementioned studies, examining the connections between their findings in detail and discussing the potential implications for assessment, intervention, and future research.

In summary, this dissertation provides evidence of the impact of environmental factors on EF development in the first years of life. These findings have important implications for intervention, as they suggest that improving maternal sensitivity and mind-mindedness, while reducing parental toxic stress, may promote more adaptive EF developmental trajectories in children. Nevertheless, substantially more research is needed in this area, and there is an urgent need for well-validated assessment tools for infants and toddlers to advance research and inform early intervention efforts.

Figure 1

Schematic outline of the dissertation: state of the art, research problems, and objectives.



CHAPTER I

Theoretical Background

The Development of Early Executive Functioning

Executive functioning (EF) has been defined as a set of cognitive processes that allow individuals to regulate thoughts, actions, and emotions to achieve goal-directed behaviours (Diamond, 2013; Garon et al., 2008). This group of high-order EF abilities includes three core interrelated components: inhibitory control, the necessary ability to control attention, behaviours, thoughts, and emotions, to suppress a prepotent responses in favor of goal-directed behaviour; working memory, the capacity to process and manipulate information during brief periods of time; and cognitive flexibility, the capability to adapt to new situations, activities, and tasks, which require modification and integration of new rules (Diamond, 2013; Miyake et al., 2000; Miyake et al., 2012).

Although extensive research has been conducted on the topic, considerable debate persists about the EF construct and its components, which can make it challenging to understand the developmental trajectory of EF during the early years of life. Two opposing perspectives have become evident: a unitary framework that conceptualizes EF as a single construct, with its components loading onto a single factor (Duncan et al., 1997), and a multidimensional theory that proposes the existence of a set of independent components (Stuss & Alexander, 2000). Miyake et al. (2000) have integrated both perspectives into a unified framework ("unity and diversity"), arguing that EF components – i.e., working memory, cognitive flexibility, and inhibitory control – make distinct contributions to performance on complex EF tasks, while still being interrelated and sharing common underlying processes.

Accumulated evidence from studies involving children and adolescents indicates that the structure of EF evolves over the years, pointing to increasing specialization (Best & Miller, 2010; Garon et al., 2008). In particular, findings from preschool samples support a two-factor model in which inhibitory control and working memory already function as distinct components (Lee et al., 2013; Miller et al., 2012). Lee and colleagues (2013) followed children over 10 years to examine the developmental organization of EF abilities. Their findings showed that the intercorrelations among the core EF components decrease during adolescence. A two-factor structure - working memory and inhibition - best explains the organization of EF up to around the age of 15, after which a three-factor structure provides a better fit. Although cognitive flexibility emerges earlier in development (Cuevas et al., 2017), its structure does not yet

differentiate early, likely because it heavily depends on working memory (Vandierendonck, 2012). Working memory appears to reach a sufficient level of maturity only in adolescence, allowing cognitive flexibility to consolidate as a distinct EF component (Lee et al., 2013).

A useful conceptual distinction within EF differentiates between cool and hot EF abilities (Prencipe & Zelazo, 2005; Zelazo & Carlson, 2020; Zelazo & Muller, 2002). Cool EF are typically involved in contexts that elicit strictly analytical behaviours and seem to predict academic achievement (Brock et al., 2009; Willoughby et al., 2011); while hot EF concern the EF behaviours that are needed in emotional or motivational situations (Zelazo & Muller, 2002) and are strongly linked to behavioural and emotional difficulties (Willoughby et al., 2011). Interestingly, studies investigating the validity of the hot versus cool EF distinction in early childhood have produced mixed findings. Researchers who support a one-factor model have demonstrated that these constructs load onto the same factor (Allan & Lonigan, 2011, 2014), while another group of authors (Willoughby et al., 2011) found the exact opposite, with hot and cool constructs loading onto different factors, although being correlated. In light of recent research, the distinction between hot and cool EF abilities in early childhood seems to be of great relevance, although these boundaries are not always clear (Moriguchi & Phillips, 2023).

Examining EF development in the first years of life is essential, given that a clearly organized structure of EF does not appear until around the age of 24 months (Miller et al., 2023). Research shows that infants begin demonstrating simple EF skills within the first year, with substantial improvement between infancy and the preschool years (Carlson, 2005; Diamond, 2006), with the developmental course of each core component seeming to differ. Inhibitory control and working memory seem to emerge at around six months of age (Holmboe et al., 2018), with these abilities improving gradually with age (Diamond, 2013).

Regarding inhibitory control, infants as young as 6 months can inhibit gazes towards distractors (Holmboe et al., 2018), and at 8 months, inhibit actions when prompted by caregivers (Kochanska et al., 1998). From 8 to 10 months, some can resist touching an attractive toy (Kochanska et al., 1998), and across 7.5 to 12 months, there is steady progress in these abilities (Diamond, 2013).

Similar to inhibitory control, infants exhibit a continuous increase in working memory abilities from 7.5 to 12 months (Diamond, 2013), during which children between 9 and 12 months already show the ability to update information in working memory. When reaching 12 months of age, they are able to tolerate 10-second delays, signalling a meaningful growth in their capacities (Diamond, 1990, 2013).

Working memory and inhibitory control appear, therefore, to be co-dependents, commonly operating together and supporting each other (Diamond, 2013). Working memory enables inhibitory control by allowing individuals to keep task-relevant information in mind, which helps determine what responses should be suppressed. On the other hand, inhibition may be supporting working memory abilities by inhibiting distractor stimuli that may prevent irrelevant thoughts from occupying limited mental resources.

In the second year of life, inhibitory control and working memory abilities are gradually developing (Miller & Marcovitch, 2015), with the emergence of rudimentary cognitive flexibility abilities, which seem to rely on the developing inhibition and memory abilities (Diamond, 2013). For cognitive flexibility, 2-year-old children can succeed in tasks that elicit them to incorporate a rule into their behaviour (Cuevas et al., 2017).

Despite the growing evidence on EF, research examining EF during the first two years of life remains relatively scarce, even though this period is critical for understanding the foundations of cognitive development (Huttenlocher, 2002). The first year, in particular, is characterized by rapid neural growth (Fiske & Holmboe, 2019), during which the prefrontal circuits that later support EF begin to organize (Fiske & Holmboe, 2019; Fiske et al., 2022), even if EF behavioural expression is still rudimentary. Three main arguments further explain the relevance of examining early EF: (a) the known implications of early EF to children's outcomes, (b) stability in EF individual differences from infancy and toddlerhood onward (Hughes & Ensor, 2007; Hughes et al., 2020), and (c) the fact that EF abilities seem to be malleable (Diamond et al., 2007).

a) Implications of Early EF for Other Developmental Outcomes

EF has increasingly been recognized as a key transdiagnostic mechanism underlying vulnerability to a wide range of psychopathological outcomes (Martel et al., 2017; McLaughlin, 2016). Evidence suggests that many psychological disorders (e.g., oppositional defiant disorder, anxiety, depression) share a common pattern of atypical brain activity in regions involved in EF tasks. Furthermore, McTeague et al. (2017) found in their meta-analysis that individuals with diverse psychological conditions exhibited reduced grey matter volume in the dorsal anterior cingulate region. Interestingly, even among individuals without psychopathology, a smaller grey matter volume in this region was associated with poorer EF.

Studies that link EF deficits to autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD) further supports this argument, in which children with EF problems seem to have more ASD and ADHD symptomatology (Gewirtz et al., 2009; Kofler et al., 2011; Raiker et al., 2012; Willcutt et al., 2005).

Another foundational set of evidence to consider is the widely researched contribution of EF to children's later developmental outcomes. This includes academic and reading achievement (Arrington et al., 2014; Bull & Lee, 2014; St. Clair-Thompson & Gathercole, 2006; Schmitt et al., 2017), entry-level school readiness (Blair & Raver, 2015; Ribner, 2020), theory of mind (Benson et al., 2013), language (Kuhn et al., 2014) and socioemotional (Caporaso et al., 2019; Devine & Hughes, 2014; Kochanska et al., 2000; Sulik et al., 2015) development.

Longitudinal research with children under the age of three is quite scarce. Nonetheless, Mulder and colleagues (2017) in a study with two-year-old children, assessed the predictive role of EF on children's later mathematics and literacy abilities at the age of five. They found that early EF predicted academic abilities. These results reinforce the importance of evaluating early EF abilities so practitioners can identify potential difficulties and successfully intervene.

b) Stability of EF individual differences

The existence of relative stability in EF abilities—meaning that a child's rank relative to peers remains largely consistent over time—underscores the importance of studying them in children's early development, as these individual differences appear to persist. An example of developmental continuity is the study of Blankenship and colleagues (2019), in which children's EF was assessed at 10 months, 3 years, 4 years, and 6 years, with performance at each time point predicting EF at the next, reflecting developmental continuity.

Hughes and Ensor (2007) have examined older children between the ages of 2 and 4 for EF and theory of mind individual differences. In particular, these researchers found that individual differences in EF, assessed by resorting to four tasks, remained stable from 2 to 4 years of age. More recently, Hughes and colleagues (2020) corroborated these results when studying 14- and 24-month-old children's EF developmental trajectories. Findings using the Freeze-Frame task are aligned with previous research, showing that performance at 6 and 9 months of age remains stable during the first year of life (Holmboe et al., 2018).

Despite this, studies that assessed EF stability from 10- to 16-months, from 18- to 21-months, and from 21- to 24-months, using the Early Childhood Inhibitory Touchscreen Task (Hendry et al., 2022) found different results. EF showed little stability between 10 and 16 months (Hendry et al., 2022), whereas greater performance stability emerged across the subsequent two developmental periods – 18 to 21 months, and 21 to 24 months of age (Holmboe et al., 2021). These results further support theoretical models of development that suggest that early EF lays the foundations for later and more complex abilities (Feldman, 2009).

The demonstrated stability in EF individual differences is important because it enables the early detection of potential difficulties and intervention when needed.

c) Malleability of EF

Regardless of the developmental stability observed in EF, these abilities remain malleable. Diamond and colleagues (2007) found that preschool children's EF abilities improved after attending an intervention program, Tools of the Mind. In this study, the intervention explained more variability in EF performance than children's age. From another perspective, the longitudinal Bucharest Early Intervention Project and the English and Romanian Adoptees studies, which aimed to understand the consequences of exposure to early psychosocial deprivation on overall development, further support that EF are malleable, but offer critical evidence on the importance of the intervention timing. Colvert et al. (2008) found no significant difference in EF at 11 years when comparing children adopted before the age of six months, and adopted children with no history of institutionalization. This study provided evidence to the hypothesis that when an intervention is received at an early age, it greatly improves children's abilities that could have been undermined by the exposition to a negative experience in early childhood (Bick & Nelson, 2017).

Several researchers understand the impact of early experiences differently. Fraley et al. (2013), for one, consider that the effects of early experience are long-lasting, whereas others defend that although early experiences shape the child's developmental trajectory, subsequent experiences seem to dictate its development (Lewis, 1998). Another theory acknowledges the importance of both early and subsequent experiences for development, in which early experiences initiate a cascade of effects, where each stage influences the next, emphasizing the dynamic and transactional nature of development over time (Sameroff, 2009; Sroufe et al., 2010).

Notwithstanding, this does not invalidate the existence of sensitive periods for EF in which the brain might be particularly susceptible to environmental influences (e.g., Knudsen, 2004), including to intervention. In a review, Wass and colleagues (2012) found that attentional control training in younger children was linked to a wider transfer of effects across domains – i.e., improvement generalizations to other cognitive functions. Thus, although intervention can support development at any stage, intervening early is particularly effective because infancy is marked by an overproduction of synapses, creating a period of heightened neural plasticity that facilitates more substantial developmental change (Huttenlocher, 2002; O'Muircheartaigh et al., 2014).

Assessing Early Executive Functioning

The preceding evidence underscores the importance of investigating early EF, highlighting the need to consider not only the abilities themselves but also how these abilities are assessed. However, limited measures have been developed to assess early EF, mainly due to difficulties in assessing rudimentary EF abilities in preverbal infants (e.g., Cuevas et al., 2012a; Cuevas et al., 2012b; Holmboe et al., 2008; Holmboe et al., 2018). Recently, researchers have made efforts to overcome this challenge by designing tasks targeting EF (Hendry et al., 2022; Holmboe et al., 2008). Below are presented some of the most commonly used measures in the assessment of EF.

Performance-based tasks to assess executive functioning in the first year

The *Freeze-Frame task* (Holmboe et al., 2008) is a measure of inhibitory control, in which infants were required to inhibit the prepotent response of gazing at a distractor in the peripheral area of the screen. An animation is presented in the center of a screen and, later, a distractor in the periphery. The animation stopped if the infant looked at the distractor. When infants were able to ignore the distracting stimuli, the animation that was presented in the center of the screen would resume playing. The *Early Childhood Inhibitory Touchscreen Task* (Hendry et al., 2022) was developed to assess inhibitory control in children aged 10 and 16 months. In this measure, when children touch an icon on one of the sides of the screen, an animation is generated. The location of this animation-starter icon is switched. Another tool that is considered to evaluate inhibitory control is the *Toy Prohibition task* (Friedman et al., 2011), a delay of gratification task, in which experimenters instruct the child not to touch an attractive toy that is placed in front of them.

In parallel, the classic version of the *A-not-B task* (Piaget, 1954) – an object-search paradigm originally developed to assess infants' object permanence – underwent several modifications to address the current needs of EF assessment. Currently, this task is among the most widely used measures of EF in infancy (Cuevas et al., 2017). Several perspectives have emerged to explain the occurrence of the A-not-B error – i.e., reaching for the A location when the object is hidden in the B location. For instance, Spencer and colleagues (2001) stated that a dynamic interplay between cognition, motor abilities, and visuospatial processing systems may influence the A-not-B performance. More recently, Marcovitch and Zelazo (2009) present the Hierarchical Competing Systems Model, in which this error seems to arise from a competition between two systems: the habit system based on where the object was previously found, and the representation system on how infants are mental representing the objects' locations. As the

representation system is strengthening – related to the development of EF -, infants are less likely to commit the A-not-B error.

Parent-report measures to assess executive functioning in the first year

As mentioned, the lack of developmentally appropriate measures for assessing EF in the first year of life has led researchers to rely on alternative instruments. A clear example is the use of the Infant Behavior Questionnaire Revised (IBQ-R; Garstein & Rothbart, 2003), which was originally designed to assess temperament rather than EF, to capture early regulatory processes. Adding to this, given that direct measures of EF based on children's performance in standardized procedures and parental reports of their children's behaviours as indicators of their ability to perform EF in everyday situations are weakly correlated, perhaps since these complementary abilities may measure different outcomes, such as processing efficiency and an individual's actions that support the attainment of a goal (Toplak et al., 2013), there is a need to develop questionnaires appropriate to evaluate EF in younger children.

Relying on parental reports, the *Early Executive Functions Questionnaire* (EEFQ; Hendry & Holmboe, 2021) was developed to ecologically assess EF in children aged between 9 and 30 months, addressing the notable paucity of instruments for the assessment of EF during the first two years of life. This tool requires caregivers to respond to 31 items regarding their children's behaviour over the past two weeks, including three game-based items that caregivers are instructed to play at home with their children before reporting.

Predictors of Early Executive Functioning

The use of these measures has been essential for identifying the factors that influence the development of EF.

Blair and Ursache's (2011) bidirectional model for EF and self-regulation proposes a dynamic, interactional, feedback-based relationship between EF and self-regulation, defined by these authors as the deliberate regulation of attention and arousal. Specifically, EF appears to top-down influence attention and emotion regulation, while, on the other hand, it is bottom-up influenced by attentional, emotional, and stress systems. Brain regions are thought to support this interaction, in which the prefrontal cortex underlies EF abilities (Fiske & Holmboe, 2019), while subcortical areas such as the amygdala and hippocampus seem to modulate emotional and stress responses (Sergerie et al., 2008). Moderate levels of arousal optimize this loop, whereas very high or very low arousal impairs EF (Arnsten & Goldman-Rakic, 1998). The authors describe an inverted-U-shaped relationship between emotion and cognition, in which

moderate arousal promotes EF development, which in turn enhances self-regulation. Importantly, these brain systems are shaped by experience, with sensitive environments seeming to promote the development of brain regions (e.g., Kok et al., 2015; Sethna et al., 2017), and subsequently EF, whereas chronic stress or unpredictable environments can hinder this development (Glynn & Baram, 2019).

Following this model, research in the first year of life has been mostly dedicated to understanding the individual predictors, which include attention and brain development (e.g., Blankenship et al., 2019; Cuevas et al., 2012; Holmboe et al., 2018; Johansson et al., 2015). Research is still scarce on the impact of environmental factors, which needs to be encouraged, mainly given this is a period of rapid and crucial changes (e.g., Fiske & Holmboe, 2019) in which EF develops. The existing research is presented in the following subsection.

Individual Predictors of Early Executive Functioning

The Role of Attention

Attention, defined as the ability to select relevant information and control actions, thoughts, and emotions (Conejero & Rueda, 2017), is a significant predictor for the development of EF. Johansson et al. (2015) found that sustained attention at 12 months was predictive of EF at 36 months. 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 early as 5 months, is predictive of EF at 10 months. The predictive value of early infant attention for EF development has been confirmed by Cuevas & Bell (2014) and Kraybill et al. (2019).

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

The Role of Brain Development

EF abilities also appear to be related to the development of the prefrontal cortex (Fiske & Holmboe, 2019). This brain region, implicated in decision-making (Kim & Lee, 2011) and complex cognitive behavior planning (Tanji et al., 2007), is one of the last regions of the brain to reach full structural and functional maturation (Diamond, 2002). The former involves

progressive changes, observed in terms of neuron proliferation and myelination (which facilitates the connection between neurons), and regressive changes (cell death and grey matter loss) (O'Hare et al., 2008). Functional development is assisted by the increase of cortical volume, which facilitates information processing through the establishment of connections between the PFC and other cortical areas (Fiske & Holmboe, 2019).

This increase in cortical volume appears to develop alongside children's emerging cognitive abilities (Goldman-Rakic, 1987; Huttenlocher, 1994). Studies with 9- to 10-month-olds show that inhibitory control is linked to frontal cortex functioning (Cuevas et al., 2012; Holmboe et al., 2018), and more recent work confirms prefrontal and parietal activation during inhibitory control tasks in 10-month-old infants (Fiske et al., 2022). Sustaining this evidence is also the classic research demonstrating that individuals with impairments in this brain region seem to have EF deficits (Luria, 1973).

Moreover, frontal axon myelination begins around 6-8 months of age, supporting early EF by facilitating neural communication (Deoni et al., 2011; Diamond, 2002), and dorsolateral prefrontal cortex changes between 7 and 12 months align with improvements on the A-not-B task (Bell & Fox, 1992; 1997; Koenderink et al., 1994).

Environmental Predictors of Early Executive Functioning

Understanding how environmental factors shape EF development benefits from theoretical models that emphasize the dynamic interplay between the child and their surroundings. The transactional model for development (Sameroff, 2009) highlights development as a continuous, bidirectional process in which children and their environments mutually influence one another over time, resulting in developmental pathways that build on earlier experiences and are context dependent. In line with this transactional perspective, authors suggest that EF emerges through the ongoing interplay of neural maturation, cognitive processes, emotional regulation, and environmental inputs, developing in a nonlinear and context-dependent manner (Diamond, 2006).

The quality of caregiver-infant interactions and parental stress are two strong candidates associated with the development of EF during the first year of life. Evidence supporting this claim comes from (a) studies with older children, in which interaction quality and parental stress are linked to EF later in childhood, for instance in preschool years (Baptista et al., 2017; Fay-Stammbach et al., 2014; Hughes & Devine, 2019; Wagner et al., 2016), and (b) research in infancy showing that both interaction quality and stress are associated with development in other domains (Bernier et al., 2017; Centifanti et al., 2016; Laranjo et al., 2014; Magill-Evans

& Harrison, 2001). These findings highlight the critical role of early experiences in shaping EF development. These factors will be further explained below.

The Role of Early Mother-Infant Interactions: From Sensitivity to Mind-Mindedness

Early mother-infant interactions are recognized as critical for shaping infants' overall development (Fraley et al., 2013). Specifically, research with children has found consistent associations between mother-child interaction and EF development (Bernier et al., 2010; Bernier et al., 2012; Hughes & Ensor, 2009). This is supported by the influence of caregiving on the prefrontal cortex, amygdala, and hippocampus, regions responsible for emotion and cognition (Ilyka et al., 2021). Infants' dependence on their primary caregivers for early emotion regulation highlights the crucial role of caregiving in shaping children's emerging self-regulatory skills (Eisenberg et al., 1998; Rocha et al., 2020).

Since its introduction by Ainsworth et al. (1978), the concept of maternal sensitivity - defined as the caregiver's ability to accurately perceive, interpret, and respond promptly and appropriately to an infant's cues - has been repeatedly confirmed as a key predictor of children's developmental outcomes (Samdan et al., 2020), namely for EF (Frick et al., 2019; Hughes & Devine, 2019). For instance, studies with preschoolers – a period with extensive research - have consistently found that sensitivity contributes to EF development (Bernier et al., 2010; Kok et al., 2014; Kraybill & Bell, 2013).

This may occur because sensitive caregiving appears to foster children's confidence in exploring the world – crucial for cognitive development (Jacobsen et al., 1994) - by signaling that their needs are valued and that expressing them will result in predictable parental support (Landry et al., 2008). Sensitive caregiving also depends on recognizing children's developmental abilities to ensure appropriately adjusted responses (Crawley & Spiker, 1983). These experiences are viewed as fundamental, forming the first behavioural patterns that children use as foundations for new experiences (Sroufe, 2000).

Children, at first, are heavily dependent on their caregivers to regulate their emotions, and sensitivity is related to emotion regulation (Conradt & Ablow, 2010; Leerkes et al., 2009), which in turn has important implications for EF expression. For instance, if children have difficulty in regulating strong emotions, this could undermine EF development (Zelazo et al., 2010), with moderate levels of arousal being most favorable to cognitive performance (Ramos & Arnsten, 2007). The attachment theory informs these findings through the activation of both attachment and exploratory systems, depending on their children's needs (Bowlby, 1969). When infants face emotionally challenging situations, they typically seek their caregivers to help them regulate their internal states (Kopp, 1982; Stifter et al., 1999), thereby activating the

attachment system. Once caregivers successfully support this regulation, infants experience a sense of safety and are able to return to an exploration mode, engaging in and learning from their environment (Jacobsen et al., 1994; Marvin et al., 2002), supporting their self-regulatory abilities. Despite this, no studies have looked at the role of sensitivity on early EF abilities during the first year of life, in particular.

