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Advances and Challenges in the Assessment of Executive Functions in Under 36 Months: a Scoping Review

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Abstract

Objectives Neurodevelopmental disorders present deficits in executive functions (EFs). Before 36 months old, EFs act as basic abilities that allow adequate executive functioning at later ages. Three basic EFs are assessable before the child reaches 36 months old: working memory, inhibition, and cognitive flexibility. This review aims to provide an overview of the progress and difficulties in assessing these three basic executive functions before children reach 36 months old.

Methods Four databases were systematically searched without time or language limitations. The selection process was done using a PRISMA flowchart for scoping reviews. Sixteen studies were included, all in English and published between 2004 and 2021.

Results Out of 277 studies, 16 met the inclusion criteria. The general data of the studies were summarized, such as sample age, type of study, measurement features, types of EFs assessed, task names, internal structure, reliability, and main contributions. The findings on available tasks and scales, factor structure, biological and environmental factors, and the variables influencing EFs before 36 months old are described.

Conclusions Multiple factors influenced the evolution of EFs. The unidimensional model seems to better explain EFs before 36 months old. Expanding psychometric research with large samples and studying samples of children with symptoms at risk for neurodevelopmental disorders may help to improve the measurement of EFs before 36 months old.

Keywords Executive functions · Working memory · Inhibition · Cognitive flexibility · Infant · Toddlers

Executive functions (EFs) can be defined as a set of cognitive functions that control complex, goal-directed thoughts and behaviors (Zelazo, 2015), although there is no consensus on a single definition. EFs involve multiple domains developed throughout life. There are three basic EFs reported in the literature that can be measured before 36 months old: working memory (WM), inhibition, and cognitive flexibility (CF) (García-Molina et al., 2009; Hoskyn et al., 2017).

The study of EFs had an upswing in the 90s, based mainly on adult samples, and at that time, it was considered that these functions emerged at ages later than those known now (Sparrow, 2012). Current research has identified two key moments in the development of EFs: first, before 36 months old, when EFs operate as basic abilities that allow adequate executive functioning at later ages, and, second, after 36 months old, when these abilities have become coordinated with each other and with other skills (García-Molina et al., 2009). Moreover, between late infancy and early toddlerhood, EFs are not functionally silent (García-Molina et al., 2009). Studies suggest that this period may be a sensitive stage for EF development (Diamond, 2002; Zelazo et al., 2003). Furthermore, there is evidence that EFs can be improved if interventions are made at early ages, especially during periods of high relative plasticity of the prefrontal cortex (PFC) (Diamond, 2015; Zelazo, 2020).

The PFC is the brain region responsible for executive functioning. After birth, there is a stage of rapid synapse production with significant synaptic density increases in the first year of life. Subsequently, between 2 and 3 years old, peaks in synaptic density occur, and the synaptic

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pruning begins at the age of seven. Adult levels of synaptic density are reached in mid-adolescence (García-Molina et al., 2009). The developmental trajectory of synaptogenesis of PFC appears to contribute to EF abilities (Hoskyn et al., 2017). Moreover, alterations in PFC white matter have been observed in people with autism spectrum disorder (ASD) and attention deficit hyperactivity disorder (ADHD) (Ameis et al., 2016). Other conditions such as phenylketonuria, premature birth, hypothyroidism, Down syndrome, school learning difficulties, and behavioral control have also been associated with executive dysfunction (Blanco Villaseñor et al., 2010). Although the literature reports a strong association between neurodevelopmental disorders and EF difficulties, it is important to clarify that not all people with neurodevelopmental disorders have EF deficits and likewise not all people with EF deficits have a neurodevelopmental disorder.

The strong link between neurodevelopmental disorders and EF deficits has prompted research in adolescents and children (Hunter & Sparrow, 2012), but neurodevelopmental disorders before 36 months old have been difficult to diagnose as sample collection is challenging. The main problem is that the term EF is a complex construct with a wide variety of theoretical models and processes that influence the standards to assess them (Demetriou et al., 2019; Soto et al., 2020). A scoping review is highly relevant to summarize the current literature in the assessment of EFs under 36 months old.

In recent years, the study of EFs at early ages has generated some controversy. Firstly, researchers consider that the initial sightings of EFs are very poorly developed in that age range and can be considered as embryonic forms of executive functioning (García-Molina et al., 2009). Secondly, it is a concept that is difficult to define and measure (Blair et al., 2005). Until the 2000s, from a neuropsychological point of view, it was considered that adequate models with predictive capacity were not available. Therefore, the description and conceptualization process for EFs was previously based on theories and assumptions that hindered their objective conception (Tirapu-Ustárroz et al., 2002).