Stability in sensitive behaviours has been a clear indicator of the relevance of examining the impact of early sensitivity on EF development. Several studies have found that sensitivity is stable throughout infancy and toddlerhood (Bigelow et al., 2010; Célia et al., 2018; Holmberg et al., 2022) and into school age (Kim & Kochanska, 2025) and adolescence (Bornstein & Putnick, 2021). Notwithstanding, Foley et al. (2024), in a longitudinal study comparing mothers' sensitivity and its implications on children's development over the course of 15 years, concluded that individual mothers' sensitivity (within-person analysis) fluctuated in response to developmental and contextual changes and challenges: they showed little stability from 6 to 24 months, became moderately stable from preschool to first grade, and then declined again through age 15. Nonetheless, mothers with high levels of sensitivity from the start seem to have children with better EF abilities in early childhood, while, on the contrary, mothers with lower levels of sensitivity appear to have children with less developed EF skills (Deans, 2020; Foley et al., 2024). These differences between-person remained highly stable across these developmental periods (Foley et al., 2024).

The importance of the first year of life was established when discussing the emergence and malleability of EF key components. Research on the links between sensitivity and early brain development corroborates this assumption. Parental sensitivity in infancy is thought to be associated with concurrent and later subcortical grey matter volume (Kok et al., 2015; Sethna et al., 2017), hippocampal functional connectivity (Wang et al., 2019), concurrent greater white maturation (Milgrom et al., 2010), and later larger total brain volume (Kok et al., 2015); but even more important than these findings are the ones of Copeland and colleagues (2022), who reported that maternal sensitivity in infancy – but not in toddlerhood – predicted prefrontal cortex functional connectivity at the age of 5. This suggests that infancy may constitute a sensitive period for the development of neural systems supporting EF, during which sensitivity may exert a particularly strong influence, underscoring the relevance of studying EF in infancy.

Literature on mind-mindedness – the ability to understand children as mental agents with their own cognitions, emotions, and desires (Meins et al., 2001) – also supports these results, with mind-mindedness at the age of one being associated with grey matter volumes in the dorsal prefrontal cortex at the age of 10 (Guo et al., 2023). Interestingly, the concept of mind-

mindedness appears to derive from the broader notion of parental sensitivity; therefore, exhibiting a close association with sensitivity in several studies (Meins et al., 2001; Zeegers et al., 2017; Zeegers et al., 2018). Mind-mindedness can be understood as a more specific form of sensitivity, one that explicitly attends to infants' mental states (Meins et al., 2001). Like sensitivity, evidence connects mind-mindedness to emotion regulation and attachment security (Zeegers et al., 2018) and, most relevant to the current investigation, to EF (Baptista et al., 2017; Bernier et al., 2010; Toor & Hanif, 2022). Particularly in infancy, a study has examined the role of mind-mindedness on later EF, finding that the use of maternal mind-related terms at the age of 9 months was linked to inhibitory control abilities at 2 and 3 years (Cheng et al., 2018), corroborating the findings from Dong et al. (2023) with children in the second year of life. Mind-mindedness' temporal (Giovanelli et al., 2019; Illingworth et al., 2016; Kirk et al., 2015) and relational stability - with maternal mind-mindedness demonstrating consistency across interactions with both younger and older children (Illingworth et al., 2016) – further supports the importance of examining early mind-mindedness implications for EF.

Importantly, research has coded mind-mindedness as either appropriate or non-attuned mental comments (Meins et al., 2012), with appropriate mental comments referring to the mental terms uttered that are correct interpretations of the infants' current mental states, whereas non-attuned are related to incorrect interpretations. The use of these appropriate mental comments as a preferred coding approach further underscores the intrinsic link between sensitivity and mind-mindedness. In spite of this, Meins et al. (2001) have claimed that mind-mindedness may be exerting a stronger influence on EF in the first year than maternal sensitivity. Both Bernier and colleagues (2010, 2012) and, more recently, Cheng et al. (2018) have investigated how these parenting behaviours in the first year of life predict children's later EF abilities. These authors found that mind-mindedness assessed at 9 and 12-15 months predicted EF at 18 months and at age 2 and 3, but maternal sensitivity did not.

The context in which maternal sensitivity and mind-mindedness are expressed may contribute to a richer interpretation of the impact of the parenting domains on EF development. Two lines of research will be introduced to clarify this assumption.

The first, considering sensitivity, concerns Leerkes et al. (2012)'s proposal of a distinction between two dimensions of sensitivity – sensitivity to distress and sensitivity to non-distress cues – and how they support the study of children's development. These two dimensions can be defined, respectively, as the sensitive behaviours elicited in response to the children's distress cues (fear, frustration, sadness) and in response to the children's neutral or positive affect cues (Leerkes et al., 2012). This group of authors provides relevant arguments supporting these

claims, as evidence corroborating that sensitivity to distress and non-distress cues seems to have more unshared than shared variance (Leerkes et al., 2009), and the fact that caregivers, when responding to their infants' social or distress cues, exhibit different neurological and physiological activations (Groh & Roisman, 2009). Moreover, sensitivity to non-distress cues seems to be associated with attention (Bornstein & Tamis-LeMonda, 1997), and sensitivity to distress seems to be a predictor of attachment security (Del Carmen et al., 1993; Leerkes, 2011; McElwain & Booth-LaForce, 2006).

Secondly, regarding caregivers' mind-mindedness, the differences in distress or non-distress contexts have not been examined; however, there are reasons to expect that they may exert similar effects on mind-mindedness, as observed for sensitivity. For instance, recent studies have compared the use of mind-related terms in various contexts, such as bath, mealtime, and play, reporting differences. Farkas and colleagues (2018) coded maternal mind-mindedness when their children were 12 and 30 months in two contexts – storytelling and free-play, finding that mothers used more mental references when storytelling. Moreover, Longobardi et al. (2022) found that, when comparing mealtime and play, mothers of 16-month-old children had a greater proportion of attuned mental comments during playtime.

Parental Stress

Another environmental factor that has been consistently implicated in EF is parenting stress - defined as the perception that the demands of parenting exceed one's available coping resources (Abidin, 1990). Extensive research has linked parenting stress to various children's developmental outcomes (preschool-age children: Huang et al., 2025; Ward & Lee, 2020; school-age children: Ribas et al., 2024; Koutra et al., 2025; adolescence: Koutra et al., 2025), with higher levels of parenting stress predicting more developmental difficulties. Regarding EF, the same results were found, with lower levels of parenting stress being associated with better-developed EF abilities (de Cock et al., 2017; Hutchinson et al., 2016; Wagner et al., 2016).

In Wagner et al. (2016)'s study, preschool-age children were divided into two groups: children with high and low EF abilities. Children whose EF skills were considered to be lower had higher cortisol, and parents with higher levels of stress. These findings corroborate the ones from de Cock and colleagues (2017), in which toddlers were reported to have more EF problems at 24 months when mothers reported higher parenting stress.

Given that parenting stress may undermine parents' abilities to regulate their emotions and respond to children's distress cues (Moreno et al., 2021; Rahman et al., 2023), the parent-child interaction may represent a plausible mechanism that could explain the relationship between

parenting stress and EF. Baptista and colleagues (2024) examined the role of parental toxic stress – defined as chronic stress experienced by parents that negatively interferes with daily functioning (Moreno et al., 2021) – and maternal emotional reactions to infant crying, finding that high levels of toxic stress predicted more mother-oriented responses to infants' crying. This may suggest that toxic stress may diminish empathic concern and responsiveness by overloading caregivers' cognitive and emotional resources (Hiraoke & Nomura, 2017). Furthermore, lower levels of parenting stress were found to be associated with both sensitivity and mind-mindedness (Dai et al., 2019; Demers et al., 2010; Evans et al., 2008; Feldman et al., 2004; Landry et al., 2006; McMahon & Meins, 2012). Regarding mind-mindedness, Dai et al. (2019) and Demers et al. (2010) found these negative associations in samples of parents of 15- and 18-month-old children. Another study, which examined differences between groups of parents of preschoolers who were more susceptible to stress and community control groups, corroborated these results by finding that parenting stress and mind-mindedness in clinical samples were negatively correlated (Walker et al., 2012). Research on sensitivity found that parenting stress decreased parental responsiveness (Landry et al., 2006). Studies looking at infancy and toddlerhood found the same results (Pereira et al., 2012; Ward & Lee, 2020).

Despite this, a paucity of studies on parenting stress and early EF remains, with further research needed in this area.

CHAPTER II

Research Problems and Objectives

Research Problems

The reviewed evidence presented in the previous chapter emphasizes the importance of examining EF in early childhood. Theorists on EF development and its organizational structure have debated the existence of a two-factor model regarding the motivational continuum of EF, differentiating them into hot and cool EF abilities (Prencipe & Zelazo, 2005; Zelazo & Carlson, 2020; Zelazo & Muller, 2002). There are mixed findings, in which some evidence supports a one-factor model in early childhood (Allan & Lonigan, 2011, 2014), while another line of work supports the two-factor perspective (Willoughby et al., 2011). More research is needed to understand whether hot and cool abilities are apparent in early childhood.

The attachment theory (Bowlby, 1969/1979) and Blair and Ursache's bidirectional model (Blair & Ursache, 2011) are important frameworks for examining the early development of EF. These models inform that caregivers are needed to co-regulate children's immature self-regulatory abilities, which are closely related to EF. In fact, moderate levels of arousal are considered to be ideal to promote EF development (Arnsten & Goldman-Rakic, 1998). For this to occur, caregivers need to heavily assist young children (Ainsworth & Bell, 1974; Sroufe, 1979, 2000). Despite this, the influence of environmental factors on EF development in infancy has been comparatively less studied. This is quite surprising given that, for instance, the measures of caregiver-child interaction quality have been consistently associated with EF in preschool years (Baptista et al., 2017; Fay-Stammbach et al., 2014; Hughes & Devine, 2019) and with EF individual predictors during infancy (Bornstein & Tamis-LeMonda, 2017; Guo et al., 2023; Kok et al., 2015).

The inexistence of this research may be related to the difficulties in assessing young children whose abilities are still rudimentary (Cuevas et al., 2012a; Cuevas et al., 2012b). Although a lack of assessment measures persists, recent efforts were made to address this issue, with several adaptations and modifications to the A-not-B task to assess EF abilities – leading to a use of multiple procedures, which may result in difficulties in interpreting results -, and the development of the Early Executive Functions Questionnaire (EEFQ; Hendry & Holmboe, 2021), an ecologically measure designed to assess EF in children between 9 and 30 months of age, relying on parental reports of their children's behaviours in the past two weeks. Research is needed to review and map the administration procedures of the A-not-B task and to evaluate

the psychometric properties of the EEFQ, particularly the convergent and external validity of this tool.

The use of these measures can be particularly relevant to investigate whether parenting behaviours are already operating in the first year of life for the development of rudimentary EF. It is reasonable to expect that, for instance, sensitivity and mind-mindedness are contributing to early EF, given that (i) they seem to be related to later EF (e.g., Baptista et al., 2017; Fay-Stammbach et al., 2014; Hughes & Devine, 2019) and (ii) that both these parenting behaviours exhibit temporal stability (e.g., Bigelow et al., 2010; Giovanelli et al., 2019; Illingworth et al., 2016; Kim & Kochanska, 2025). Moreover, Meins et al. (2001) advanced that mind-mindedness may be a stronger predictor than sensitivity for EF development in the first year of life. This perspective has gained strength from studies that found that mind-mindedness, at 9 and 12-15 months, predicted EF at 18 months, and 2 and 3 years of age, but sensitivity did not (Cheng et al., 2018; Bernier et al., 2010; Bernier et al., 2012). But no study examined this assumption with rudimentary EF abilities in the first year of life.

Examining the contexts in which these behaviours are expressed may provide further explanations for this phenomenon, since differences in sensitivity and mind-mindedness seem to emerge. Leerkes et al. (2012) identified sensitivity in non-distress and distress eliciting contexts, which prompted different neurological and physiological responses from the caregivers (Groh & Roisman, 2009) and resulted in different outcomes (Bornstein & Tamis-LeMonda, 1997; Del Carmen et al., 1993; Leerkes, 2011; McElwain & Booth-LaForce, 2006). The use of appropriate mind-minded comments was also distinct according to the context of interaction (e.g., mealtime, storytelling, or playtime). This suggests that the context matters. However, to our knowledge, no research has been dedicated to understanding how the context in which these behaviours are expressed influences early EF.

Parenting stress, a well-researched environmental factor, has exhibited close connections to EF in preschool years (Wagner et al., 2016), similar to parental sensitivity and mind-mindedness. Importantly, parenting stress may influence parents' capacity to scaffold and regulate their children's emerging self-regulation (Crnic et al., 2005). Nevertheless, parenting stress has been relatively underexplored in relation to the early emergence of EF abilities in infants and young children.

The existence of these research gaps underscores the need to investigate early EF development in relation to environmental factors that may promote or hinder its emergence. Addressing these gaps requires studies that further examine these assumptions, with important

implications for the early identification of EF difficulties and the development of timely, targeted interventions.

Research Objectives

As previously mentioned, insufficient research has been conducted on EF in infancy and its potential contributors. This dissertation aims to advance the current understanding of early EF development and the potential impact of environmental factors, such as early mother–infant interactions and parenting stress, on this development. To this end, four studies were conducted.

The first study, a theoretical review (Chapter III), aimed to integrate existing research on early EF and proposed two distinct pathways in which sensitivity, one of the most researched parenting behaviours (Ilyka et al., 2021), may explain EF development, based on the conceptually defended hot and cool EF distinction (Prencipe & Zelazo, 2005; Zelazo & Carlson, 2020; Zelazo & Muller, 2002).

The second study (Chapter IV), following the PRISMA guidelines, is a scoping review of the procedures used in the A-not-B administration to assess EF and related terms in children up to 24 months. As this measure was repeatedly modified to make it more suitable for EF evaluation, diverse variations emerged. This scoping review was conducted to address this issue.

The third study (Chapter V) was an empirical, quantitative study that aimed to examine the associations between maternal sensitivity and mind-mindedness—assessed in both non-distress and distress interaction contexts— and children's EF, measured using the A-not-B task, in infants aged between 9 and 13 months. The study tested the hypotheses that different interaction contexts would exert distinct influences on EF, and that mind-mindedness would have a stronger association with early EF than maternal sensitivity.

Finally, the fourth study (Chapter VI) comprised two independent samples that also correspond to distinct objectives. The first sample included children aged between 9 and 13 months and aimed to examine the convergent and external validity of the Early Executive Functions Questionnaire (EEFQ; Hendry & Holmboe, 2021), a parent-report measure of EF. Mothers completed the EEFQ and a measure of children's developmental status (CREDI; McCoy et al., 2018), while children completed the Toy Prohibition task (Friedman et al., 2011). Given evidence of convergent validity for the EEFQ, a second objective was subsequently pursued. In this second sample, mothers of children aged between 9 and 24 months completed a sociodemographic questionnaire, the EEFQ, and a measure assessing the functional impact of

parental toxic stress (Moreno et al., 2021), in order to test the hypothesis that parental toxic stress would predict parent-reported EF, over and above sociodemographic factors.

This dissertation used performance-based measures (the A-not-B task and the Toy Prohibition task) and report-based measures (the EEFQ) to assess early executive function (EF) and employed observational and self-report methods to investigate environmental factors. This strengthened the methodological rigour of the investigation and offered a more comprehensive assessment. Together, these studies aim to provide theoretical and empirical evidence to explain the early environmental contributions to early forms of EF abilities at a time when such research is greatly needed.

CHAPTER III

How does sensitivity influence early executive function? A critical review on hot and cool processes[1]

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.

Keywords: Children; Executive Function; Sensitivity.

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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, 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).

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 (Buzs´aki & 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.

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).

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.

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.

CHAPTER IV

Executive Functioning in the First 24 Months: A Scoping Review of the A-not-B Task[2]

Abstract

Recent studies highlight the importance of early executive functioning (EF); notwithstanding, these studies remain limited due to methodological difficulties. The A-not-B task has been adapted to assess EF; however, variations in its administration hinder result comparability and standardization. This scoping review mapped the procedures used in studies employing the A-not-B task to assess EF in children up to 24 months. Searches were conducted in PubMed, Scopus, and Web of Science for empirical studies published in English. From 350 references, 53 articles were included. Most studies primarily focused on assessing global EF, working memory, and inhibitory control; employed the standard two-locations task with fixed delays, used two consecutive correct trials to switch locations, and measured accuracy as the main outcome. Testing typically ended after the completion of trials/sequences. Few studies reported inclusion criteria. This review summarizes A-not-B procedures to identify research gaps and support methodological consistency in early EF assessment.

Keywords: Executive functioning, Early childhood, A-not-B, Scoping review.

[2] The study is currently under review:
Ramos, C., Pereira, A. F., & Baptista, J. (under review). Executive Functioning in the First 24 Months: A Scoping Review of the A-not-B Task. *Infant Mental Health: Infancy and Early Childhood*.

Introduction

Executive functioning (EF) refers to a set of higher-order cognitive abilities that support flexible, goal-directed behavior and underlie early learning, self-regulation, and socio-emotional development (Diamond, 2013). Among its core components, working memory, involves the capacity to maintain and manipulate information over short periods; cognitive flexibility enables shifting between rules or perspectives in response to changing environmental demands; and inhibitory control, encompasses the ability to suppress prepotent responses, in favor of more adaptive ones (e.g., Diamond, 2013; Miyake et al., 2000).

A robust body of research demonstrates that individual differences in EF during early childhood are consistently associated with a wide range of developmental outcomes, including academic achievement (Zelazo & Carlson, 2020), social competence (Kochanska et al., 2000), emotion regulation (Carlson & Wang, 2007), and overall health and well-being (Moffitt et al., 2011). Conversely, early EF difficulties predict greater peer problems throughout childhood (Holmes et al., 2016), and are linked to conditions such as attention-deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) (Ozonoff et al., 1991; Rommelse et al., 2011).

These associations highlight the need to examine EF as early as possible in development. Evidence shows that emerging EF difficulties can already be observed by 9 months of age in high-risk populations (e.g., Lipina et al., 2005; Sun et al., 2008). Early detection is particularly important because interventions introduced during periods of heightened neural plasticity may alter developmental trajectories more effectively (Wass, 2015). This is supported by evidence from children exposed to psychological deprivation, who show developmental gains when placed early in enriched caregiving environments such as foster or adoptive care (Colvert et al., 2008; Moulson et al., 2009). Since EF develops gradually yet individual differences remain relatively stable (Best & Miller, 2010; Miyake & Friedman, 2012), assessing EF from infancy represents a crucial step for identifying developmental difficulties before they consolidate. Reliable assessments in infancy are therefore essential, both for improving early clinical identification and for advancing scientific understanding of EF's developmental course.

Early Development of Executive Functioning

The emergence of core EF components within the first years of life strengthens the rationale for early assessment. Infants as young as 5 to 6 months display rudimentary inhibitory control and working memory (Cuevas et al., 2012a; Holmboe et al., 2018; MacNeill et al., 2018). By 8

months, they can pause their actions in response to caregivers' instructions (Kochanska et al., 1998), and by 9 months, they can reduce their attention to distracting stimuli (Holmboe et al., 2008). From 7.5 to 12 months, infants exhibit steady improvements in inhibition and maintenance of information, with 12-month-olds tolerating delays of up to 10 seconds (Diamond, 1985; 1990). By 18 months, children retrieve objects from one of four possible locations after a delay with around 75% accuracy (Garon et al., 2014), and, by 2 years of age, they are already able to regulate their behavior by following and integrating simple rules (Best & Miller, 2010).

Neuroscientific evidence supports this developmental trajectory. Myelination of frontal axons begins around 6-8 months of age (Deoni et al., 2011), coinciding with emerging inhibition and working memory (e.g., Cuevas et al., 2012a). Structural and functional changes in the dorsolateral prefrontal cortex—such as dendritic growth between 7 to 12 months of age and increased frontal EEG activity—correspond with improvements in the A-not-B performance (Bell & Fox, 1992; 1997). Further studies show that inhibitory control in 9–10-month-olds is linked to frontal cortical activity (Cuevas et al., 2012b; Holmboe et al., 2018), with 10-month-olds displaying prefrontal and parietal activation during tasks tapping inhibition (Fiske et al., 2022). The first year of life is therefore a period of pronounced neural reorganization, including synaptic pruning, myelination (Huttenlocher, 2002), and a rapid increase in brain volume—from 36% of adult size at 2–4 weeks to 72% by 12 months (Knickmeyer et al., 2008). The onset of crawling at about 5 months is associated with EEG coherence changes (Bell & Fox, 1996), and frontal myelination accelerates around 6 months (O'Muircheartaigh et al., 2014), further underscoring the rapid neural maturation that supports emerging EF skills.

The A-not-B Task: A Window into Early Executive Functioning

Despite the importance of early EF, studies in infancy remain comparatively limited, partly due to challenges in assessing preverbal children and capturing emerging cognitive abilities (e.g., Cuevas et al., 2012a; 2012b; Holmboe et al., 2008; Holmboe et al., 2018). Few tasks have been designed for this developmental window (Hendry et al., 2022), though recent efforts include the Freeze-Frame task (Holmboe et al., 2008) and the Early Childhood Inhibitory Touchscreen Task (Hendry et al., 2022), both targeting inhibitory control. Existing measures typically isolate a single EF component; yet the multidimensional nature of EF calls for measures that more holistically engage multiple processes (Banich, 2009).

Among the tools developed for infants, the A-not-B task has become one of the most widely used indicators of early EF (Cuevas et al., 2017). Originally developed by Piaget (1954) to study object permanence, the task involves repeatedly hiding a toy at location A (non-reversal trials) and then switching to location B (reversal trials). Infants between 8 and 12 months often commit the A-not-B error—reaching back to location A despite seeing the toy hidden at B. Successful performance requires maintaining and updating the object's location (working memory), as well as inhibiting a previously reinforced motor response (inhibitory control). Shifting from A to B may also draw on early forms of cognitive flexibility, positioning the A-not-B task as a multidimensional index of emerging EF skills during a period when infants increasingly organize attention and coordinate actions with caregivers (e.g., Gago Galvagno et al., 2019).

Performance on the A-not-B task is shaped by several developmental and procedural factors. Older infants typically show fewer perseverative errors; longer delays between hiding and retrieval increase the likelihood of errors; and increasing the number of hiding locations often reduces perseveration (Lipina et al., 2005; Marcovitch & Zelazo, 1999; Wellman et al., 1986). Task format also matters. Looking versions primarily rely on oculomotor control, whereas reaching versions additionally recruit motor planning, though both engage attention, working memory, and inhibitory control skills (Bell & Adams, 1999). Findings comparing these formats are mixed: some studies report better performance in looking versions (Hofstadter & Reznick, 1996; Diamond, 1988), others find comparable outcomes (Matthews et al., 1996), and still others highlight divergences across error types (Bell & Adams, 1999). The results underscore the sensitivity of the A-not-B task to methodological variation and suggest that procedural features may modulate the cognitive demands placed on infants.

Theoretical accounts of the A-not-B error have also evolved. Although Piaget attributed the A-not-B error to a transitional understanding of object permanence, subsequent accounts have emphasized attention (Horobin & Acredolo, 1986), memory–attention interactions (Perner, 1991), or distinctions between long- and short-term memory encoding (Harris, 1989; Sophian & Wellman, 1983). Dynamic systems models further emphasize that performance reflects an interaction of cognitive, motor, and visuospatial processes (Smith et al., 1999; Spencer et al., 2001). Contemporary perspectives, however, explicitly link A-not-B performance to EF (Diamond, 2013), with reversal errors reflecting inhibitory control demands (Bell & Adams, 1999) and non-perseverative errors reflecting attentional limitations (Diamond & Goldman-Rakic, 1989). Neurodevelopmental evidence corroborates this view, linking A-not-B

performance to maturation of prefrontal systems critical for EF (Diamond & Goldman-Rakic, 1989; Hodel, 2019).

1.1. Aim and structure of the scoping review

Despite its theoretical significance and widespread use, the A-not-B task shows considerable variability in design and methodology across studies. Even subtle procedural differences can markedly influence the cognitive and regulatory demands placed on infants, thereby affecting performance outcomes and shaping how results are interpreted across studies. In light of these challenges, the present scoping review aims to map the procedures used to administer the A-not-B task in studies of children up to 24 months of age, as well as related constructs—such as executive attention and executive control—often examined alongside EF in infancy. Executive attention is conceptualized as a top-down regulatory mechanism of attentional control (Posner & DiGirolamo, 1998) closely linked to EF, while executive control substantially overlaps with core EF components (Nigg, 2017).

To achieve this aim, the review systematically identifies and synthesizes the methodological approaches used across studies, providing an overview of how the A-not-B task has been implemented to assess early EF. By bringing together these disparate procedures, the review highlights areas of consistency and divergence that currently limit comparability across studies. Given the rapid neurocognitive changes that characterize the first two years of life, clarifying the methodological foundations of the A-not-B task is particularly important. Ultimately, this synthesis may support movement toward greater consensus in the administration and interpretation of the A-not-B task as a measure of early EF, thereby helping guide future studies in the field.

Method

The present scoping review followed the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping reviews) guidelines (Tricco et al., 2018). This study was not preregistered.

2.1. Search strategy

We conducted a comprehensive search for all studies published up to December 31, 2024, across the following databases: PubMed, Scopus, and Web of Science. The keywords “A-not-B AND (infant* OR child*)” were applied across each database to identify relevant literature.

The search was limited to empirical studies published in English. Further studies were identified by manually searching the reference lists of pertinent articles.

2.2. Inclusion and exclusion criteria

The inclusion criteria considered the following: (a) empirical studies; (b) studies that assessed infants and children up to 24 months of age; (c) studies that administered the A-not-B task; and (d) studies that used the A-not-B to assess EF or related concepts, such as attention, executive attention, or executive control. The exclusion criteria considered the following: (a) meta-analyses, systematic and non-systematic reviews, randomized controlled trials, and case studies; (b) studies that included animals or children older than 24 months of age; and (c) studies that assessed other cognitive abilities other than EF or related concepts, such as object permanence and cognitive development.

2.3. Study selection

The records that were retrieved through the systematic search of the databases were exported to Rayyan, a software designed to facilitate literature reviews (Rayyan Systems Inc., 2023). The removal of duplicate literature was conducted using a standard function in Rayyan; afterwards, titles and abstracts were reviewed. Two independent raters reviewed these to exclude articles that did not meet the inclusion criteria for the scoping review. Disagreements were resolved by consensus. Inter-rater reliability was assessed using Cohen's Kappa, indicating excellent agreement ($\kappa = .852$, $p < .001$). Articles meeting the inclusion criteria proceeded to the next stage—i.e., full-text screening.

2.4. Data Charting and Synthesis

A data-extraction form was developed, incorporating variables deemed pertinent to the research questions and study characteristics. The included variables were: authors; year of publication; study population; abilities assessed; inclusion criteria; the A-not-B version used to measure EF or related concepts; the format of the task (looking and/or reaching); the number of locations; delay between hiding and searching; criteria for switching between locations; dependent measures; and the criteria for the end of testing.

The results are presented below, organized according to the following: (a) researchers' assessment interests when administering the A-not-B task; (b) the most common procedures administered; (c) specific administration procedures; (d) researchers' scoring methods of the children's performance; and (e) the participant inclusion criteria used for the analysis.

Results

The initial search of electronic databases yielded 350 records (Figure 2). After removing 194 duplicates, 60 records were excluded based on title and abstract screening. On the full-text screening, one article was not retrieved, and a further number of 53 records were excluded by not meet the inclusion criteria. An additional 11 studies were included through reference checking, resulting in a total of 53 eligible papers, corresponding to 55 studies, given that two articles described two studies each (See Tables 1 and 2 for a synthesis of the included studies and details of the corresponding administration procedures).

3.1. Researchers' assessment interests when administering the A-not-B task

In the present review, we aimed to examine researchers' interests in using the A-not-B task as a tool for assessing EF and related cognitive concepts. The majority of studies primarily focused on assessing global EF (n = 25; e.g., Blankenship et al., 2019), followed by the core components of working memory (n = 19; e.g., Pushina et al., 2005), inhibitory control (n = 13; e.g., Hendry et al., 2022), and cognitive flexibility (n = 3; e.g., Borioni et al., 2022). Additionally, a more recent study (Nimmapirat et al., 2024) explored cool EF. Among the studies that examined EF-related concepts, four specifically investigated attention/distractibility (e.g., Sun et al., 2009), while one focused on executive control (Wiebe et al., 2010).

3.2. Most common procedures administered

Several variations of the A-not-B task have been commonly used in research to assess EF and related cognitive processes. These variations differ in the specific procedural modifications made to assess different aspects of the child's cognitive abilities. Below, the four most frequently used administration procedures are described: the standard A-not-B task, the procedures based on Clearfield and colleagues (2006), the A-not-B task with invisible displacement, and the A-not-B task with multiple hiding locations.

A. Standard A-not-B task

The majority of the studies have resorted to the standard A-not-B task (n = 39; e.g., Abubakar et al., 2013), with the majority of research focused on the first year of life (n = 20; e.g., Cuevas et al., 2012a), which is a cognitive task in which the experimenter first places an object under location A in full view of the infant and allows them to observe the object being hidden. After the infant is encouraged to search for the object and successfully retrieve it from location A, the experimenter then hides the object in location B, repeating this procedure.

Some of these studies have made some adaptations in terms of delay, in which authors included an associated delay that either is fixed according to the children's age (e.g., Hogan et al., 2013) or varies according to the infants' performance (e.g., Holmboe et al., 2008); or in terms of establishing a fixed order of hidings and patterns of delay levels (e.g., Karonen et al., 2023).

B. Procedures based on Clearfield et al., 2006

The second most used procedure referred to the procedures based on Clearfield and colleagues (2006) (n = 6; e.g., Shinya & Ishibashi, 2022). The existing six studies that assessed EF using the procedures of Clearfield et al. (2006) on the A-not-B task have been more used in children up to 12 months (n = 4; e.g., Johansson et al., 2014), followed by studies that assessed children between the ages of 13 and 24 months (n = 1; Borioni et al., 2022) and both age groups (n = 1; Johansson et al., 2015).

In this procedure, two lids are placed on a display box, each corresponding to locations A and B, in front of the infant. Initially, the object is hidden under location A for six consecutive trials. On the first trial, location A is positioned closer to the infant than location B, at the front edge of the box. After a delay, the box is moved forward into the infant's reaching space, allowing the infant to reach for the hidden object. This process is repeated across multiple trials, with the position of location A gradually being moved further back on the display box until, by trials A4 to A6, location A is aligned with location B. In the critical switch trial, the experimenter shifts the focus to location B by waving it to attract the infant's attention. After another moment of delay, the box is moved forward again, and the infant is allowed to reach for the object. In the original procedure, six A trials (pre-switch) are followed by one B trial (post-switch). However, some studies have made slight adjustments, such as using six A trials and two B trials (e.g., Johansson et al., 2014) or reducing to four A trials and one B trial (e.g., Wang et al., 2021).

C. A-not-B task with Invisible Displacement

Equally used as the procedures based on Clearfield et al. (2006) was the A-not-B task with invisible displacement (ABID) (n = 6; e.g., Wiebe et al., 2010), which assessed children in the second year of life (e.g., Cuevas & Bell, 2014). This procedure, originally designed by Diamond et al. (1997), is a protocol in which the experimenter first places an object under a container (Location A) in plain sight of the infant, allowing them to see where the object is hidden. Then, a barrier is placed between the hidden object and the infant to prevent the infant from fully maintaining their gaze upon the toy; afterward, the experimenter can either move it to the left or right and change position to the second location.

D. A-not-B task with multiple hiding locations

The least used administration procedure was the A-not-B with multiple hiding locations (ABMHL; n = 4; e.g., Mulder et al., 2020). All studies conducting the ABMHL version of the task were focused on children in the second year of life (e.g., Gago Galvagno et al., 2019). This procedure is another variation of the standard A-not-B task, which expands the number of hiding locations beyond two. The outer locations are selected as the A and B locations, where the experimenter would hide the object, while the center locations are considered neutral.

3.3. A-not-B administration procedures

The administration of the A-not-B task, while generally consistent in its underlying structure, can vary depending on the specific goals of the study and the cognitive components being assessed. Below, the standard procedures for administering the A-not-B task and its variations are described to provide a clearer understanding of how researchers implement these tasks to assess EF and related cognitive processes.

A. A-not-B Task Format

In terms of task format, reaching is the most chosen A-not-B task format (n = 40; e.g., Karonen et al., 2023) for all age groups, followed by the looking version (n = 11; e.g., Shinya & Ishibashi, 2022) – which was mostly selected to assess infants up to 12 months of age (e.g., Cuevas et al., 2012b) – and finally, resorting to both formats (n = 4; e.g., Frick et al., 2018).

All age groups have mostly resorted to the standard two-location version of the A-not-B task (n = 46), whereas a few studies have introduced variability in the locations throughout the testing to increase task complexity (n = 4), particularly research focused on infants up to 12 months of age (e.g., Jia et al., 2021). In these studies, the number of hiding locations was not fixed but instead varied across trials; for instance, a study varied between one to two locations (n = 1; Phillips et al., 2011), while others (n = 3; e.g., Jia et al., 2021) introduced one to three locations during testing. Additionally, some studies have incorporated multiple but fixed hiding locations (n = 5; e.g., Mulder et al., 2020), varying from three to five locations.

B. Delay Between Hiding and Searching and Criteria for Location Switching

Concerning the delay between hiding and searching, a fixed delay was employed mostly in studies with children in the second year of life (n = 20; e.g., Miller & Marcovitch, 2015), while a delay that varied according to the children's performance was mostly used in infants up to 12 months of age (n = 14; e.g., Cuevas & Bell, 2011). Overall, most studies employed a fixed delay (n = 28; e.g., Mulder et al., 2020), with some specifying that the delay was set based on the child's age or particular goals (e.g., Hogan et al., 2013). However, some studies did not impose

any delay (n = 7), while others used delays that varied according to the infant's performance on the task (n = 20).

When considering the delays that varied based on the infant's performance, there was variability in the criteria used. In ten studies, the delay was adjusted by adding a few seconds after the child completed a certain number of consecutive correct trials or reducing the delay if the child made a number of errors (e.g., Holmboe et al., 2008). Five studies (e.g., Karonen et al., 2023) used a criterion based on task difficulty levels, adjusting the delay according to the child's performance. If the child provided a certain number of correct responses, they were then allowed to progress to a more difficult level of the task, with an increased delay. Finally, five studies (e.g., Nimmapirat et al., 2024) only introduced a delay when the child completed a certain number of reversal trials correctly.

As for the criteria for switching between locations, the majority of researchers used two consecutive correct trials as reference (n = 34); other studies employed similar criteria, for instance, used three consecutive correct trials (n = 2; e.g., Carlson et al., 2004) or chose either two or three consecutive correct trials depending on the children's age at testing (n = 1; Hendry et al., 2022). Another common approach involved using a pattern or sequence of trials (n = 10), for example, the procedure outlined by Clearfield et al. (2006). Two studies opted to switch after a certain number of correct responses in location A (e.g., Zmyj et al., 2015). Finally, six studies did not specify the requirements used for switching between locations.

C. Pre-Test Training and Test Conclusion Criteria

As for the training phase, only ten out of 55 studies implemented a pre-test training procedure for the children (e.g., van de Weijer-Bergsma et al., 2010; Wiebe et al., 2010). For example, in a study by Toth et al. (2008), the examiner hid the object in one of two locations while the child watched. If the children could find the hidden object successfully, they would proceed to the test phase.

Several criteria were used to determine the conclusion of testing: the completion of trials or sequences (n = 22; e.g., Frick et al., 2018), reaching the maximum number of trials or reversals (n = 4; e.g., St. John et al., 2016), the occurrence of a specific number of (consecutive) errors or errors during reversal trials (n = 17; e.g., Bacher et al., 2017), or the completion of all trials or occurrence of incorrect responses (n = 1; Sun et al., 2009). Other criteria included successfully locating the object (n = 4; e.g., Miller & Marcovitch, 2015), such as finding the object in location B once or twice. Finally, seven studies did not specify criteria for determining the end of testing.

3.4. Researchers' scoring methods of the children's performance

Scoring infants' performance on the A-not-B task has varied across studies, with researchers employing different methods to attribute an EF score. The details of researchers' scoring methods will be presented per domain of assessment and per category of assessment.

A. Per domain of assessment

When focusing on global EF, the majority of researchers have resorted to total correct (n = 12; e.g., Cuevas & Bell, 2014), followed by a number of perseverative errors (n = 11; e.g., Abubakar et al., 2013), and to a scale (n = 4; e.g., Noland et al., 2003). Cool EF was assessed only through the number of perseverative errors (Nimmapirat et al., 2024).

For working memory, total correct continued to be the scoring method with the most expression (n = 12; e.g., Cuevas & Bell, 2011), followed by perseverative errors (n = 5; e.g., Bell, 2012) and non-perseverative errors (n = 3; e.g., Cuevas et al., 2012a), and correct switch/finding object in B (n = 3; e.g., Pyykko et al., 2020).

When interested in inhibitory control, total correct was the most used measure (n = 5; e.g., Ishibashi & Moriguchi, 2017), followed by perseverative errors (n = 4; e.g., Toth et al., 2008), correct switch/finding object in B1 (n = 3; e.g., Hendry et al., 2022), and maximum (observed) delay (n = 3; e.g., Holmboe et al., 2008).

Three studies assessed cognitive flexibility, resorting to profiles of behavior (n = 2; e.g., Johansson et al., 2014), followed by total correct, perseverative errors, percentage of infants reaching A on B1, and speed (Borioni et al., 2022; Clearfield & Niman, 2012).

Finally, for EF-related concepts, attention/distractibility was assessed mainly through the number of times the infant continued to play with the cup (n = 3; e.g., Jia et al., 2022), i.e., when an infant reached for the hidden location of the toy correctly but preferred to play with the lid for more than 2 seconds; and executive control through the performance on the first and second post-reversal trials, number of reversal sets administered, and number of trials administered before the criterion of two consecutive correct trials was obtained (Wiebe, 2010).

B. Per categories of assessment

This subsection outlines the scoring methods used for assessing EF and related concepts, categorized according to different assessment approaches, such as (a) accuracy, for studies that used correct/incorrect procedures; (b) delay, when the performance in the task was scored from the delay they could endure; (c) distractibility, for studies that were interested in understanding whether the child became distracted during the task; (d) looking behavior, when measures as looking time were used; and (e) others, when the procedures employed were diverse and could not find a fit in the previous categories. The most common assessment category focused on

infants' accuracy on the A-not-B task (n = 68). In this category, the most used measures concern the total correct trials (n = 26), perseverative errors (n = 21), non-perseverative errors (n = 5), and correct switches (n = 4). Noteworthy to mention is the fact that Holmboe et al. (2008) have opted to use a cumulative measure to compare participants with different trial completion, which refers to the sum of observed delays for correct change trials divided by total correct trials.

Additionally, in the delay category, researchers employed measures such as maximum delay (n = 3; e.g., Colombo et al., 2014), maximum observed delay (n = 1; Holmboe et al., 2008), and maximum delay at which the infant performed correctly twice (n = 1; Tsetlin et al., 2012). It is important to add that the scoring method "maximum observed delay" differs from "maximum delay" in the sense that the latter only considers the delay that was set to that given trial; with maximum observed delay referring to the delay between the moment the object is hidden and when the infants effectively search for the object.

The distractibility category specifically concerns the number of times the infant interacted with the lid for more than 2 seconds (n = 3; e.g., Jia et al., 2021). The looking behavior category included measures such as the proportion of looking time (n = 2; e.g., Johansson et al., 2015) and the proportion of correct anticipatory looks (n = 1; Shinya & Ishibashi, 2022).

Finally, another category was created to include the following scoring methods. These included scale (n = 4; e.g., van de Weijer-Bergsma et al., 2010), whether children completed all the trials (n = 3; e.g., Prado et al., 2016b), a profile of behaviors (n = 3; e.g., Hogan et al., 2013), the proportion of infants performing different types of performance (n = 1; Johansson et al., 2014), and speed (n = 1; Borioni et al., 2022). One notable scale for assessing global EF was developed by Bell and colleagues (Bell & Adams, 1999; Bell & Fox, 1992) and later used in a study by Noland et al. (2003). This scale ranged from 0 (performance never merited a single reversal trial) to 7 (failed A-not-B criteria at an 8-sec delay) and was coded depending on infants' performance at different delay levels. In addition, as an example of a behavioral profile approach, Hogan et al. (2013) categorized infants into four groups - partial, complete, A-not-B or AB – based on their ability to locate a hidden toy. Hogan et al. (2013)'s four classifications depended on whether the infant could retrieve the object when it was partially or fully hidden and whether they could successfully find it in both locations A and B.

3.5. Participation inclusion criteria

Most studies did not provide information regarding participation inclusion criteria (n = 36). Among the remaining studies, the inclusion criteria varied considerably. Completion of all trials

had the most expression (n = 7; e.g., Espy et al., 1999a), with other studies having used similar criteria, which referred to including participants in the analysis that completed at least one trial (n = 1; Frick et al., 2018), have codable behavior on the first three trials (n = 1; Nolvi et al., 2018), more than a half of the trials (n = 1; Carlson et al., 2004), or a minimum of 10 trials (n = 2). The studies that included participants with a minimum of 10 trials also required the administration of change trials (n = 1; Holmboe et al., 2018), and one correct reach for each location (n = 1; Hendry et al., 2022). Out of the ten studies with a pre-test phase, two clearly stated that passing the "warm-up" phase was necessary to be included in the study (e.g., Noland et al., 2003). The existence of correct and incorrect trials was also required in one study, combined with a minimum of three minutes of assessment (n = 1; Bacher et al., 2017). Similarly, the study of Johansson et al. (2015) used the baseline criteria of infants performing two times correctly in location A and one in location B, and having longer looking times to the correct location. Researchers also expressed concern about infants exhibiting a strong side bias (n = 1; Johansson et al., 2014), which was evident in infants who consistently reached for and looked toward the incorrect hiding location during all A trials and continued searching on the same side during the B trials; and being inattentive (n = 1; Shinya & Ishibashi, 2022) with the looking time being above or below 3 standard deviations. Finally, a score of 0 was attributed to infants who did not reach the required criteria, so they could be included in the analysis (n = 1; Wiebe et al., 2010).

Discussion

The A-not-B task, originally developed to assess object permanence in children (Piaget, 1954), has more recently been adapted to provide valuable insights into early EF development, which has critical implications for children's later development (e.g., Holmes et al., 2016; Zelazo & Carlson, 2020). However, the use of various administrational procedures of the A-not-B task to assess EF in children up to 24 months of age presents several challenges in terms of result interpretation. Variability in task design and procedural differences across studies can significantly influence outcomes, making it difficult to draw consistent conclusions.

To address these issues, in this review, we examined the administration procedures of the A-not-B task as a measure of EF and related cognitive concepts in this age group. Fifty-three reports, which were published from 1999 to 2024, were identified as being eligible. Notably, all but two were published between 2003 and 2024, which clearly shows that resorting to the

A-not-B task to assess EF in the first two years of life is a recent phenomenon, with this task still proving to be a fit and valuable resource despite its original purpose.

Our findings highlight considerable methodological diversity across studies. Variations were observed in task format (reaching vs. looking), number and configuration of hiding locations, delay intervals, criteria for switching locations, pre-test training, test termination rules, and scoring methods—including total correct responses, perseverative errors, behavioral profiles, and attention or distractibility measures. Participation inclusion criteria were also inconsistent. Such heterogeneity can significantly affect the cognitive and regulatory demands placed on infants, potentially impacting performance and the interpretation of EF abilities. These findings underscore the need for greater standardization and transparency in A-not-B administration and scoring to improve comparability across studies and strengthen the utility of the task for research on early EF.

Amidst procedural heterogeneity, some commonalities emerged. Most studies assessed global EF or its core components, primarily working memory and inhibitory control, consistent with the developmental trajectory of EF, as cognitive flexibility develops more prominently during preschool years and builds on working memory and inhibitory control (Garon et al., 2008; Cuevas & Bell, 2014). EF-related constructs such as executive control and executive attention were less frequently examined. Notably, cool EF was measured at 12- and 18-month time points (Nimmapirat et al., 2024), indicating that this emerging ability can be assessed in infancy and highlighting the potential for further investigation into the early differentiation of EF components.

Regarding specific administration procedures, overall, most researchers resorted to the reaching format of the task (e.g., Clearfield & Niman, 2012) and used the standard two locations (e.g., Zmyj et al., 2015). Most of the procedures did not include a training phase before testing (e.g., Bell, 2012) and used a fixed delay (e.g., Tofail et al., 2018) or varied according to children's performance (e.g., Tsetlin et al., 2012). The criteria for switching between locations were mostly two consecutive correct responses or the existence of a pattern/sequence of trials (e.g., St. John et al., 2016; Wang et al., 2021); and the ending of testing was determined by an established number of trials or sequences (e.g., Johansson et al., 2014), or if the children committed a certain number of errors (e.g., van de Weijer-Bergsma et al., 2010). Specifically, some researchers terminated the testing when infants made consecutive errors on reversal trials (e.g., Bacher et al., 2017).

To address researchers' scoring methods, measures were presented by domain and category of assessment. Across domains, total correct responses and perseverative errors were commonly

used for global EF, working memory, inhibitory control, and cognitive flexibility. Working memory was also measured via non-perseverative errors, while inhibitory control primarily relied on total correct and perseverative errors, consistent with Bell and Adams (1999), who suggest that working memory demands remain similar across non-reversal and reversal trials, whereas inhibitory demands increase during reversal trials. Attention/distractibility was assessed by the number of times infants continued to play with the cup, and executive control through performance on post-reversal trials, the number of reversal sets, and trials required to reach two consecutive correct responses.

To score children's performance, researchers have primarily relied on accuracy measures, such as accuracy on reversal and non-reversal trials, and total correct trials (e.g., Cuevas et al., 2012a; Lipina et al., 2005). The delay was also considered with some researchers coding the maximum delay at which the infant performed correctly (e.g., Colombo et al., 2014; Holmboe et al., 2018). Most researchers did not report any data on the criteria for including participants in the analysis. Seven studies required participants to complete all trials (e.g., Ishibashi & Moriguchi, 2017; Pyykko et al., 2020); the remaining presented a wide range of criteria. As mentioned, this lack of standardization in participant inclusion criteria can introduce variability across studies, making it difficult to draw consistent conclusions. To ensure that research findings can be comparable, future studies should clearly state the inclusion criteria used.

The role of age could also impact the administration procedures. A great part of the analyzed studies was carried out with infants up to 12 months, followed by research with children between 13 and 24 months of age (some of the studies included older children, but task administration did not vary), and finally, studies that included both age groups. It is noteworthy to mention that the youngest child to be tested with the A-not-B task to assess EF or similar concepts was 5 months old (e.g., Wang et al., 2021).

Interestingly, the looking task format was more commonly used with infants up to 12 months than when compared to older children. This could be explained by children's developmental status concerning motor abilities in the first year of life and Berger's (2004) suggestion that this procedure aims to reduce the cognitive load associated with motor control demands and, therefore, make the task more accessible to younger children.

Another result worth mentioning refers to the use of multiple locations with older infants, which is expected given its complexity. Notwithstanding, meta-analyses have shown that the number of locations is a negative predictor of perseverative searching (Marcovitch & Zelazo, 1999; Wellman et al., 1986). This could be either explained by the gradual improvement of EF abilities (Best & Miller, 2010) or due to the distance between locations being a positive

predictor of correct responses (Marcovitch & Zelazo, 1999), with the selected A and B locations in this task variation being usually the outer locations.

Finally, concerning the employed delay, although when considering the total sample, the type of delay most frequently selected was the fixed delay, the delay that varied according to the infant's performance was chosen by the majority of researchers who studied infants in the first year of life (e.g., Colombo et al., 2014). Perhaps this option allowed the task to be more flexible, adaptable, and capture slighter changes in results in a population of smaller children.

Limitations and directions for future research

Limitations of this work should be considered. Information on some of these studies could not be extracted (e.g., characteristics of the population) since they were not reported in detail, constraining a more thorough analysis. Additionally, studies that did not clearly state that they were employing the A-not-B task were not included in this review, even though they shared similar procedures, which could impair some of the drawn conclusions. Finally, the review includes a small sample of studies, so results should be interpreted cautiously.

Despite these limitations, this review provides an overview of how the A-not-B task has been used to assess EF in children up to 24 months. The observed methodological variability highlights the need for future research to systematically examine how procedural differences—such as task format, hiding locations, delays, switching criteria, and pre-test training—affect performance. Empirical studies identifying the most valid and reliable procedures, combined with collaborative efforts to develop consensus guidelines, could support standardized administration, improve comparability across studies, and strengthen assessment of early EF, ultimately informing developmental research and interventions.

Declarations

Conflict of Interest. The authors declare that they have no conflict of interest.

Figure 2.

PRISMA flow diagram of study selection procedure

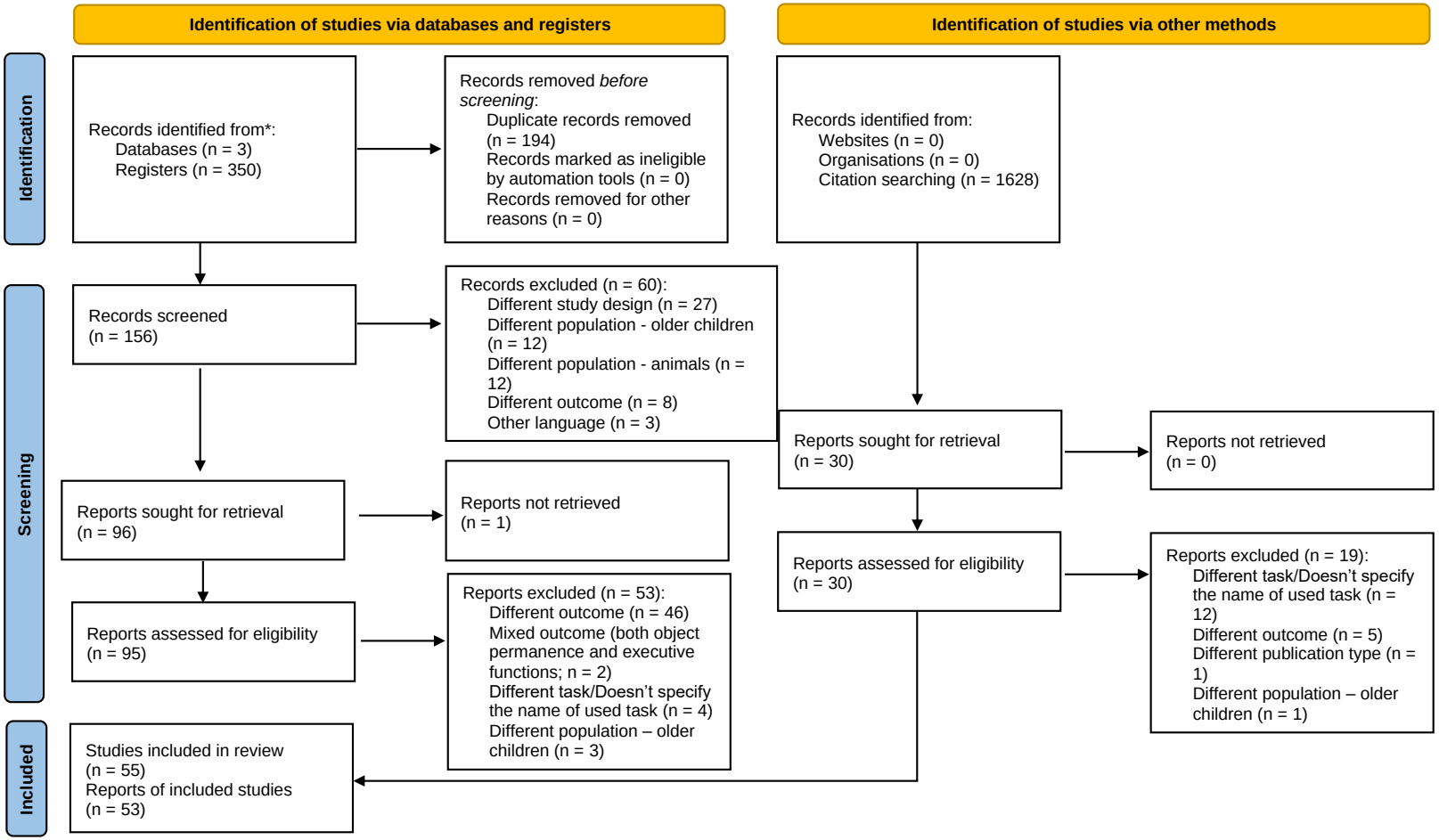


Table 1.

Results from the scoping review per study: Study characteristics and task information

Author, year	Study population	Abilities assessed	Version of the task	Task format	# Locations	Training	Delay	Switch between locations
Abubakar et al., 2013	6 to 35 months	EF	Standard A-not-B task	Reaching	2	No	Fixed delay	2 consecutive correct trials
Bacher et al., 2017	10 months	WM	Standard A-not-B task	Looking	2	No	No delay	2 consecutive correct trials
Bell & Wolfe, 2007	8 months	WM and IC	Standard A-not-B task	Looking	2	No	No delay	2 consecutive correct trials
Bell, 2012	8 months	WM	Standard A-not-B task	Looking	2	No	No delay	2 consecutive correct trials
Blankenship et al., 2019	10 months	EF	Standard A-not-B task	Looking	2	No	No delay	2 consecutive correct trials
Borioni et al. 2022	13 to 22 and 15 to 24 months	CF	Clearfield et al. 2006	Reaching	2	No	Fixed delay	Established sequence
Carlson et al., 2004	24 months	EF	Multilocation search	Reaching	5	Yes	Fixed delay on reversal trials	3 consecutive correct trials
Clearfield & Niman, 2012	6, 9 and 12 months	CF	Clearfield et al. 2006	Reaching	2	No	Fixed delay	Established sequence

Colombo et al., 2014	9 and 12 months	WM and IC	Standard A-not-B task	Reaching	2	No	Increasing fixed delay	Not established
Cuevas & Bell, 2011	5 to 10 months	WM	Standard A-not-B task	Looking	2	No	Varies according to performance: if criterion is achieved, children were then tested with a delay.	2 consecutive correct trials
Cuevas & Bell, 2014	24 months	EF	ABID	Looking	2	No	Fixed delay	2 consecutive correct trials
Cuevas et al., 2012a	5 to 10 months	WM	Standard A-not-B task	Looking	2	No	Varies according to performance: if criterion is achieved, children were then tested with a delay.	2 consecutive correct trials
Cuevas et al., 2012b	10 months	WM and IC	Standard A-not-B task	Looking	2	No	Varies according to performance: if criterion is achieved, children were then tested with a delay.	2 consecutive correct trials
Espy et al., 1999a	17 to 21 months	EF	Standard A-not-B	Reaching	2	No	Fixed delay	2 consecutive correct trials
Espy et al., 1999b	23 to 66 months	EF	Standard A-not-B	Reaching	2	No	Fixed delay	2 consecutive correct trials
Frick et al., 2018	18 months	EF	Standard A-not-B task	Reaching and looking	2	No	Fixed delay	Established sequence

Gago Galvagno et al., 2019	18 to 24 months	EF	ABMHL	Reaching	5	No	Fixed delay	A trials were repeated until the child found the object on A 3 times.
Hendry et al., 2022	10 and 16 months	IC	Standard A-not-B task	Reaching	2	No	No delay	2 or 3 consecutive correct trials (depending on age)
Hogan et al., 2013	9 and 12 months	EF	Standard A-not-B task	Reaching	2	No	Fixed delay	2 consecutive correct trials
Holmboe et al., 2008	9 months	IC	Standard A-not-B task	Reaching	2	No	Varies according to performance	2 consecutive correct trials
Holmboe et al., 2018	9 months	IC	Standard A-not-B task	Reaching	2	No	Varies according to performance	2 consecutive correct trials
Ishibashi & Moriguchi, 2017	16 to 37 months	IC	Standard A-not-B task	Reaching	2	No	No delay	Not established
Jia et al., 2021	8 months	WM, distractibility, and IC	Standard A-not-B task	Reaching	1 to 3	No	Varies according to performance	Not established
Jia et al., 2022	8 months	WM and attention	Standard A-not-B task	Reaching	1 to 3	No	Varies according to performance	Not established
Johansson et al., 2014	10 months	CF	Clearfield et al. 2006	Reaching and looking	2	No	Fixed delay	Established sequence
Johansson et al., 2015	12 to 13 months and 24 to 25 months	EF	Clearfield et al. 2006	Looking	2	No	Fixed delay	Established sequence
Karonen et al., 2023	8 months	EF	Standard A-not-B task	Reaching	2	No	Varies according to performance: Delay levels	Established sequence

Lipina et al., 2005	6 to 14 months	EF	Standard A-not-B task	Reaching	2	No	Varies according to performance	2 consecutive correct trials
Miller & Marcovitch, 2015	14 to 18 months	EF	ABMHL	Reaching	5	Yes	Fixed delay	3 consecutive correct trials
Mulder et al., 2020	14 months	EF	ABMHL	Reaching	4	Yes	Fixed delay	2 consecutive correct trials
Nampijja et al., 2012	15 months	EF	Standard A-not-B task	Reaching	2	No	Fixed delay	2 consecutive correct trials
Nimmapirat et al., 2024	12 and 18 months	Cool EF	Standard A-not-B task	Looking	2	No	Varies according to performance: if criterion is achieved, children were then tested with a delay.	2 consecutive correct trials
Noland et al., 2003	9.5 to 12.5 months	EF	Standard A-not-B task	Reaching	3	Yes	Varies according to performance	2 consecutive correct trials
Nolvi et al., 2018	8 months	EF	Standard A-not-B task	Reaching	2	No	Varies according to performance: Delay levels	Established sequence
Phillips et al., 2011	18 to 22 months	WM and IC	Standard A-not-B task	Reaching	1 to 2	No	Fixed delay	Not established
Prado et al., 2016a	18 months	EF	Standard A-not-B task	Reaching	2	No	Fixed delay	2 consecutive correct trials
Prado et al., 2016b	18 months	EF	Standard A-not-B task	Reaching	2	No	Fixed delay	2 consecutive correct trials
Prado et al., 2016c	18 months	EF	Standard A-not-B task	Reaching	2	No	Fixed delay	2 consecutive correct trials
Prado et al., 2016d	18 months	EF	Standard A-not-B task	Reaching	2	No	Fixed delay	2 consecutive correct trials
Prado et al., 2018	18 months	EF	Standard A-not-B	Reaching	2	No	Fixed delay	2 consecutive correct trials

Pushina et al., 2005	7 to 12 months	WM	Standard A-not-B	Reaching	2	Yes	Varies according to performance: if criterion is achieved, children were then tested with a delay.	Established sequence
Pyykko et al., 2020	9 and 18 months	WM	Standard A-not-B task	Reaching	2	No	Fixed delay	2 consecutive correct trials
Shinya & Ishibashi, 2022	12 months	Perseverative attention and sustained attention	Standard A-not-B task	Looking	2	No	Fixed delay	Established sequence
St. John et al., 2016	12 and 24 months	WM and IC	Standard A-not-B task	Reaching	2	No	Varies according to performance: Delay levels	2 consecutive correct trials
Sun et al., 2009	8 months	WM and distractibility	Standard A-not-B task	Reaching	1 to 3	No	Varies according to performance: Delay levels	2 consecutive correct trials
Tofail et al., 2018	24 months	WM	Standard A-not-B task	Reaching	2	No	Fixed delay	Not established
Toth et al., 2008	18 months	WM and IC	Standard A-not-B task	Reaching	2	Yes	Varies according to performance: Delay levels	2 consecutive correct trials
Toth et al., 2008	18 months	WM and IC	ABID	Reaching	2	Yes	Fixed delay	2 consecutive correct trials
Tsetlin et al., 2012	10 to 11 months	WM	Standard A-not-B task	Reaching	2	No	Varies according to performance	2 consecutive correct trials

van de Weijer-Bergsma et al., 2010	7 and 10 months	EF	Standard A-not-B task/ABID	Reaching and looking	2	Yes	Varies according to performance	2 consecutive correct trials
van de Weijer-Bergsma et al., 2010	14 months	EF	ABID	Reaching	2	No	Varies according to performance: increases or decreases according to performance	2 consecutive correct trials
van de Weijer-Bergsma et al., 2016	7, 10 and 14 months	EF	Standard A-not-B task/ABID	Reaching and looking	2	Yes	Varies according to performance	2 consecutive correct trials
Wang et al., 2021	5 to 7 months	IC	Clearfield et al., 2006	Reaching	2	No	No delay	Established sequence
Wiebe et al., 2010	15 and 20 months	Executive control	ABID	Reaching	2	Yes	Fixed delay	2 consecutive correct trials
Zmyj et al., 2015	18 months	WM	Standard A-not-B task	Reaching	2	No	Fixed delay	4 successful retrievals from A

Table 2.

Results from the scoping review per study: End of Testing, scoring, and inclusion criteria.

Author, year	End of testing	Scoring	Inclusion criteria
Abubakar et al., 2013	End of trials	Total correct, perseverative errors, maximum error run	All ten trials
Bacher et al., 2017	2 consecutive errors on reversal trials	Total correct	Performance that includes correct and incorrect trials and trials that lasted at least 3 mins
Bell & Wolfe, 2007	Incorrect responses in two reversal trials	Total correct	Not established
Bell, 2012	Incorrect responses in two reversal trials	Perseverative and non-perseverative errors	Not established
Blankenship et al., 2019	Not established	Perseverative and non-perseverative errors	Not established
Borioni et al. 2022	End of trials	Total correct, perseveration errors, speed	Not established
Carlson et al., 2004	Correct response on reversal trials	Perseverative errors	Completion of more than half of test trials
Clearfield & Niman, 2012	End of trials	Percentage of infants reaching A on B1 and Profile	Not established
Colombo et al., 2014	Not established	Maximum delay	Not established
Cuevas & Bell, 2011	Incorrect responses in two out of three reversal trials	Total correct	Not established
Cuevas & Bell, 2014	Not established	Total correct	Not established
Cuevas et al., 2012a	Incorrect responses in two out of three reversal trials	Total correct, perseverative and non-perseverative errors	Not established

Espy et al., 1999a	End of trials	Perseverative errors, perseverative runs, and the number of times the child had two consecutive correct responses	All ten trials
Espy et al., 1999b	End of trials	Total correct, number of correct consecutive responses, perseverative errors, and perseverative runs	All ten trials
Cuevas et al., 2012b	Incorrect responses in two out of three reversal trials	Perseverative and non-perseverative errors	Not established
Frick et al., 2018	End of trials	Sum of reaching and looking divided by two	Have codable behaviors on at least one trial
Gago Galvagno et al., 2019	After finding object in B two times	Perseverative errors, and searching correctly in B twice	Not established
Hendry et al., 2022	End of trials	Correct switching, accuracy	A minimum of 10 trials, one correct reach to each location
Hogan et al., 2013	Not established	Profile	Not established
Holmboe et al., 2008	End of trials	Maximum observed delay and cumulative measure in change trials	Not established
Holmboe et al., 2018	End of trials	Maximum delay in change trials	At least 10 trials and change trials
Ishibashi & Moriguchi, 2017	End of trials	Total correct	All six trials
Jia et al., 2021	Not established	Total correct, number of times the child continued to play with the lid more than 2 seconds in correct trials, correct switching	Not established
Jia et al., 2022	Not established	Total correct, number of times the child continued to play with the lid more than 2 seconds in correct trials	Not established

Johansson et al., 2014	End of trials	Profile	Infants not strong side bias
Johansson et al., 2015	End of trials	Looking time	Completing at least two A trials, and one B trial, and having looking times to the correct location in A trials than to the incorrect location.
Karonen et al., 2023	Incorrect responses in more than a half of the trials	Total correct	Not established
Lipina et al., 2005	Five consecutive incorrect trials	Total correct, consecutive correct responses, perseverative errors, non-perseverative errors, number of A trials to get 2 consecutive correct responses	Not established
Miller & Marcovitch, 2015	B trials were repeated until children retrieved the object correctly at B location twice or refused to continue to reach	A trials, searching correctly on B1/correct switching	Not established
Mulder et al., 2020	Incorrect responses on two consecutive A trials in a maximum of four attempts	Correct switching	Not established
Nampijja et al., 2012	End of trials	Total correct	All ten trials
Nimmapirat et al., 2024	Four consecutive incorrect trials	Perseverative errors	Not established
Noland et al., 2003	Incorrect responses in two out of three reversal trials	Scale	Pass the warm-up phase
Nolvi et al., 2018	Incorrect responses in more than a half of the trials	Total correct	Codable behavior in at least the first three trials
Phillips et al., 2011	Not established	Total correct	Not established
Prado et al., 2016a	End of trials	Total correct	Not established
Prado et al., 2016b	End of trials	Total correct, perseverative errors, and whether the child was able to complete all trials	Not established

Prado et al., 2016c	End of trials	Total correct, perseverative errors, and whether the child was able to complete all trials	Not established
Prado et al., 2016d	End of trials	Total correct, perseverative errors, and whether the child was able to complete all trials	Not established
Prado et al., 2018	End of trials	Total correct and perseverative errors	All ten trials
Pushina et al., 2005	Two incorrect responses in a certain delay	Maximum delay	Not established
Pyykko et al., 2020	End of trials	Correct switching	All ten trials
Shinya & Ishibashi, 2022	End of trials	Looking time, proportion of correct anticipatory looks	Inattentiveness
St. John et al., 2016	A maximum of 24 trials and 4 reversal trials administered	Total correct, perseverative errors	Not established
Sun et al., 2009	Completion of all trials on the 3 cup task or failed 3 consecutive trials	Total correct, number of times the child continued to play with the lid more than 2 seconds in correct trials	Not established
Tofail et al., 2018	End of trials	Total correct	Not established
Toth et al., 2008	2 reversals followed by two consecutive correct trials at 12s or 24 trials	Total correct, perseverative errors, searching correctly on B1	Pass the warm-up phase
Toth et al., 2008	3 reversals followed by two consecutive correct trials or 14 trials	Total correct, perseverative errors, searching correctly on B1	Not established
Tsetlin et al., 2012	Incorrect responses in a certain delay	Maximum delay in which children performed correctly twice	Not established
van de Weijer-Bergsma et al., 2010	Incorrect responses in two out of three attempts in an item	Scale	Not established
van de Weijer-Bergsma et al., 2010	Incorrect responses in an item twice	Scale	Not established
van de Weijer-Bergsma et al., 2016	Incorrect responses in two out of three attempts in an item	Scale	Not established

Wang et al., 2021	End of trials	Profile of behavior	Not established
Wiebe et al., 2010	4 reversals administered	Performance on the first and second post-reversal trials, number of reversal sets administered, number of trials administered before the criterion of two consecutive correct trials was attained.	Children who never reached criterion were assigned a score of 0 on the post-reversal measures to permit their inclusion in the analyses.
Zmyj et al., 2015	Successfully finding the object in B	Number of trials in which infants searched at location A before they finally searched at location B.	Not established

CHAPTER V

Early Predictors of Infant Executive Functioning: Contributions of Maternal Sensitivity and Mind-Mindedness Across Distress and Non-Distress Contexts[3]

Abstract

Executive functioning (EF) in early childhood plays a critical role in shaping later cognitive, socioemotional, and academic outcomes. Although the influence of caregiving on EF is well documented in preschool and older children, relatively little is known about how early relational factors contribute to the emergence of rudimentary EF abilities during the first year of life. The present study examined the contributions of maternal sensitivity and mind-mindedness to the emergence of EF in infancy. Fifty-one typically developing children aged 9–13 months were invited to participate. Infants completed the A-not-B task to assess their EF abilities. Maternal sensitivity and attuned mind-minded comments were assessed during a structured interaction task, which included both non-distress (free-play) and distress-eliciting episodes. Results showed that both maternal sensitivity and appropriate mind-minded comments were related to infant EF, yet only mind-mindedness in non-distress contexts emerged as a significant predictor of early EF abilities. These findings emphasize the importance of caregivers' attunement to their infants' mental states in fostering the emergence of EF.

Keywords: executive functioning, infancy, sensitivity, mind-mindedness.

[3] The study is currently under review:
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Introduction

Executive functioning (EF) refers to a set of higher-order cognitive processes that enable individuals to regulate their thoughts and behaviours in pursuit of goal-directed actions (Diamond, 2013). A widely used model of EF's internal structure, by Miyake and colleagues (2000) has proposed that EF is comprised of three separable, but also partially interrelated components: working memory (WM), inhibitory control (IC), and cognitive flexibility (CF). Studies of EF's putative components, that use batteries of EF tasks and factor analysis, also revealed that EF is less differentiated in children (Karr et al., 2018). Together, these core components support the emergence of increasingly complex forms of self-regulation during early development (Buss & Spencer, 2014; Diamond, 2013; Hendry et al., 2016; Miyake et al., 2000).

Early EF skills have wide-ranging implications for later developmental outcomes: they shape children's socioemotional functioning (Caporaso et al., 2019; Kochanska et al., 2000; Riggs et al., 2004; Sulik et al., 2015), language development (Kuhn et al., 2014), and key domains of cognition, such as theory of mind (Benson et al., 2013). Early EF is also a predictor of academic achievements (Bull & Lee, 2014; Schmitt et al., 2017; Zelazo & Carlson, 2020), school readiness (Blair & Raver, 2015), children's competencies to learn from classroom instructions (Ribner, 2020), and reading abilities (Arrington et al., 2014). Moreover, difficulties in EF have been consistently linked to symptoms of neurodevelopmental conditions, including ADHD and ASD (Gewirtz et al., 2009; Hill, 2004; Kofler et al., 2011; Raiker et al., 2012), underscoring the importance of assessing these abilities in early childhood.

While substantial advances in EF occur during the first years of life, with particularly rapid growth observed across the preschool period (Best & Miller, 2010; Garon et al., 2008), our understanding of EF development during infancy remains comparatively underexplored. This is in part because EF processes are still rudimentary, but also because methodological constraints limit assessment in preverbal infants. Yet, accumulating evidence indicates that early precursors of EF can be detected within the first year of life, including emerging forms of executive control, observable from approximately six months of age (Cuevas et al., 2017; Holmboe et al., 2018). These early EF indicators parallel rapid structural and functional developmental of the prefrontal cortex, a pattern demonstrated in classic studies showing that improvements in the A-not-B task performance correlate with dorsolateral prefrontal cortex development (Bell & Fox, 1992, 1997). Given the long-term predictive value of EF (Benson et al., 2013; Caporaso et al., 2019; Kuhn et al., 2014; Zelazo & Carlson, 2020) and increasing

stability from infancy onward (Devine et al., 2019; Hughes et al., 2020), expanding research on EF during the first year of life is essential.

The few studies conducted on EF in the first year of life have largely focused on identifying individual predictors of EF development (e.g., Bell, 2012; Blankenship et al., 2019). This research has consistently shown, for instance, that early attentional abilities are associated with EF, with infant attention at five months predicting EF outcomes at 10 months (Blankenship et al., 2019), as well as at 24, 36, and 48 months (Cuevas & Bell, 2014). However, environmental factors—especially those rooted in early caregiver–infant interactions—have been strikingly understudied during this sensitive developmental window, despite the high plasticity of the infant brain and its heightened sensitivity to environmental input (Hodel et al., 2018). Caregiver–infant interactions have been proposed as a critical factor in shaping individual differences in EF (Ramos et al., 2023). Although most evidence comes from preschoolers (e.g., Baptista et al., 2017), theoretical perspectives grounded in attachment theory emphasise that infants depend heavily on caregivers for the regulation of their emotional and behavioural states, suggesting that interactive quality may already influence rudimentary EF processes during infancy (Eisenberg et al., 1998; Sroufe, 1997).

Among the caregiving behaviours found to contribute to early child development, maternal sensitivity—defined as the caregiver's ability to accurately perceive, interpret, and respond promptly and appropriately to an infant's cues (Ainsworth et al., 1978)—has received particular attention. Research with preschool-aged children shows that sensitivity supports EF development (e.g., Bernier et al., 2010; Kraybill & Bell, 2012), although findings are not entirely consistent, with a study conducted with preschool-aged children reporting that sensitivity was associated with higher levels of inhibitory control, but not with its growth (Geeraerts et al., 2021). Moilanen et al. (2010) found a different result, revealing that positive parenting behaviors were associated with faster growth in inhibitory control abilities from 2 to 4 years old. These mixed results suggest that sensitivity may not be the only parenting dimension influencing EF, particularly as children grow older. Nevertheless, infancy is characterized by heightened dependency on caregivers, implying that sensitivity may play an especially foundational role in supporting early processes related to EF during this formative period. This is supported by evidence showing that maternal sensitivity in early infancy supports development in attention and brain structure (Bornstein & Tamis-LeMonda, 1997; Samdan et al., 2020; Sethna et al., 2017; Yu & Smith, 2016). Given that both attention and early neurodevelopment are critical contributors to the emergence of EF, maternal sensitivity may play a foundational role in fostering the development of early EF processes. Surprisingly,

however, the role of maternal sensitivity in predicting EF during infancy remains largely unexplored.

While maternal sensitivity is believed to play a critical role in supporting early EF, it may not account for all variation in these emerging abilities, highlighting the potential contribution of other parenting dimensions. Meins and colleagues (2012) proposed that maternal mind-mindedness—a caregiver's tendency to treat the infant as an intentional agent with mental states (Meins et al., 2001)—may exert distinct and potentially stronger effects on EF than sensitivity alone. Indeed, parental attuned mind-related comments appear particularly influential during infancy, shaping infants' emerging emotion regulation capacities, which in turn may scaffold early EF, by providing a predictable, socially contingent context in which infants learn to monitor, interpret, and modulate their own internal states (Zeegers et al., 2018). Supporting this view, evidence shows that maternal mind-mindedness at 9 months predicts later inhibitory control at ages 2 and 3, whereas sensitivity does not (Cheng et al., 2018). More recently, Dong et al. (2023) also found that maternal mind-mindedness during the second year of life was associated with children's inhibitory control. Although conducted with preschool-aged children, other studies have shown that maternal use of mental-state comments during picture-storybook sharing tasks significantly predicts children's EF performance, even after accounting for sociodemographic factors such as age, sex, and parental education (Baptista et al., 2017; Toor & Hanif, 2022). Taken together, this body of evidence suggests that mind-mindedness may function as a key relational mechanism supporting the emergence of EF, complementing the potential foundational role of maternal sensitivity.

An additional gap in the literature concerns whether the caregiving context—distress vs. non-distress—matters for EF development during infancy. We recently proposed that sensitivity expressed in distress-eliciting situations may support different developmental pathways than sensitivity expressed during positive or neutral interactions (Ramos et al., 2023). Sensitivity to distress has been linked to attachment security (Del Carmen et al., 1993; Leerkes, 2011), whereas sensitivity to non-distress has been associated with attentional processes (Bornstein & Tamis-LeMonda, 1997). Importantly, evidence indicates that these forms of sensitivity have more unshared than shared variance, and that caregiving responses to distress versus non-distress cues differentially activate neural and physiological processes (Groh & Roisman, 2009; Leerkes et al., 2009). Interestingly, attuned mind-related comments (mother's speech that reveals mind-mindedness towards the infant and is also appropriate to the context), typically assessed in free play, have likewise been shown to vary across caregiving contexts—e.g., bath, mealtime, and play (Farkas et al., 2018; Flynn & Masur, 2007). Longobardi and

colleagues (2022), for instance, found that mothers produced more attuned mind-related comments during free-play with their 16-month-old children than during other everyday routines such as mealtime. This raises the possibility that both sensitivity and mind-mindedness may function differently depending on the interactional context, with potential implications for how these behaviours support EF during the first year of life.

1.1. The present study

Despite substantial evidence highlighting the influence of maternal sensitivity and mind-mindedness on multiple domains of child development (e.g., Bornstein & Tamis-LeMonda, 1997; Cheng et al., 2018; Samdan et al., 2020), their specific contribution to infants' emerging EF abilities has yet to be directly examined. The present study addresses this gap by investigating the associations between three measures: (1) maternal sensitivity, (2) mind-mindedness—assessed in response to infants' cues during both non-distress and distress-eliciting interaction contexts—and (3) infants' EF skills within the first year of life. We measured the infant's EF using the A-not-B task, a task already used in studies of EF development in early infancy (Blankenship et al., 2019; Holmboe et al., 2008; Holmboe et al., 2018).

Drawing on previous findings linking these parenting dimensions to EF development in older children (Baptista et al., 2017; Bernier et al., 2010), we expect that both higher levels of maternal sensitivity and higher levels of attuned mind-related comments will be associated with more advanced infant EF performance. Based on theoretical accounts that have emphasized the role of parents' mental-state awareness in scaffolding self-regulatory development (Baptista et al., 2017; Meins et al., 2001), we further anticipate that maternal mind-mindedness will show a stronger relation to infants' EF skills than sensitivity alone. In addition, we hypothesize that maternal behaviours during non-distress contexts will more strongly predict EF development. This expectation is informed by studies suggesting that maternal engagement during free-play interactions supports early cognitive processes, e.g. (Yu & Smith, 2016), including attentional control, a foundational precursor to later EF (Blankenship et al., 2019; Cuevas & Bell, 2014).

Method

2.1. Participants

Participants were drawn from a larger project examining individual and relational predictors of rudimentary EF during the first year of life. A total of 66 infants and their mothers were initially

recruited; however, 15 infants were excluded from the present analyses because they did not complete the minimum number of valid trials on the A-not-B task used to assess EF (see procedure below). No significant differences emerged between included and excluded infants in age ($t(64) = 1.960$, $p = .059$), sex ($\chi^2(1) = .183$, $p = .669$), or maternal education ($\chi^2(1) = 2.282$, $p = .131$). The final sample, therefore, comprised of 51 mother-infant dyads (sample description is in Table 3). Infants ranged in age from 9 to 13 months ($M = 10.78$, $SD = 1.63$), and just over half were male ($n = 27$; 52.9%). Mothers were between 20 and 43 years old ($M = 33.63$, $SD = 5.19$), and the majority were married or cohabiting ($n = 47$; 92.2%), and held a bachelor's degree or higher ($n = 43$; 84.3%).

2.2. Procedure

Families were recruited from Portuguese daycare centres. Eligible infants were required to be between 9 and 13 months of age, born full-term, free of significant medical conditions or birth complications, and within the typical developmental range. Developmental functioning was screened using the short form of the Caregiver-Reported Early Development Instruments (CREDI), a 20-item measure of early development for children under 36 months (McCoy et al., 2018). Caregivers completed the age-appropriate form (6–11 or 12–17 months) using a yes/no format, and all infants scored within the expected developmental range. This study was approved by the Institutional Ethics Committee of [University name removed for blind review] (Ref 128/2022). Written informed consent was obtained from all participating mothers.

Assessments were conducted at the daycare centres or in families' homes, depending on caregiver availability. Mothers first completed a set of questionnaires, including demographic information. Infants' EF was then assessed using the A-not-B task, administered while infants were seated on their mothers' lap. Subsequently, each dyad participated in a 12-minute structured interaction task, following the procedure described by Baptista et al. (2018), designed to assess parental quality of relational care. The task comprised four consecutive three-minute episodes presented as a continuous interaction. The first was a non-distress free-play episode during which mothers and infants interacted with developmentally appropriate toys. This was followed by three episodes intended to elicit progressively greater levels of challenge for the dyad – that will refer to as distress episodes. In the first of these, mothers and infants interacted without toys; in the second, they engaged with a toy selected to be above the infant's developmental level; and in the final episode, the mother briefly left the room for three minutes while a trained researcher interacted with the infant, after which the mother and infant were reunited. All interactions were video-recorded for subsequent coding of maternal sensitivity

and maternal mind-mindedness. Families received a small token of appreciation for their participation.

2.3. Measures

2.3.1. Infant executive functioning.

The A-not-B task (Piaget, 1954) was used to assess early EF. The apparatus, based in the design described by Smith et al. (1999), consisted of a rectangular box measuring 30x23x5.5 cm. It featured two circular wells, each with a radius of 4.5cm and a depth of 4.5cm; the center of the wells was 12.5cm apart. The lids had a radius ranging from 4.7cm to 5cm and were equipped with handles. Children sat on their mothers' laps, and faced the experimenter, that also provided instructions to the mother. The instructions included saying that the infant was not allowed to touch the box before the signal from the experimenter and that the mother could not indicate where the toy was hidden.

The procedure used is a version of the A-not-B task that uses multiple reversals and varying delays over time, see (Diamond, 1985; Holmboe, 2008). In the first trial, the experimenter hides the toy on location A and covers the locations with the lids simultaneously. An initial delay of 2s was imposed for 9-10-month-old and of 5s for 12-13-month-old children (Diamond, 1990). The delay imposed varied according with the infant's performance: if the child reached correctly two times in a row, the location of the hidden toy would switch and the delay would increase by 1s; if the child answered incorrectly in two consecutive trials, the delay would decrease by 2s. If the child touched the two lids, the trial was repeated. Testing would end after 25 trials or if the child refused to continue. A different hiding toy would be introduced when the child demonstrated no longer being interested in the task to maintain the child's engagement in the task. A cumulative measure of the A-not-B task was obtained by calculating the sum of delays tolerated in the correct trials and dividing by the total number of trials completed, with higher scores indicating better EF performance (Holmboe et al., 2018). Children were included in the analysis if they completed a minimum of eight trials (blind for review). To assess reliability, 25% of the sessions were independently coded by two trained raters, yielding excellent interrater reliability (ICC = .95).

2.3.2. Maternal Sensitivity.

Maternal sensitivity refers to the mother's ability to perceive and accurately interpret her infant's signals and respond promptly and appropriately to those cues. Maternal sensitivity was assessed using the Ainsworth, Blehar, Waters, and Wall (1978) Sensitivity/Insensitivity scale. This instrument was applied to the 12-minute videotaped interaction task. Scores range from 1

(highly insensitive) to 9 (highly sensitive). Each episode of the interaction task was coded independently. The three episodes that were more distress-eliciting (no toys, difficult toy, and reunion) were also significantly intercorrelated (all $p < .001$). Based on this finding, we averaged them and created a composite distress sensitivity score. Interrater reliability was assessed for 18% of the sample, coded independently by two trained raters, and demonstrated excellent agreement (ICC ranging between .78 and .97).

2.3.3. Maternal appropriate mind-minded comments.

Maternal mind-mindedness was coded from verbatim transcripts of the videotaped mother–infant interaction task, following the coding system developed by Meins and Fernyhough (2015). Verbal references to the infant's internal states—such as thoughts, emotions, or desires—were classified as mind-related comments. These comments were subsequently coded as appropriate when they accurately described or inferred the infant's internal state, or as non-attuned when they misinterpreted or imposed an incorrect mental state. To control maternal verbosity, a proportion of appropriate mind-related comments was calculated relative to the mother's total number of utterances; this was done for the non-distress and distress episodes, and this proportion served as the mind-mindedness variable used in all analyses. As with maternal sensitivity, the three distress-eliciting episodes were averaged, creating a mean score that captures mind-mindedness in distress-eliciting contexts and that we also label as distress attuned. Interrater reliability was assessed for 22% of the sample and was excellent (ICC ranged between .86 and .99).

2.3.4. Sociodemographic questionnaire.

Mothers completed a sociodemographic questionnaire providing information on their educational attainment, marital status, and their child's characteristics, including age and sex.

2.4. Data analysis

All analyses were conducted using IBM SPSS Statistics (version 29.0.2). We began by computing descriptive statistics for all study variables. Paired-sample comparisons were then performed to examine differences in maternal sensitivity and mind-mindedness between the non-distress episode (free-play) and the distress-eliciting episodes (no toys, difficult toy, and reunion). Next, we examined bivariate associations between infants' performance on the A-not-B task and each parenting measure—maternal sensitivity and appropriate mind-mindedness—using Pearson correlations. Additional correlations were conducted to explore associations between EF and parenting variables and sociodemographic characteristics. Finally, to assess the unique contribution of maternal relational care to infants' emerging EF abilities, hierarchical

regression analyses were conducted. Sociodemographic variables that showed significant associations with A-not-B performance in preliminary analyses were entered as covariates in the first step, followed by maternal care.

Results

Table 3 presents the descriptive statistics for all study variables, and Table 4 shows the bivariate correlations. With regard to the A-not-B task, infants completed an average of 11.43 trials (*SD* = 3.32). Performance showed substantial variability, with cumulative scores ranging from 0.00 to 4.89 (*M* = .92, *SD* = .91).

Mothers displayed significantly higher sensitivity in the non-distress episode (*M* = 6.8, *SD* = 1.3) than in the distress-eliciting episodes (*M* = 6.07, *SD* = 1.3), $t(50) = -4.387$, $p < .001$. Maternal sensitivity in the non-distress and distress contexts was strongly correlated ($r = .571$, $p < .001$), indicating that mothers who were more sensitive during free play tended to maintain higher sensitivity when interactions became more challenging. For mind-mindedness, no significant differences were observed in the proportion of appropriate mind-related comments across contexts (i.e. proportion of mothers' comments that were about the infant's internal mental state and were also adequate for the situation), although mothers tended to produce slightly more appropriate comments in the non-distress episode (*M* = .014, *SD* = .02) than in the distress-eliciting episodes (*M* = .011, *SD* = .01), $t(50) = 1.499$, $p = .140$. Appropriate mind-minded comments in the non-distress episode were positively correlated with maternal sensitivity in the same context ($r = .409$, $p = .003$). In contrast, appropriate mind-mindedness in the distress-eliciting episodes showed only a marginally significant association with appropriate mind-mindedness in the non-distress episode ($r = .272$, $p = .058$). No significant correlations were found between mind-mindedness and maternal sensitivity in the distress-eliciting episodes ($p > .05$).

3.1. Associations Between Early EF and Quality of Relational Care

As shown in Table 4, both the proportion of appropriate mind-minded comments in the non-distress episode ($r = .349$, $p = .012$) and maternal sensitivity in the distress-eliciting episodes ($r = .289$, $p = .039$) were positively associated with infants' performance on the A-not-B task.

Regarding sociodemographic factors, children's age was positively associated with A-not-B performance ($r = .544$, $p < .001$), indicating that older infants displayed better EF performance. Child age was also positively related to maternal sensitivity in the distress context

(r = .439, p = .001), but not in the non-distress episode (p > .05). Maternal age was similarly associated with sensitivity in the distress context (r = .283, p = .044), suggesting that older mothers tended to display higher sensitivity when interactions became more challenging. Neither child sex nor maternal education was significantly associated with EF performance, sensitivity, or the proportion of appropriate mind-minded comments (p > .05).

3.2. Predicting Early EF from Maternal Relational Care

Table 5 summarizes the regression models. A linear regression analysis was conducted to evaluate whether maternal sensitivity and mind-mindedness predicted infants' A-not-B performance while controlling for child age—the only sociodemographic factor significantly associated with EF. The overall model was statistically significant, explaining 33% of the variance in the A-not-B performance, $F(3, 47) = 9.233$, $p < .001$. Child age emerged as a significant predictor ($\beta = .498$, $t(47) = 3.858$, $p < .001$). In addition, the proportion of appropriate mind-minded comments in the non-distress episode predicted higher A-not-B scores ($\beta = .274$, $t(47) = 2.314$, $p = .025$). In contrast, maternal sensitivity in the distress-eliciting contexts did not significantly contribute to the prediction of EF performance (p = .908).

Discussion

Only a small number of studies have investigated the predictors of EF during infancy (Bell, 2012; Blankenship et al., 2019), despite growing evidence that foundational EF abilities start to emerge within the first year of life (Cuevas et al., 2017; Holmboe et al., 2018) and predict a wide range of developmental outcomes (e.g., Benson et al., 2013; Caporaso et al., 2019; Zelazo & Carlson, 2020). Attention and early brain development play a central role in supporting rudimentary forms of EF skills (Blankenship et al., 2019; Cuevas & Bell, 2014; Holmboe et al., 2018; MacNeill et al., 2018), yet have offered comparatively limited insight into how environmental inputs—particularly parenting behaviours—shape these early developmental pathways.

Prior research with preschool-age samples (e.g., Bernier et al., 2010; Kraybill & Bell, 2012) suggests that maternal sensitivity may already be contributing to early EF. The temporal stability of sensitivity further reinforces this inference (Bigelow et al. 2010; Kim & Kochanska, 2025). Notwithstanding, Meins and colleagues (2012) suggested that mind-mindedness—with known links to EF in preschool years (Baptista et al., 2017)—may also be contributing to rudimentary EF processes during the first year of life, even playing a more significant role than

sensitivity. Accordingly, this study examined how maternal sensitivity and mind-mindedness, assessed in both non-distress and distress-eliciting interaction contexts, relate to infants' EF skills during the first year of life.

4.1. Maternal Sensitivity and Mind-Mindedness Across Contexts

Consistent with previous research, mothers in this study exhibited significantly higher sensitivity in contexts that are more neural (non-distress/free-play) than in contexts that are more likely to elicit distress signals from the infant. Non-distress contexts are emotionally less demanding and occur in low-arousal settings (Leerkes et al., 2009), whereas distress-eliciting contexts require rapid regulation of caregivers' own emotions, making sensitive responses more challenging (Leerkes, 2010). Experimental and observational research has documented the negative impact of stress on maternal sensitive behaviours (Booth et al., 2018; Finegood et al., 2016; Qian et al., 2024), potentially mediated by cascading effects of parental psychological distress on emotion regulation and responsiveness (Carreras et al., 2019). Mind-minded comments were also more frequent in the non-distress episode than in distress-eliciting contexts, although this difference did not reach statistical significance. This pattern may reflect the less disruptive nature of infants' social cues during free play, which do not require intense regulation of affect, whereas in distressing situations, caregivers are primarily focused on soothing and managing the child's emotional state (Leerkes et al., 2012), leaving fewer opportunities to produce mind-related comments.

Interestingly, appropriate mind-minded comments in the non-distress episode were positively correlated with sensitivity in the same context, consistent with previous research (Meins et al., 2012). Mind-mindedness is conceptualised as a specific aspect of sensitivity directed toward infants' internal states, which may explain the association between these dimensions (Zeegers et al., 2017). Furthermore, maternal sensitivity across non-distress and distress contexts was also intercorrelated, supporting the conceptual link between these two dimensions (Leerkes et al., 2009). However, mind-mindedness did not show stability across contexts, in line with studies suggesting that maternal mind-mindedness may be context-dependent and relational rather than a fixed trait (Giovanelli et al., 2019; Helmerhorst et al., 2019; Longobardi et al., 2022). The fact that mothers were assessed solely in play contexts—albeit under varying levels of induced stress—may have limited opportunities for mind-mindedness to manifest consistently across episodes, helping explain the lack of contextual stability observed.

4.2. Associations Between Caregiving and Early EF

Regarding links between parenting behaviours and EF, only maternal sensitivity in distress-eliciting contexts was positively associated with infants' A-not-B performance. This is contrary to our initial expectation that sensitivity in the non-distress episode would be more strongly predictive. Attachment theory provides a plausible explanation for the finding: the activation of the attachment system in response to child distress elicits sensitive caregiving, promoting a sense of security and allowing infants to regulate their emotions within a safe environment (Ainsworth et al., 1978; Bowlby, 1969, 1979; Sroufe, 2000). Failure to respond to distress cues may impair regulation of the hypothalamic-pituitary-adrenal (HPA) axis (Atkinson et al., 2013; Lupien et al., 2009), which can in turn constrain cognitive processing (Lupien et al., 2005). Once regulatory needs are met, infants can safely engage their exploratory system, highlighting the co-regulatory role of caregivers in supporting emerging EF (Feldman et al., 1999).

Similarly, the proportion of appropriate mind-minded comments in the non-distress episode was positively associated with EF. These maternal comments focused on infants' current activities, potentially supporting infants' cognitive engagement by providing contingent, meaningful framing of their ongoing experiences. This aligns with previous research showing that exposure to a higher quality of maternal mental-state talk in preschool predicts overall EF (Baptista et al., 2017). In preschool-age children, exposure to mental-state talk facilitates EF partly by enriching the vocabulary and representational tools used to reflect on thoughts and emotions (Vallotton & Ayoub, 2011). Infants, however, benefit in more foundational—prelinguistic—ways: appropriate mind-related comments may act as regulatory cues that help infants organise attention, detect regularities between their internal states and caregivers' responses, and experience affective states as predictable and co-regulated. These early relational processes may constitute the developmental groundwork upon which later representational abilities relevant to EF are built.

Our linear regression analyses further indicated that, after controlling for child age, appropriate mind-minded comments in the non-distress episode significantly predicted EF, whereas sensitivity in distress-eliciting contexts did not. These findings support Meins et al. (2001)'s proposition that mind-mindedness may exert a stronger influence on early EF than sensitivity. Conceptually, sensitivity primarily facilitates emotional regulation, helping children manage affective arousal (Zelazo & Müller, 2002) and buffering stress-related HPA activation (Gunnar & Donzella, 2002). Mind-mindedness, in contrast, reflects a reflective, cognitive orientation toward the child as an intentional agent with distinct desires, emotions, and cognitions, thereby supporting behaviours linked to these mental states. Taken together, these

findings suggest that sensitivity and mind-mindedness may play complementary roles: sensitivity provides emotional scaffolding, whereas mind-mindedness contributes to early cognitive scaffolding (Meins, 1997; Meins et al., 2001).

High variability in A-not-B performance is consistent with the developmental emergence of EF during the first year (Cuevas et al., 2017; Holmboe et al., 2018) and reflects the interplay between maturational and environmental factors (Bernier et al., 2016). Child age was a significant predictor of EF, with older infants performing better. This is expectable, given the considerable amount of evidence on the A-not-B task and the period of 8 to 10-12 months of age; it is also consistent with prior findings that EF improves with age (Best & Miller, 2010). Child age was also associated with higher maternal sensitivity in distress-eliciting contexts but not in non-distress episodes. This pattern suggests that as children grow, mothers may become more effective in regulating infants' emotional arousal during distress, whereas sensitivity in non-distress settings – contexts that are more neutral and less likely to elicit distress signals – may be less contingent on developmental level, given that they also are less demanding in terms of emotional regulation.

4.3. Limitations and Directions for Future Research

Despite the contributions to research on EF in infancy, this study does not exist without its limitations. First, the small sample size limits the generalizability of the findings. Reduced statistical power may have obscured associations of small to moderate magnitude, and therefore some effects should be interpreted with caution. Second, maternal psychopathology was not assessed, representing a significant limitation given its documented impact on maternal sensitivity (Ku & Feng, 2023), on mind-mindedness (Baron-Cohen et al., 2025), and on children's EF development (e.g., Gueron-Sela et al., 2018; Hughes et al., 2013). Furthermore, individual differences in attentional processes—central predictors of early EF (Blankenship et al., 2019)—were not included. Attentional control may moderate the influence of proximal caregiving behaviours on EF, and studies integrating both biological and environmental factors are needed to clarify such interactional mechanisms. Additionally, the study relied solely on observational play-based episodes, which, although ecologically valid, may not fully capture the breadth of sensitivity and mind-mindedness expressions across daily routines. Future research should consider multi-method, multi-context approaches, including naturalistic home observations, physiological measures of stress regulation, and longitudinal designs to map developmental change. Finally, future studies should examine these associations in at-risk or clinically vulnerable populations, such as premature infants. Preterm children display

heightened difficulties in early cognitive tasks and stress regulation during the first year of life (Feher et al., 2025), and caregiving processes may operate differently—or exert stronger effects—in these populations. Understanding how sensitivity and mind-mindedness function as protective factors may guide the development of targeted early interventions.

Conclusions

Despite these limitations, very few studies have examined environmental predictors of EF during the first year of life, particularly distinguishing the contributions of sensitivity and mind-mindedness across distress and non-distress contexts. The present findings advance the literature by showing that both maternal sensitivity and mind-mindedness are linked to infants' emerging EF, and by illustrating how these distinct caregiving dimensions—emotional attunement and mental-state attunement—may differentially support early EF processes. Importantly, the results indicate that sensitivity and mind-mindedness are already developmentally meaningful for EF within the first year, suggesting that the relational foundations of EF begin to take shape earlier than typically assumed. These insights have implications for early intervention: programmes designed to foster EF development may benefit from strategies that strengthen sensitive caregiving in emotionally demanding moments and promote caregivers' awareness and interpretation of infants' mental states. Together, these relational capacities may provide a dual scaffolding—emotional and cognitive—supporting the earliest building blocks of EF.

Table 3.

Sociodemographic Characteristics of Participants.

	n	***M (SD)***	**%**	**range**
Children's age	51	10.78 (1.63)		9-13
Mothers' age	51	33.63 (5.19)		20-43
Children's sex				
Male	27		52.9	
Female	24		47.1	
Children’s age group				
9-10 months	28		54.9	
12-13 months	23		45.1	
Maternal education				
9 years of education	1		2.0	
12 years of education	7		13.7	
Bachelor degree	27		52.9	
Master's or PhD	16		31.4	
Marital status				
Single	2		3.9	
Married	47		92.2	
Divorced	2		3.9	

Note. AB = A-not-B task.

Table 4.

Descriptive Statistics and Correlations for Study Variables.

	n	*M*	*SD*	1	2	3	4	5	6	7	8	9
1. Children's sex [a]	51			-								
2. Children's age	51	10.78	1.63	.199	-							
3. Mothers' age	51	33.63	5.19	.076	.137	-						
4. Maternal education [a b]	51			.407**	.009	.336*	-					
5. Non-distress: Maternal appropriate mind-minded comments	51	.014	.016	.088	.145	-.151	.115	-				
6. Distress-eliciting: Maternal appropriate mind-minded comments	51	.011	.01	.006	.036	-.042	.028	.272+	-			
7. Non-distress: Maternal sensitivity	51	6.82	1.29	.192	.181	.148	.236^{+}	.409**	.132	-		
8. Distress-eliciting: Maternal sensitivity	51	6.07	1.35	.136	.439**	.283*	.225	.204	.050	.571***	-	
9. AB: Cumulative measure	51	.92	.91	-.159	.544***	-.003	-.162	.349*	.051	.126	.289*	-

Note. [a] Point-biserial correlations are reported for associations involving dichotomous variables; all other values represent Pearson correlations. [b] Maternal education was dichotomized as up to 12 years of education vs. higher education; AB = A-not-B task; $^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5.

Prediction of children's EF.

	B	***SE***	***β***	***t***	***p***
Block 1					
(Constant)	-2.356	.730	-	-3.227	.002
Children's age	.304	.067	.544	4.538	<.001
Block 2					
(Constant)	-2.364	.730	-	-3.238	.002
Children's age	.278	.072	.498	3.858	<.001
Non-distress: Maternal appropriate mind-minded comments	15.628	6.754	.274	2.314	.025
Distress-eliciting: Maternal sensitivity	.010	.088	.015	.116	.908

Note. Adjusted $R^2 = .33$, $F(3, 47) = 9.233$, $p < .001$.

CHAPTER VI

Early Executive Function in the First Two Years: Insights from the EEFQ and Associations with Child and Family Factors[4]

Abstract

Plenty of evidence supports the importance of early executive functioning (EF) for later developmental outcomes. However, studying rudimentary EF abilities in the first two years of life remains challenging due to their immature nature and the difficulty of administering traditional behavioural tasks with very young children. The Early Executive Functions Questionnaire (EEFQ; Hendry & Holmboe, 2021) was developed to assess EF in 9-30-month-old children using parent reports and ecologically valid situations. The present work consisted of two studies: Study 1 examined EEFQ's convergent validity, and Study 2 explored child and family factors–including child age and sex, maternal education, and parental toxic stress–potentially associated with EF assessed with the EEFQ. Participants included N = 61 children aged 9-13 months in Study 1, and N = 124 children aged 9-24 months in Study 2, along with their mothers. Study 1 revealed a positive association between the EEFQ-inhibitory control subscale and children's performance on the Toy Prohibition Task, supporting the construct validity of the questionnaire. In Study 2, regression analyses showed that children's age predicted EEFQ-cognitive flexibility scores, whereas both age and parental toxic stress were associated with regulation. The findings underscore the role of individual and family factors in early EF development and suggest targeting parenting stress to support children's emerging regulatory skills.

Keywords: Executive functioning, assessment, infants, toddlers, parenting stress.

[4] The study is currently under review:
Ramos, C., Pereira, A. F., & Baptista, J. (under review). Early Executive Function in the First Two Years: Insights from the EEFQ and Associations with Child and Family Factors. *Child Neuropsychology.*

Introduction

Executive Functioning (EF) refers to a set of higher-order cognitive processes that support goal-directed regulation of thoughts, emotions, and behaviours (Diamond, 2013). EF has been consistently linked to key developmental outcomes, such as theory of mind (Wilson et al., 2018), socioemotional abilities (Holmes et al., 2016), reading (Arrington et al., 2014) and academic achievement (Zelazo & Carlson, 2020). This is also supported by studies on autism spectrum disorder (ASD) and attention deficit hyperactivity disorder (ADHD) that suggest that EF deficits may be implicated in its clinical symptomatology (Hill, 2004; Raiker et al., 2012). Given its broad relevance, understanding EF development from the earliest years has become a central topic in developmental science (Fiske et al., 2025).

A highly influential model of EF, using the latent variable approach, has proposed that EF is composed of three separable domains, that also share commonalities (Miyake et al., 2000): Inhibitory control (IC), cognitive flexibility (CF), and working memory. IC refers to the ability to suppress a typical response in the presence of different stimuli, CF is the ability to switch between tasks and activities or acquire and integrate new rules, and, finally, WM concerns the ability to manipulate and keep in mind temporary information (Buss & Spencer, 2014; Diamond, 2013). Studies of EF structure also found that the most parsimonious models of child and adolescent data have to two factors and that EF abilities likely undergoes differentiation, that is not an all-or-none change, and starts earlier that the preschool years (Karr et al., 2018).

Development of EF in the First Years of Life

While most EF research has focused on preschool-aged children and beyond (e.g., Best & Miller, 2010; Garon et al., 2008), growing evidence suggests that the foundational components of EF begin to emerge within the first year of life, with substantial improvements occurring within the first three years (Morgan et al., 2024). According to a recent review, a coherent structure for EF is not apparent until around the age of 24 months (Miller et al., 2023), which indirectly supports the view that the first two years of life are a crucial period during which the foundational abilities supporting further EF are likely being established (Fiske et al., 2025).

Neurodevelopmental research has shown that frontal cortical areas—strongly associated with EF—are already functional by six months of age (Fiske & Holmboe, 2019), and infants as young as five or six months of age demonstrate rudimentary forms of IC and WM (e.g., Holmboe et al., 2018). By eight months, infants can inhibit actions in response to caregivers' verbal instructions (Kochanska et al., 1998), and by 9 months, they are capable of suppressing

attention to distracting stimuli (Holmboe et al., 2008). At 8 to 10 months, some infants can resist touching an attractive toy (Kochanska et al., 1998); and between 7.5 and 12 months of age, infants exhibit a progressive improvement in their ability to inhibit responses and to maintain information in memory. By 12 months, they are capable of maintaining visuo-spatial memory of hiding events and later succeed in goal-directed reaching: they can tolerate delays of up to 10 seconds, reflecting measurable advances in EF development (Diamond, 1990, 2013).

In the second year of life, EF abilities are gradually developing (Miller & Marcovitch, 2015), with the emergence of rudimentary CF abilities, in which children can already regulate their behaviour by incorporating a rule (Cuevas et al., 2017). These early EF skills, though still fragile and developing, provide the groundwork for later cognitive and behavioural regulation (Hendry et al., 2016).

Despite its early emergence, studying EF in infants and toddlers remains challenging due to the limited behavioural repertoire of preverbal children and the still-developing nature of EF at this stage (Hendry et al., 2016). Moreover, traditional task-based assessments often lack ecological validity and can be time-consuming and difficult to administer with very young children (Wallisch et al., 2018). Existing caregiver-report questionnaires have primarily targeted preschool-aged children or older, leaving a gap in tools suitable for infants and toddlers (Gioia et al., 2000). To address this gap, the Early Executive Functions Questionnaire (EEFQ; Hendry & Holmboe, 2021) was developed as an ecologically grounded, parent-report measure specifically designed to assess EF in children aged 9 to 30 months. The EEFQ is composed of 31 items, split into two parts: three games that parents play at home with the child, and report on the results; 28 questions that assess IC, CF, WM and Regulation using everyday behaviours in naturalistic settings – a goal of the EEFQ: provide a developmentally sensitive and accessible alternative to performance-based tasks. As such, the EEFQ presents a promising opportunity to investigate early predictors of EF in infancy and toddlerhood, with important implications for early identification and intervention.

The original validation study demonstrated that the EEFQ shows adequate psychometric properties, with good internal consistency and test-retest reliability (Hendry & Holmboe, 2021). Construct validity was supported by convergent associations between cognitive executive function (a composite of IC, CF, and WM) and the IBQ (Infant Behavior Questionnaire) Orienting/Regulation dimension; discriminant validity was supported by by negative associations found with Negative Affect. The Regulation subscale showed only correlations with Negative Affect, exhibiting closer connections to emotion regulation than with cognitive control-like abilities (Hendry & Holmboe, 2021). Recent research found that the cognitive

executive functioning subscale of EEFQ was positively associated with performance on the Early Childhood Inhibitory Touchscreen Task (ECITT; Holmboe et al., 2021), but not with the Toy Prohibition task (Lui et al., 2021). No significant associations emerged between the other EEFQ subscales and either of the performance-based measures. Although these findings offer preliminary insight into how the EEFQ relates to performance-based EF tasks, the evidence remains limited and mixed. Thus, further research is required to clarify these associations and, importantly, to deepen our understanding of the child and family factors that may shape EF outcomes as assessed by the EEFQ. This is one of the objectives of the current study.

Child and Family Factors Associated with Early Executive Functioning

Understanding early influences on EF is essential for identifying children at risk of maladaptive developmental trajectories. Extensive research with preschoolers and older children has shown that both child- and family-level variables shape their development (e.g., Chung et al., 2021; Granero et al., 2015; Halse et al., 2019; Isquith et al., 2004).

Studies examining children's characteristics have produced mixed findings. Regarding comparisons between boys and girls, no differences were found in Wagner et al. (2016)'s study for global EF, IC, CF, and metacognition; contradicting previous findings in which girls showed more developed inhibition abilities (Isquith et al., 2004). Recently, Hendry and Holmboe (2021) found evidence supporting that girls appear to have more developed global EF abilities than boys. As for age, EF abilities seem to improve gradually (Best & Miller, 2010). However, according to parental reports, 3-year-olds seem to have more difficulties in inhibitory and emotional control competencies, compare with younger children at 2 years of age or with older children, aged 4 to 5 years (Guy et al., 2012; Isquith et al., 2004).

Family-level variables, such as socioeconomic status (SES) and maternal education alone, are also considered important determinants of parental reports on EF. Granero et al. (2015) found that SES is associated with IC and WM. Another study, conducted by Halse and colleagues (2019), found similar results, measuring SES through parental education and occupation, revealing that higher education, but not occupation predicted better reported EF. For education, this effect was found for global EF, IC, and emergent metacognition domains. Nonetheless, other studies using performance-based measures did not find significant associations between these variables (Hackman et al., 2014; Hughes et al., 2010).

In recent years, increasing attention has been devoted to parenting-related variables that may play a role in shaping children's EF (Baptista et al., 2017; Ramos et al., 2023). One such variable is parenting stress, conceptualized as the perception that the demands of parenting

exceed one's available coping resources (Abidin, 1990). A growing body of evidence suggests that parenting stress is associated with multiple domains of child development, including cognitive functioning (e.g., Joyner et al., 2009; Molfese et al., 2010). Within this line of research, studies have consistently shown that higher levels of parenting stress are linked to greater parent-reported EF difficulties in children (Hutchinson et al., 2016; Wagner et al., 2016). In particular, Wagner and colleagues (2016) found that increased parenting stress was associated with reports of less developed global EF, IC, CF, and metacognitive skills in preschool children.

Other work has suggested that these associations also apply to even younger children (e.g., Molfese et al., 2010), although research specifically focusing on this age group remains relatively limited. One notable exception is a study by de Cock and colleagues (2017), which reported that parenting stress assessed at 24 months was concurrently associated with children's emerging EF abilities. One potential mechanism underlying these associations is that lower parenting stress may help foster a more supportive and responsive environment for EF development. In contrast, higher levels of stress may reduce the quality and frequency of parent–child interactions and limit engagement in cognitively enriching activities, thereby constraining opportunities for children to practice and strengthen EF skills (Booth et al., 2018; Qian et al., 2024). Also, the impact of stress on child development may be particularly pronounced under chronic stress, which can erode parents' emotional and psychological resources and compromise responsive parenting (Moreno et al., 2021; Nascimento et al., 2025). Following this possibility, this study aims to add to our understanding of EF by exploring the role of parental toxic stress on early EF, as measured by the EEFQ. To measure parental toxic stress we used FITS-P questionnaire (Functional Impact of Toxic Stress on Parents Questionnaire; Moreno et al., 2021)

Aim of the present study

There are significant associations between child and family characteristics and EF during the preschool years (e.g., Chung et al., 2021; de Cock et al., 2017; Granero et al., 2015). Far less attention, however, has been devoted to identifying early predictors of EF during infancy and toddlerhood—a particularly sensitive period for the emergence of self-regulatory abilities (Hendry et al., 2016; Cuevas et al., 2017). The present work sought to address this gap through two complementary studies.

Study 1 aimed to examine the convergent and external validity of the Early Executive Functioning Questionnaire (EEFQ; Hendry & Holmboe, 2021), a recent and ecologically

grounded parent-report measure designed to assess rudimentary EF abilities in very young children. Specifically, the study evaluated whether EEFQ scores were associated with performance on a behavioural measure of inhibitory control—the Toy Prohibition Task—to assess the questionnaire's convergent validity. In addition, and to further evaluate the measure's external validity, Study 1 examined the associations between EEFQ scores, sociodemographic variables (e.g., child's age, sex, parental education), and children's global developmental functioning. We made three hypotheses: (1) that EEFQ scores would be significantly and positively correlated with performance on the Toy Prohibition Task; (2) that all EEFQ subscales—Inhibitory Control, Cognitive Flexibility, Working Memory, and Regulation—would be positively intercorrelated, reflecting their shared underlying construct of early EF; and (3) that EEFQ scores would be positively associated with children's global developmental level, age, female sex, and maternal education.

Building on previous research that has highlighted the influence of individual and environmental factors on early self-regulation (e.g., de Cock et al., 2017; Hutchinson et al., 2016; Isquith et al., 2004; Joyner et al., 2009), Study 2 aimed to extend Study 1 by examining whether parental toxic stress is associated with early EF development, over and above sociodemographic factors. We hypothesized that EEFQ scores would be positively associated with age, female sex, and parental education. In addition, we expected that higher levels of parental toxic stress would be associated with lower EEFQ scores, and that these associations would remain significant after controlling for sociodemographic variables.

Together, these studies intended to provide a comprehensive examination of early EF assessment and its early-life correlates, contributing to a deeper understanding of the developmental foundations of self-regulation.

Study 1

Method

Participants

Sixty-one children aged between 9 and 13 months (M = 10.89, SD = 1.55, n = 31 females) and their mothers participated in the present study. All of the children were born full-term without any medical complications. Mothers ranged in age from 20 to 43 years (M = 34.07, SD = 4.98). Most mothers were married *(*n = 56; 91.8%) and had attained at least a bachelor's degree (n = 47; 77.1%). Table 6 summarizes the sample characteristics.

Measures

Sociodemographic questionnaire. Mothers were asked to complete a sociodemographic questionnaire, providing information on their education level, marital status, and the characteristics of their children (i.e., age and sex).

Caregiver-Reported Early Development Instruments (CREDI) - Short-Form. Mothers completed the short form of the CREDI, a 20-item questionnaire designed to assess population-level early childhood development, in children under the age of three years (e.g., Item B1, "Can the child pick up a small object (e.g., a small toy or small stone) using just one hand?"). In previous studies, this questionnaire demonstrated strong internal consistency, adequate criterion validity, and evidence of discriminant validity (McCoy et al., 2018). Caregivers responded to age-specific forms (6–11 months or 12–17 months) using a binary (yes/no) response format. A summary score of children's overall developmental status was obtained.

The Early Executive Functions Questionnaire (EEFQ; Hendry & Holmboe, 2021). The EEFQ is a 31-item parental report measure assessing EF in 9 to 30-month-old children. Specifically, this measure is composed of two parts: a) the first part consists of three games to play at home with their child – parents are asked to report the child's performance in these three game-based items, and the games (the waiting game, the finding game, and the sorting game) are designed to assess IC, WM, and CF, respectively; b) the second parts includes 28 items assessing IC, CF, WM, and Regulation, in which caregivers need to report their children's behaviour in the past two weeks, on a 7-point scale from Never to Always (e.g., *"Hesitate for at least a second when you said "no / don't touch" or similar"*). Caregivers were provided with written and video instructions to play the games with their children. Children under 12 months of age are not required to complete the sorting game. To be included in the analysis, participants had to complete at least 70% of the items of each subscale following the recommendation of the authors of the measure (*Hendry & Holmboe, 2021)*. For items in which mothers indicated they did not know whether the child exhibited a certain behaviour, their response would be coded as "Never". Subscale scores for EEFQ-IC (1 game, 7 items), EEFQ-CF (1 game, 7 items), EEFQ-WM (1 game, 6 items), and EEFQ-Regulation (8 items) were computed by summing the items.

The EEFQ was translated, back-translated, and adapted for the Portuguese context following a *think-aloud* protocol (Willis, 2005) to explore how participants interpreted and responded to the items. Previous research has demonstrated that the EEFQ possesses adequate psychometric properties, including evidence of convergent and divergent validity with measures of infant temperament, good test–retest reliability, and satisfactory internal

consistency (IC, *Cronbach's α: .63-.72;* CF, *Cronbach's α: .54-.76;* WM*, Cronbach's α: .66-.71;* and regulation*, Cronbach's α: .82-.86)* (Hendry & Holmboe, 2021).

Toy Prohibition task (Friedman et al., 2011). The Toy Prohibition is a behavioural measure of EF. In this task, the child is shown an attractive toy and asked not to touch it. The child is thus required to inhibit their impulse to touch the object. The toy is placed at the center of the table within the child's reach. As soon as the toy was placed at the table, the experimenter gave the instruction "[Child's name], you can't touch this. Don't touch". The experimenter would then avoid looking at the child and wait until the child touched the toy. If the child did not touch the toy within 30 seconds, the experimenter would provide a verbal prompt to encourage the child to touch the toy at 30, 35, and 40 seconds. The task ended once the infant touched the toy. Toy Prohibition performance was defined as the latency (in seconds) to touch the toy, with higher scores indicating better EF performance. To assess reliability, 20% of the sessions were independently coded by two trained raters, with excellent interrater reliability (ICC = .99).

Procedure

Participants were recruited in Portuguese daycares. To be eligible for inclusion, children had to be between 9 and 13 months of age, born full-term (≥ 37 weeks of gestation), and have no known medical conditions, developmental delays, or significant birth complications. Data collection took place either at the daycare centres or in the families' homes, depending on participant availability. All procedures were conducted by trained research assistants following standardized protocols to ensure consistency across settings. Written informed consent was obtained from all participating mothers before data collection, and the study was approved by the institutional ethics committee of the [name of the University, for blind review] (Refs 125/2022 and 128/2022). During the sessions, children completed the Toy Prohibition task, which was administered while they were seated on their mothers' laps. Following the task, mothers completed a battery of questionnaires. For the games subsection of the EEFQ, parents were instructed to complete this portion at home and return it within a specified timeframe (1 week). Reminder messages were subsequently sent to encourage the completion and return of the data. All participating families received a small token of appreciation for their time and collaboration.

Data analysis

Descriptive statistics were first computed to summarize the means, standard deviations, and ranges of the main study variables. The internal consistency of the EEFQ subscales was

assessed using Cronbach's alpha. To examine the convergent validity of the EEFQ, bivariate correlations were conducted between EEFQ subscale scores (parent-report measure) and the Toy Prohibition task (behavioural measure). Additional bivariate correlations were computed to explore associations between the EEFQ subscales, the CREDI (global developmental level), and sociodemographic variables (e.g., child age and maternal age). Correction for multiple tests was done using the false discovery rate method with the Benjamini–Hochberg procedure (Benjamini & Hochberg, 1995). If not noted, the p-value reported is the corrected p-value.

Results

Descriptive statistics and internal consistency of the EEFQ

The descriptive statistics for the study variables are presented in Table 6, including the mean, standard deviation, and range. All infants scored above the cut-off point on the CREDI.

The EEFQ-IC, EEFQ-CF, and EEFQ-Regulation subscales showed acceptable to good internal consistency (α = .70, .76, and .78, respectively), whereas the EEFQ-WM subscale displayed lower reliability (α = .53).

Convergent validity

Table 7 presents the results of the bivariate correlational analyses, including between the EEFQ subscales. The three subscales, EEFQ-IC, EEFQ-CF, and EEFQ-WM, were intercorrelated, with significant positive correlations (r = .344-.509), while no association with Regulation reached significance (p > .05). Next, we examined the associations between the EEFQ subscales and the Toy Prohibition task. We found that the Toy Prohibition score was marginally positively correlated with IC (r = .283, uncorrected p = .027, corrected p = .081), but not with EEFQ-WM, EEFQ-CF, or EEFQ-Regulation subscales (all p > .05).

Associations between the EEFQ and other study variables

Finally, we examined the correlations that were computed between the child's EF (as measured by EEFQ), the child's global developmental level (as measured by CREDI), and the sociodemographic variables. The CREDI score was significantly associated with the EEFQ-CF (r = .33, p = .037) and marginally with EEFQ-WM subscales (r = .31, p = .053), but not with EEFQ-IC (r = .23, uncorrected p = .075, corrected p = 0.196). There was no association between the CREDI score and EEFQ-Regulation (p > .05). Also, no significant association was found between the CREDI score and the Toy Prohibition performance. Regarding sociodemographic variables, maternal age was, marginally, significantly correlated with the EEFQ-CF subscale (r

= -.326, uncorrected p = .010, corrected p = 0.067). Child age was strongly and significantly associated with the CREDI score (r = .695, p < .001), but not with Toy Prohibition performance or with any of the EEFQ subscales (all, p > .05).

Study 2

Method

Participants

The sample consisted of 124 children aged 9 to 24 months (M = 14.31, SD = 4.43) and their mothers, who ranged in age from 20 to 50 years (M = 34.21, SD = 5.20). The majority of the children were female (n = 68; 54.8%). A small proportion (n = 8; 6.5%) had a family history of neurodevelopmental disorders, such as ASD or ADHD. Most mothers (n = 89; 71.7%) held at least a bachelor's degree, and the majority were married (n = 105; 84.7%). Table 8 summarizes the sample characteristics.

Measures

Sociodemographic questionnaire. Mothers completed a sociodemographic questionnaire, providing information on themselves (i.e., age, education level, and marital status), as well as on their children (i.e., age and sex). Caregivers were also asked to report whether their children had a family history of neurodevelopmental disorders, specifically ASD or ADHD.

The Early Executive Functions Questionnaire (EEFQ; Hendry & Holmboe, 2021). The EEFQ is described in detail in Study 1. As in Study 1, the same criteria for data inclusion and item coding were applied. In the present study, the internal consistency values (Cronbach's α) ranged from .61 to .85, except the IC scale, which showed a lower reliability coefficient (α = .48).

The Functional Impact of Toxic Stress on Parents Questionnaire (FITS-P; Moreno et al., 2021). The FITS-P is a four-item questionnaire assessing four domains of parental toxic stress: (1) thinking ("In the last month, has it been hard to manage your thinking, such as: can't think straight, constantly distracted, replaying over and over in your mind something that makes you sad or mad?"); (2) behaviour ("In the last month, has it been hard to manage your behaviour, such as: angering too quickly at people, saying things you quickly regret, can't bring yourself to do your daily tasks?"); (3) schedule ("In the last month, has it been difficult to manage your schedule, such as: if you work, are you able to get there, are able to take care of your baby, and keep up with appointments?"); and (4) baby ("In the last month, has it been difficult to manage

your relationship with your baby, such as: feeling like you don't enjoy your baby, getting angry at them, finding it very hard to feed them or change their diaper?"). Each item is answered on a dichotomous (yes/no) scale. In the original validation study (Moreno et al., 2021), the FITS-P demonstrated adequate psychometric properties, including evidence of convergent and discriminant validity. Internal consistency, as measured by Cronbach's alpha, ranged from .57 in a clinic sample to .65 in a pilot sample (Moreno et al., 2021). Following the recommendation by Moreno and colleagues (2021), both the four individual items and the total sum score were included in the statistical analyses.

Procedure

Participants were recruited from daycares and through online parenting forums. To be eligible, children had to be between 9 and 24 months of age, born full-term (≥ 37 weeks of gestation), and without any known medical conditions or significant birth complications. After providing written informed consents, mothers completed the sociodemographic questionnaire, the EEFQ, and the FITS-P. All study procedures were approved by the institutional ethics committee of the [name of the University, for blind review] (Ref 125/2022). Participation was voluntary, and no monetary compensation was provided.

Data analysis

We explored the associations between child and family factors (children's sex, age, mother's age, maternal education, and parental toxic stress), and the child's EF, using bivariate correlations. Correction for multiple tests was done using the false discovery rate method with the Benjamini–Hochberg procedure (Benjamini & Hochberg, 1995). If not noted, the p-value reported is the corrected p-value. In the main analysis we conducted hierarchical linear regression analysis explore the potential effect of parental toxic stress on children's EF, as measured by the EEFQ, controlling for children's sex, age, and maternal education.

Results

Descriptive Statistics and Associations between Study Variables

Descriptive statistics of EEFQ subscales and FITS-P scores are presented in Table 8. Regarding parental responses on the FITS-P, 36% of parents (n = 32) reported experiencing stress affecting thinking, 30.3% (n = 27) reported stress affecting behaviour, 50.6% (n = 45) reported stress affecting schedule, and 5.6% (n = 7) reported stress related to the baby. Overall, 64 mothers

(72%) reported that stress had an impact on at least one dimension of their functioning (*M* = .31, *SD* = .27).

Bivariate correlations are presented in Table 9. The EEFQ-CF subscale was significantly and positively associated with child age (r = .380, p < .001). The EEFQ-Regulation subscale was also significantly associated with child age, although negatively (r = -.358, p < .001), and was, marginally, positively associated with maternal education (r = .181, uncorrected p = .036, corrected p = 0.129). Regarding EEFQ-Regulation subscale the FITS, EEFQ-Regulation score was negatively associated with parental stress in overall score (r = -.267, p = .047) and in the behaviour domain (r = -.327, p = .008). No other significant associations with the EEFQ subscales were observed (all p > .05).

Predictors of Early EF

Hierarchical linear regression analyses were then conducted to examine whether theoretically derived variables predicted each domain of child EF assessed with the EEFQ (see Table 10). In Block 1, child demographic variables (child sex and age) were entered; in block 2, maternal education was added; and finally, block 3, included parental toxic stress. For EEFQ-IC and EEFQ-WM, the overall regression models were not statistically significant (p > .05), i.e. no model was statistically different from a null model. The regression model for EEFQ-CF was statistically significant (F(4, 84) = 3.002, p = .023) and accounted for 8% of the variance. Only child age (β = .313, t(84) = 2.986, p = .004) emerged as a significant predictor of EEFQ-CF scores. These findings suggest that older children demonstrated higher CF scores. Finally, the EEFQ-Regulation model was also statistically significant (F(4, 83) = 6.932, p < .001), explaining 21% of the variance. Both child age (β = -.414, t(83) = -4.244, p < .001) and overall parental toxic stress (β = -.285, t(83) = -2.891, p = .005) accounted for the variance in regulation scores, indicating that younger children and those whose mothers report lower overall parental toxic stress had higher regulation scores.

Discussion

While the evidence for the critical role of EF for a child's later developmental outcomes (e.g., Holmes et al., 2016; Wilson et al., 2018; Zelazo & Carlson, 2020), relatively few studies have examined EF during the first year of life, a period when the brain is particularly susceptible to environmental influences (Fiske & Holmboe, 2019; Hendry et al., 2016; Morgan et al., 2024). This gap persists despite evidence that rudimentary EF begins to emerge around six months of

age (Fiske & Holmboe, 2019; Holmboe et al., 2018), likely reflecting the challenges of assessing EF in preverbal infants when these abilities are still immature (Hendry et al., 2016).

To address this gap, the Early Executive Functions Questionnaire (EEFQ) was developed and validated, an instrument with adequate psychometric properties (Hendry & Holmboe, 2021). However, construct validity in relation to EF performance measures was not explored. In a subsequent study, Lui et al. (2021) found that the cognitive EF subscale was associated with performance in the ECITT, but not with the Toy Prohibition task. The authors reasoned that the cognitive EF subscales of the EEFQ were designed to capture EF abilities as they are observed in everyday life, rather than in structured and controlled environments – and this would explain the absence of the association. This highlights the need for further research to evaluate its robustness across diverse cultural contexts and populations, as well as using different assessment measures.

Study 1 aimed to address this issue. We found a positive association between the IC subscale of the EEFQ and performance on the Toy Prohibition task. However, for reasons of rigor, even when the *p*-value was recalculated using Benjamini and Hochberg's (1995) correction procedure to account for the reduced sample size, we still found a trend. This is notable given that previous research has not identified a relationship between performance-based and report-based measures. These findings are consistent with the goal of the Toy Prohibition task, which was developed to measure IC abilities (Friedman et al., 2011). It also provides additional support for the EEFQ's construct validity, complementing previous evidence obtained for the cognitive EF subscale (Lui et al., 2021). Interestingly, the Toy Prohibition task has also been conceptualized as a hot EF eliciting measure, as it involves a delay-of-gratification component (Friedman et al., 2011). The hot EF construct starts with the premise that EF skills seem to vary in a continuum spectrum, in terms of motivation (Zelazo & Muller, 2002). With this, a distinction between hot and cool EF has emerged in the literature (Prencipe & Zelazo, 2005; Zelazo & Carlson, 2020). Hot EF refers to behaviours elicited in response to emotional and motivational situations, typically assessed in delay of gratification tasks, while cool EF concerns the deliberate behaviours undertaken within strictly analytic and emotionally neutral environments (Prencipe & Zelazo, 2005).

Accordingly, and in our study, an association with the Regulation subscale of the EEFQ might have been expected. However, no significant correlation emerged, possibly reflecting differences in the constructs captured by each measure. Specifically, items in the EEFQ-Regulation subscale (e.g., *"How frequently does your child get upset during a fun activity and need to be soothed?"*) are dyadically oriented and were designed to assess emotion

regulation within the caregiver–child interaction. In contrast, the Toy Prohibition task, while motivation-driven, primarily evaluates the child's ability to inhibit behaviour in an individual, non-dyadic context.

Importantly, in Study 1, most subscales demonstrated acceptable reliability, except EEFQ-WM (α = .53). This relatively low internal consistency mirrors the variability reported in the original validation study, in which the EEFQ-CF exhibited α coefficients ranging from .54 to .76 (Hendry & Holmboe, 2021), highlighting the need for further evaluation of the questionnaire's robustness across diverse cultural contexts. A similar pattern emerged in Study 2, where EEFQ-IC showed low reliability (α = .48). Despite the limited reliability of EEFQ-WM and EEFQ-IC in Studies 1 and 2, respectively, the core cognitive components of executive function—working memory, inhibitory control, and cognitive flexibility—remained interrelated, yet they were not significantly associated with the EEFQ-Regulation subscale. This distinction reflects the proposed separation between cool EF, which involves purely cognitive processes, and hot EF, which involves affective and motivational regulation (Zelazo & Carlson, 2020). Interestingly, our results appear to suggest that this differentiation is already observable, based on maternal reports, in early childhood. However, further research is needed, as it remains unclear whether the hot and cool aspects of EF are fully distinct during the first two years of life. Moriguchi and Phillips (2023) examined the hot–cool EF framework in early childhood and suggested that, although this framework is useful for understanding EF development, the boundary between the two components is not always clearly defined.

In Study 1, no significant association was found between children's age and performance on the Toy Prohibition task. Performance scores varied considerably across participants, suggesting that individual differences were not solely explained by age. This may also reflect that IC begins to emerge as early as six months (Holmboe et al., 2018), and that by the age of eight or ten months, some infants are already capable of inhibiting the impulse to touch the attractive toy (Kochanska et al., 1998). Consequently, within the current age range in Study 1 (9-13 months), some children may have already consolidated early IC skills, while others are still developing them. This variability underscores the importance of considering individual differences in early EF, beyond chronological age.

Similarly, in Study 1, children's age was not significantly associated with any of the EEFQ subscales. However, the CREDI score, reflecting children's global developmental level, was significantly associated with the EEFQ-CF and marginally with EEFQ-WM subscalesbut not with EEFQ-IC. These results align with previous research indicating that children with developmental delays (e.g., in motor or language domains) tend to exhibit greater EF difficulties

(Cunha et al., 2024; Henry et al., 2012). No association was observed with the EEFQ-Regulation subscale, likely because the short form of the CREDI does not capture emotional or regulatory functioning. Overall, these findings underscore the role of individual developmental differences in early EF, raising the question of whether factors beyond age might further influence its emergence.

Building on these findings, Study 2 examined the potential role of parental toxic stress as a contextual predictor of parent-reported EF in children aged 9 to 24 months, over and above age and other sociodemographic factors (sex, maternal education). Age was found to be associated with EEFQ-CF, consistent with prior research indicating that CF improves with age (Best & Miller, 2010). In this sample, age-related differences may be particularly salient, as rudimentary CF abilities typically begin to emerge toward the end of the second year of life (Cuevas et al., 2017). This pattern, which aligns with the findings from Study 1, may also account for the lack of age-related associations with IC or WM, as individual differences in these domains may not yet be readily observable in everyday contexts at this early developmental stage.

Interestingly, the EEFQ-Regulatory subscale was negatively associated with child age, which also emerged as a significant predictor in the regression model. This may reflect developmental changes in emotional expression and control that occur during the second year of life (Gennis et al., 2022; Ratcliff et al., 2021). As children grow, they become increasingly autonomous and assertive, which may lead caregivers to perceive them as more difficult to regulate, even as their underlying self-regulatory skills continue to develop (Kopp, 1982; Sroufe, 2005). Similarly, Hendry and Holmboe (2021) reported that EEFQ-Regulation scores were higher at 10 months, decreased thereafter, and then increased again by the end of the second year of life. Moreover, regulation at this early age is highly context-dependent and co-regulated by caregivers, meaning that variations in parental behaviour and stress may significantly influence children's regulatory expressions (Heeman et al., 2024; Mortensen et al., 2019; Planalp et al., 2024).

In line with this, EEFQ-Regulation scores were also negatively associated with parental toxic stress in the behavioural domain, with overall levels of parental toxic stress emerging as a significant predictor of children's regulatory abilities. Higher reported stress in this domain indicates that parents may experience difficulties managing their own behavior, such as becoming easily frustrated or reacting impulsively. According to current theoretical views on regulation, primary caregivers function as co-regulators, supporting children's developing capacity for self-regulation through sensitive and consistent responses (Feldman, 2007; Kopp,

1982; Sameroff, 2009; Sroufe, 2005). Consequently, when caregivers experience difficulties in managing their own stress, their capacity to support and scaffold children's emerging regulatory abilities may be compromised. Interestingly, maternal education was positively associated with EEFQ-Regulation scores and negatively associated with parenting stress in the behavioural domain. Mothers with higher education levels may experience lower stress, potentially due to greater access to knowledge, resources, and strategies (Okelo et al., 2024), which in turn may facilitate more responsive parent–child interactions and support children's regulatory development (Duyile et al., 2025).

Limitations and Directions for Future Research

Several limitations should be acknowledged. First, the cross-sectional design of these studies limits the ability to draw causal conclusions, and the relatively small sample sizes may have reduced the power to detect subtle or moderate effects. Second, children's development status was not assessed or controlled for in Study 2, which may have influenced the findings. Third, the sole reliance on parental reports in Study 2 may have limited the detection of certain associations or introduced bias into the results. For instance, it cannot be ruled out that mothers' reports of their children's regulatory difficulties were biased in the presence of higher levels of maternal toxic stress (Joyner et al., 2009). Future research could address these limitations by employing longitudinal designs to examine developmental trajectories and test causal relationships. Investigating parental responsiveness using observational measures could help clarify the mechanisms through which parental toxic stress influences early executive functioning. In addition, further validation of the EEFQ across culturally diverse samples and among children with neurodevelopmental disorders would strengthen the generalizability and clinical utility of the questionnaire.

Conclusion

The contribution of this study should be underscored, as it examined infants and toddlers using a tool specifically designed to assess executive functioning in very young children—an area that remains markedly under-researched. Although internal consistency was low for some subscales (WM in Study 1 and IC in Study 2), Study 1 provided preliminary evidence supporting the construct validity of the EEFQ, particularly for IC. Predictive models further suggested that CF is influenced by children's age, whereas regulation development is shaped by both age and parental toxic stress. These findings highlight the potential value of interventions targeting parenting stress to support young children's regulatory abilities, given

the association between stress-related parental behaviours and the development of early self-regulation.

Table 6.

Descriptive statistics for sociodemographic and main study variables in study 1.

	n	*M (SD)*	%	range	*α* (Cronbach's)
Children's age	61	10.89 (1.55)		9-13	
Mother's age	61	34.07 (4.98)		20-43	
Children's sex					
Female	31		50.8		
Male	30		49.2		
Maternal education					
9 years of education	1		1.6		
12 years of education	13		21.3		
Bachelor degree	30		49.2		
Master or PhD	17		27.9		
Marital status					
Single	3		4.9		
Married	56		91.8		
Divorced	2		3.3		
CREDI score	61	47.49 (1.23)		45.08-51.18	
Toy Prohibition score	61	5.00 (8.74)		.00-44.00	
EEFQ – IC	61	3.19 (.77)		1.29-5.13	.70
EEFQ – CF	61	2.95 (.92)		1.25-5.13	.76
EEFQ – WM	61	3.87 (.89)		1.00-5.83	.53
EEFQ – Regulation	61	4.46 (.97)		2.38-6.00	.78

Note. EEFQ = Early Executive Functions Questionnaire, IC = inhibitory control, CF = cognitive flexibility, WM = working memory.

Table 7.

Associations between Child and Family Characteristics, CREDI Score, Toy Prohibition Performance, and EEFQ Subscales in Study 1.

	1	2	3	4	5	6	7	8	9	10
1. Children's sex [a]	-									
2. Children's age	.097	-								
3. Mothers' age	.192	.171	-							
4. Maternal education [a b]	.543***	-.142	.149	-						
5. CREDI score	.129	.695***	.060	-.029	-					
6. Toy prohibition score	.125	-.100	.021	.153	-.040	-				
7. EEFQ - IC	-.059	-.070	-.046	-.082	.230	.283+	-			
8. EEFQ - CF	.000	.140	-.326+	-.100	.333*	-.103	.509***	-		
9. EEFQ - WM	-.133	-.053	-.219	-.029	.310+	-.015	.344*	.527***	-	
10. EEFQ - Regulation	-.012	-.146	.045	.007	-.114	.069	-.019	-.101	-.177	-

p-value adjustment method: Benjamini & Hochberg (1995)

Note. EEFQ = Early Executive Functions Questionnaire, IC = inhibitory control, CF = cognitive flexibility, WM = working memory;

[a] Point-biserial correlations were calculated using Pearson's coefficient for dichotomous (i.e., children's sex, and maternal education) and continuous variables; tetrachoric correlation for two dichotomous variables;

[b] Maternal education was dichotomized as "up to 12 years of education" and "higher education";

+ p < .10, * p < .05, ** p < .01, *** p < .001.

Table 8.

Descriptive statistics for sociodemographic and main study variables in study 2.

	n	*M (SD)*	%	Range	*α* (Cronbach's)
Children's age	124	14.31 (4.43)		9-24	
Mother's age	124	34.21 (5.20)		20-50	
Children's sex					
Female	68		54.8		
Male	56		45.2		
Maternal education					
9 years of education	5		4.0		
12 years of education	30		24.2		
Bachelor degree	52		41.9		
Master or PhD	37		29.8		
Marital status					
Single	15		12.1		
Married	105		84.7		
Divorced	4		3.2		
EEFQ – IC	124	3.31 (.73)		1.14-5.25	.48
EEFQ – CF	124	3.29 (.91)		1.25-5.14	.68
EEFQ – WM	124	3.96 (.96)		1.00-5.83	.61
EEFQ – Regulation	123	4.18 (1.17)		.13-6.00	.85
FITS-P Thinking	89	.36 (.48)		.00-1.00	
FITS-P Behaviour	89	.30 (.46)		.00-1.00	
FITS-P Schedule	89	.51 (.50)		.00-1.00	
FITS-P Baby	89	.08 (.27)		.00-1.00	

Note. EEFQ = Early Executive Functions Questionnaire; IC = inhibitory control, CF = cognitive flexibility, WM = working memory, FITS-P = The Functional Impact of Toxic Stress on Parents Questionnaire.

Table 9.

Associations between Child and Family Characteristics and EEFQ Subscales in Study 2.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Children's sex [a]	-												
2. Children's age	-.018	-											
3. Mothers' age	.014	.082	-										
4. Maternal education [a b]	.190	-.229*	.315**	-									
5. Overall toxic stress	.158	-.083	-.082	-.197	-								
6. FITS-P Thinking [a c d]	.259^{+}	-.109	-.100	-.158	.693***	-							
7. FITS-P Behaviour [a c d]	-.077	.108	-.178	-.454***	.684***	.568***	-						
8. FITS-P Schedule [a c d]	.123	-.193	.010	-.119	.578***	.137	.109	-					
9. FITS-P Baby [a c d]	.488***	.035	.132	-.044	.549***	.467***	.540***	.500***	-				
10. EEFQ – IC	.145	.091	.077	.030	-.015	-.077	-.129	.108	.095	-			
11. EEFQ – CF	.032	.380***	-.102	-.139	-.051	-.024	-.089	-.002	-.006	.414***	-		
12. EEFQ – WM	-.139	.085	.066	.083	-.092	-.081	-.067	.007	-.121	.331***	.429***	-	
13. EEFQ – Regulation	.022	-.358***	.068	.188^{+}	-.267*	-.211	-.327**	-.036	-.077	.041	-.168	-.062	-

p-value adjustment method: Benjamini & Hochberg (1995)

Note. EEFQ = Early Executive Functions Questionnaire; IC = inhibitory control, CF = cognitive flexibility, WM = working memory, FITS-P = The Functional Impact of Toxic Stress on Parents Questionnaire;

[a] Point-biserial correlations were calculated using Pearson's coefficient for dichotomous (i.e., children's sex, maternal education, and stress) and continuous variables; tetrachoric correlation for two dichotomous variables;

[b] Maternal education was dichotomized as "up to 12 years of education" and "higher education";

[c] Stress was dichotomized as "no reported stress" and "reported stress";

[d] Associations based on a subsample of 89 participants.

$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 10.

Predictors of EEFQ Subscales in Study 2.

	Inhibitory Control		Cognitive Flexibility		Working Memory		Regulation	
	t	B	t	β	t	β	t	β
Block 1								
(Constant)	7.438		4.503		7.858		10.784	
Children's sex	1.561	.166	.393	.040	-.565	-.061	-.152	-.015
Children's age	.863	.092	3.322	.337**	.852	.091	-4.044	-.402***
Block 2								
(Constant)	5.396		3.880		4.638		7.053	
Children's sex	1.547	.166	.470	.048	-.719	-.077	-.282	-.028
Children's age	.839	.091	3.087	.320**	1.165	.126	-3.756	-.380***
Maternal education	-.015	-.002	-.884	-.092	1.668	.181^{+}	1.177	.120
Block 3								
(Constant)	5.217		3.838		4.497		7.880	
Children's sex	1.574	.172	.553	.058	-.645	-.070	.188	.018
Children's age	.787	.087	2.986	.313**	1.109	.122	-4.244	-.414***
Maternal education	-.093	-.011	-.976	-.105	1.535	.172	.588	.059

	Inhibitory Control		Cognitive Flexibility		Working Memory		Regulation	
	t	B	t	β	t	β	t	β
Parental toxic stress	-.333	-.037	-.513	-.055	-.327	-.036	-2.891	-.285**
F	.778		3.002*		.990		6.932***	
Adjusted R^2	-.010		.083		.000		.214	

CHAPTER VII

General Discussion

Understanding early EF development and its contributing factors is crucial for informing effective early intervention. Despite their importance, the rudimentary nature of these abilities during the first years of life poses significant challenges for their assessment. The available research has focused primarily on individual factors, such as attention and brain development (e.g., Blankenship et al., 2019; Cuevas et al., 2012; Holmboe et al., 2018; Johansson et al., 2015). Therefore, the present dissertation aimed to contribute to the current state of the art by exploring the role of environmental factors, often overlooked, in early childhood EF development. For this purpose, four studies were conducted.

This dissertation was guided by Blair & Ursache's self-regulation and attachment security models. These early self-regulation abilities, strongly associated with EF in an interactional and dynamic manner, develop within the context of the caregiver-child relationship. Research on attachment has shown that young children, whose regulatory abilities are still immature, rely on their caregivers to help manage their emotional and physiological states (Ainsworth & Bell, 1974; Sroufe, 1979, 2000). When caregivers respond consistently and sensitively, children form secure attachments, ensuring that they can turn to them for comfort when in distress (Cassidy, 1994). Through these secure relationships, caregivers are serving as co-regulators, scaffolding children's self-regulatory development (Bowlby, 1979; Sroufe, 2000) and promoting their brain development (e.g., Kok et al., 2015; Sethna et al., 2017), supporting the connections between regions responsible for EF and emotion regulation (Copeland et al., 2022; Wang et al., 2019).

Attachment theory and the bidirectional model provided the theoretical support for how early mother-infant interaction could be operating in EF abilities in the first year of life (Study 1) and how maternal sensitivity and mind-mindedness in distress contexts and parental toxic stress are operating in EF in the first two years of life (Study 3 and 4).

The subsequent section provides an integrated examination of the main findings from the four studies.

Integrated review of the main findings

The first study aimed to critically review the existing evidence and theoretically explore the potential EF developmental pathways in relation to sensitivity in non-distress and distress-eliciting contexts in early childhood. This work addressed a gap in the current literature by

proposing a theoretical explanation of the influence of two contexts in which sensitive behaviours are elicited to EF, contributing to the state of the art and guiding future research. This study primarily relied on attachment theory (Bowlby, 1969/1979) to explain how children's different needs vary when they encounter different environments that may trigger a range of emotions and, therefore, parental behaviours. Furthermore, multiple questions are raised from this theoretical review, including the importance of considering multimodal behaviours when assessing parenting's influence on EF.

The second study reviewed the procedures used in administering the A-not-B task - one of the most used tasks to assess EF in early childhood (Cuevas et al., 2017) - in children up to 24 months of age. This study responds to a known issue in the literature: all the studies of the A-not-B task for assessing EF also led to numerous procedural variations, which in turn have made interpreting results and generalizing findings difficult. Particularly, this study helped clarify the changes in the procedures as children grow older in a period of development where significant changes seem to occur (Cuevas et al., 2017; Hendry et al., 2016). The findings from this study include the use of this task in a two-location reaching format to mainly assess global EF, followed by working memory, and then inhibitory control, using a fixed delay or a delay that varied according to the child's performance with no prior training; two consecutive correct trials were the criteria for switching between locations.

This second work also informed the third study, in which the A-not-B task aimed to (a) understand the potential contribution of maternal sensitivity and mind-mindedness in the non-distress and distress-eliciting contexts to overall EF development and (b) respond to a question raised in the first study: whether multimodal behaviours are contributing differently to EF in the first years, particularly in the first year of life. Maternal sensitivity in the distress context, and appropriate mind-minded comments in the non-distress context, were found to be related to EF performance in the first year of life; however, only mind-mindedness was determined to be a significant predictor of EF, supporting Meins' (2001) claim that mind-mindedness may be more influential to EF than sensitivity in the first year of life. Nonetheless, it is essential to recognize that sensitivity and mind-mindedness are complementary due to the emotional and cognitive scaffolding they provide.

The third study employed a direct measurement of children's EF using the A-not-B task. Given the value of capturing EF in a more ecological manner, it was also deemed important to consider maternal reports of children's EF. However, although direct assessment tools exist for evaluating EF in early childhood, until recently, no report-based measures had been validated for use with children younger than 24 months. The instrument most commonly employed in

research, the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000), is validated only for children aged 3 years and older. To respond to this need, the Early Executive Functions Questionnaire (EEFQ; Hendry & Holmboe, 2021) was recently developed, enabling the assessment of EF in children between 9 and 30 months, relying on parental reports. Accordingly, the goals of the fourth study included examining the questionnaire's convergent and external validity, as well as analysing the potential relationship between parental toxic stress and reported EF. Concerning the study's first objective, the inhibitory control subscale of the EEFQ demonstrated a significant association with children's performance in the Toy Prohibition task - a widely accepted measure of inhibition (Friedman et al., 2011) – thus providing evidence for the questionnaire's convergent validity. Secondly, parental toxic stress in the behaviour domain was linked to the EEFQ's regulation subscale, with overall toxic stress predicting worse scores in children's reported regulatory abilities. This dissertation's underlying regulation models conceptualize children's regulatory abilities as emerging within relational contexts, where caregivers act as co-regulators who scaffold and shape emotional and cognitive responses (Blair & Ursache, 2011; Feldman, 2007; Sameroff, 2009; Sroufe, 2005). Parenting stress can significantly influence this co-regulatory process, with high levels of stress reducing caregivers' ability to respond consistently and appropriately to their children's needs. Interestingly, when both the findings of studies 3 and 4 are taken into consideration, this interpretation becomes more evident. We found that both sensitivity in distress contexts – i.e., contexts that are typically eliciting stress to the mother-infant dyad – and parental toxic stress, particularly in the behaviour domain affecting mothers' difficulties in managing their stress and capacity to scaffold their children's regulatory abilities, seem to contribute to children's rudimentary EF abilities. In fact, according to Blair and Ursache's (2011) model, cognition and emotion are reciprocally related. If caregivers are not regulating their children's emotional distress or exhibit more parental toxic stress, with a negative impact on the behavioural dimension of their functioning, children's EF becomes impaired. Attachment theory complements this view, suggesting that children's inability to regulate and feel safe hinders their successful exploration (Weinfield et al., 1999).

Another perspective on these results relates to the well-documented role of parental stress on parenting behaviours. Specifically, prior work has shown that lower levels of parenting stress are reliably associated with increased mind-mindedness and sensitivity (Dai et al., 2019; Demers et al., 2010; Landry et al., 2008; McMahon & Meins, 2012; Pereira et al., 2012; Ward & Lee, 2020). Longitudinal evidence further clarifies these relationships. Oxford and Lee (2011), in a study that used a subsample from the NICHD Study of Early Child Care and Youth

Development data, followed children from 6 to 54 months, showing that the only predictor of maternal sensitivity at 36 months – among other variables such as low income, being a single parent, and maternal education – was parenting stress at 6 months. Similarly, Ward and Lee (2020) found that parenting stress at 15 months was related to responsiveness at 36 months. Concurrently, parenting stress and sensitivity were negatively associated at 16 months (Pereira et al., 2012). Research on mind-mindedness has found similar results, with higher parenting stress being associated with less use of appropriate mental terms when children were 15 and 18 months (Dai et al., 2019; Demers et al., 2010). Rosenblum and colleagues (2008) explain that parental mind-mindedness might be compromised by the experienced stress overwhelming their own mental states.

The distinction between the non-distress and distress-eliciting contexts of interaction present in Study 3 was intended to test the theoretical questions of Study 1 of the influence of these two contexts on EF development. The use of appropriate mind-minded comments in the non-distress context emerged as a significant predictor of children's EF over sensitivity in the distress context, providing support for Meins et al.'s (2001) proposal that mind-mindedness seems to exert a stronger influence on EF than sensitivity. This may be due to the reflective and cognitive nature of this parenting dimension when understanding children as intentional agents with their own desires, emotions, and cognitions. Furthermore, perhaps these appropriate mind-minded comments may be assisting children's EF, as caregivers may direct children's attention to their internal states, co-regulating their affect.

It is noteworthy to mention that in the third study, EF was not distinguished between hot and cool EF processes in the first year of life. Two reasons support this decision: (i) the unclear boundaries between hot and cool EF in early childhood (Moriguchi & Phillips, 2023), and (ii) the inexistence of EF tasks that assess pure cool or hot EF abilities in this period (Zelazo & Muller, 2002). For instance, in the A-not-B task, although the task carries some hot EF load, given the exposure to a task that in part could be emotionally-laden due to the desire to obtain the toy, children who can successfully perform this task can regulate their emotions to activate the cool EF processes assessed. On the other hand, some may argue that all EF tasks in this period of life may be considered as partly hot, given that the majority of these tasks involve interactions with novel people or objects. Despite this, the distinction between hot and cool EF was evident in that, across the two sub studies of Study 4, the cognitive subscales of the EEFQ (inhibitory control, cognitive flexibility, and working memory) were interrelated but showed no association with the regulatory abilities. Perhaps the fact that this study included older children up to 24 months of age may contribute to the easier distinction between these two

processes. Moreover, caregivers - being the most reliable source of information about children's development (Gioia & Isquith, 2004; Rothbart & Mauro, 1990) – may be able to provide information more accurately than direct measures during this developmental period. Evidence suggests that performance and report-based measures are not related (Toplak et al., 2013; Wei et al., 2023), with performance capturing the abilities in contexts with minimal stimuli, whereas reported EF measures may reflect how the child performs those abilities in everyday situations with competing distractors (Anderson, 2002).

Implications for assessment, intervention, and future research

The present dissertation provides multiple contributions to the study of EF development in early childhood. Firstly, by elaborating a critical review of the potential influence of two distinct contexts of interaction on the development of hot and cool EF in early childhood. This work has the potential to inform future research on early EF development and the impact of environmental factors – quite overlooked in the first years of life.

The third study examined the role of maternal sensitivity and mind-mindedness in the distress and non-distress contexts of interaction for overall EF in the first year of life. No studies to date have examined the concurrent role of such parenting behaviours in shaping EF in the first year of life, let alone the differences between distress and non-distress contexts in EF development. The fourth study made it possible to further investigate the contribution of parental toxic stress - another environmental factor strongly associated with sensitivity and mind-mindedness – to EF by drawing on parental reports during a period of life in which such reports are typically difficult to obtain due to the limited availability of appropriate measures. These findings are quite relevant, providing evidence that corroborates the assumption that interactions shaping EF operate from as early as infancy. This has important implications for intervention, suggesting that enhancing sensitivity and mind-mindedness may concurrently support the development of children's EF, a key transdiagnostic mechanism (Martel et al., 2017; McLaughlin, 2016). Some examples of relevant interventions for promoting caregivers' sensitivity and mind-mindedness are presented. The Circle of Security 8-session program (Cooper et al., 2005) provides parents with strategies to emotionally support their children, needed to develop a secure attachment. Extensive research on its effectiveness has demonstrated that this intervention is indeed enhancing attachment security (Cassidy et al., 2011; Hoffman et al., 2006). The Attachment and Biobehavioural Catch-Up 10-session intervention (ABC; Dozier et al., 2006), stemming from attachment theory, in which caregivers

of children up to 48 months of age receive in-the-moment training on three key components: nurturing behaviours, following the children's needs, and reducing caregivers' frightening behaviours toward their children. A systematic review found that the ABC improved emotion regulation and attachment quality, and reduced externalizing and internalizing behaviours (Grube & Liming, 2018). The Baby Mind app-based intervention (Larkin et al., 2019) aims to promote caregivers' mind-mindedness abilities, in which caregivers were asked to submit an update on what their infants might have been feeling or thinking during that day. The efficacy of this intervention was assessed, with the mothers who received the intervention uttering more appropriate and fewer non-attuned mind-minded terms than mothers in the control condition (Larkin et al., 2024).

The present dissertation also has important implications for assessment in that it improved on the current scarcity of measures tailored to assess EF in the first two years of life by providing evidence that supports the suitability of the A-not-B performance task and the EEFQ parent-report measures. The second study allowed for the synthesis of the A-not-B administering procedures in EF assessment in children up to 24 months, demonstrating that this task continues to be relevant for current research and is a good measure for EF assessment in the first 24 months of age; whereas the fourth study assessed the EEFQ's external and convergent validity of this measure in a sample from infants aged 9 to 13 months. Nevertheless, more research is needed to assess its robustness across diverse cultural contexts and populations.

Research into children at risk of developmental delays (e.g. preterm children) and the distinction between interaction contexts and their effect on parenting behaviours remains insufficiently explored, offering opportunities for future work. Moreover, research on hot and cool processes in early childhood is also deserving of more investigation. Understandably, this research may be scarce given the difficulties in developing performance-based measures for this purpose. Emerging tools such as the NIH Baby Toolbox (Blackwell et al., 2025; Flynn et al., 2025) may facilitate earlier measurement of hot and cool EF abilities implicated in this study. This measure is a tablet-based developmental assessment battery designed to assess multiple domains of early development, including EF in very young children (1-42 months of age).

Limitations

Despite the aforementioned contributions of this dissertation, some limitations need to be addressed. The first concerns the cross-sectional setting of the empirical studies, not allowing to infer causality. Furthermore, the modest sample size of the studies hinders the generalization of results. The non-inclusion of parental toxic stress in Study 3 due to sample size constraints is also a limitation in this dissertation, since we cannot infer whether parental toxic stress could also negatively contribute to children's EF A-not-B performance.

Another important limitation refers to the use of a sample with a wide age range, which can be considered less ideal. Specifically, in the fourth study, in which children's age varied between 9 and 24 months, significant developmental changes appear to occur (Hendry et al., 2016; Morgan et al., 2024). A useful direction for future longitudinal research would be to examine EF abilities at specific timepoints to characterize trajectories of change and identify the predictors of these developmental changes.

The present body of work focused exclusively on the maternal role in children's development. This decision was attributed to the still poorly explored differences in mothers' and fathers' interactional styles (e.g., Lovas, 2005; Planalp & Braungart-Rieker, 2013), which could have hindered the discussion of the results. Future research should explore these differences and include fathers in the assessment of parental sensitivity, mind-mindedness, and toxic stress for children's EF development.

Beyond this, important factors were not taken into consideration in the empirical studies, such as (i) attentional abilities, well-established predictors of EF (Blankenship et al., 2019; Cuevas & Bell, 2014); (ii) maternal EF, due to the high heritability of EF abilities (Kim et al., 2017; Korucu et al., 2019) and close connections with sensitive parenting (Bridgett et al., 2015; Crandall et al., 2015); (iii) children's temperament, known predictor of EF (Liu et al., 2018), and associated with maternal mind-mindedness (Demers et al., 2010), responsiveness (Putnam et al., 2002), and parenting stress (Oddi et al., 2013); and, finally, (iv) maternal psychopathology, predictive of less developed EF abilities (Gueron-Sela et al., 2018), less sensitive behaviours (Ku & Feng, 2023), and use of fewer appropriate mental terms (Bigelow et al., 2018).

Contributions

This work presents theoretical support on how environmental factors may be contributing to early EF; and evidence on the (a) EF assessment, supporting the use of the A-not-B task for the

assessment of EF in children up to 24 months of age, and on the EEFQ's convergent and external validity; (b) relationship between sensitivity and mind-mindedness and EF abilities in the first year of life and the differences between contexts of interaction; (c) predictive role of mind-mindedness on EF over sensitivity; (d) and the association of parental toxic stress – particularly in the behavioural domain – with children's regulatory abilities.

Notwithstanding, these findings don't contribute exclusively to the theoretical knowledge of early EF development but further provide important insights into the current practice. In fact, the present research emphasizes the need to consider early EF as precursors of a healthy development, supporting the notion that early assessment and identification of difficulties may inform early interventions. The malleability of EF, in particular in the first years of life (Diamond et al., 2007; Wass et al., 2012), further promotes this. Early identification of developmental issues, combined with timely intervention, offers a cost-effective strategy to improve children's outcomes while reducing governmental costs (Papazafiri, 2025), which further supports the relevance of addressing early EF, given its implications for later developmental outcomes (e.g., Mulder et al., 2017). According to the present findings, intervening in the early relational contexts seems to be useful in promoting more adjusted EF development, since maternal sensitivity, mind-mindedness, and toxic stress are implicated in EF development in young children.

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