Currently, some models have been developed to explain the importance of EFs at these early ages for later development (Garon et al., 2008; Rose et al., 2012). One of the most reported EF models is the unity and diversity model (Miyake et al., 2000) which determined three moderately correlated, but separable EFs, namely, WM, inhibition, and CF. The unity and diversity model has been used mainly in adult samples, while in children samples and adolescents, studies suggest greater unidimensionality of EFs (Karr et al., 2018). In addition, some studies showed a better fit with a bidimensional structure (Scionti & Marzocchi, 2021).

This review focuses on these three basic EFs (WM, inhibition, and CF), which emerge and develop at different times and range even before the age of 36 months old (Garon et al., 2008). WM is understood as the ability to store and manipulate information for a short period, which allows updating and replacing irrelevant information, that is, the capacity to cognitively retain information that is no longer directly perceived to manage it in some way for a specific purpose (Demetriou et al., 2019). The WM emerges between 7 and 12 months old, and usually, the task to assess it considers both the child's response time when looking at an object in one place and the ability to maintain attention on the object (even when not seeing it) (Díaz & Guevara, 2016). Inhibitory control is defined as the ability to control attention, behaviors, thoughts, and emotions to provide a specific response. It also requires the child to suppress external stimuli that could distract him from the objective (Díaz & Guevara, 2016). Simple forms of inhibitory control emerge around the middle of the first year (García-Molina et al., 2009). The theoretical perspective of EFs is not the only one that explains inhibitory control. The temperament approach focuses mainly on socio-emotional development and also shows inhibition behaviors. As a consequence, EFs and temperament have a large amount of empirical evidence suggesting a strong relationship between them (Gagne et al., 2021; Rocha et al., 2019). Finally, CF is defined as the ability to switch the perspective given to a problem to adapt to new demands, rules, or priorities (Díaz & Guevara, 2016). At 24 months old, there is a significant increase in the ability to perform switching tasks through verbal instructions (Deák, 2004).

The literature reports several different tasks to assess these three basic EFs at early ages, but due to their validity and reliability, some of them have been used more frequently. For example, to measure WM, the two frequently reported tasks are spin-the-pots and hide-and-seek tasks (Bernier et al., 2010; Hughes & Ensor, 2005). One task used to assess inhibition is the prohibition task. It consists of measuring the time in which the child manages to control the impulse to take a prohibited object. This task has been used on children as young as 14 months old (McHarg et al., 2020). Regarding CF, various tasks have been used for its assessment at such early ages (Johansson et al., 2014; McHarg et al., 2020). The most relevant is the A-not-B task, which is related to object permanence development (Piaget, 1954). The task involves hiding an object under a location "A" within the infant's reach and then allowing the infant to search for the object, repeating this several times to ensure that the infant can find the object successfully. Afterward, the object is moved to a location "B" that is also within easy reach for the infant. This task assesses the ability to find the object in a new location. In different studies, adaptations of this task contemplate resistance to delay, which implies that examiners are controlling when the infant can search for the object. The A-not-B task has shown consistency with electroencephalographic data, functioning as a valid indicator of early cognitive processing of the frontal lobe from 8 months onwards (Bell, 2012). In this task, resistance to delay increases with age; that is, at early ages, the child may show executive functioning responses, as long as the time of delay is appropriate for the infant's age. As the children grow, they can manipulate and transform this information (between 15 and 30 months old). For example, before 36 months old, children depend on stimuli from the environment, and their responses tend to be stereotyped, rigid, and oriented to the present (García-Molina et al., 2009).

Currently, few existing tests assess EFs at early ages. The most popular test is the Behavior Rating Inventory of Executive Function-Preschool Version (BRIEF-P). It is a specific EF test that includes an assessment of inhibition, flexibility, emotional control, WM, and planning and organization. The BRIEF-P generates four indices (global, inhibitory self-control, flexibility, and emergent metacognition) and two validity scales (inconsistency and negativity). It is applied to children ranging from 2 years old up to 5 years and 11 months old. This test is an indirect measure based on the child's behavior and answered by the parents or caregivers and teacher. It takes 10 to 15 min to complete. The first BRIEF-P version was in English (Gioia et al., 2000). A Spanish version is available, with scales for the Spanish, Argentine, and Mexican populations (the last only includes 3 to 5 years age group). Additionally, the BRIEF-P also has versions in Catalan and Euskera (Gioia et al., 2016).

Another commonly used test is the Stanford-Binet Intelligence Scale, fifth edition. The test is in English and has scales in the US population (Roid & Pomplun, 2012). Although it is an intelligence test, some subtests can be used to measure EFs, specifically for verbal and non-verbal WM factors (Hoskyn et al., 2017). A battery with three EF tasks (WM, inhibition, and CF) was created by Garon et al. (2014) and applied to children aged 18 months and 5 years old. These authors assessed WM for holding-in-mind and updating-in-mind, CF for positive and negative change task sets, and inhibition for simple and complex behaviors.

Understanding executive functioning at an early age is difficult due to the diversity of variables that influence its development. Additionally, biological and environmental factors are associated with the correct performance of EFs (Hughes & Devine, 2019; Jirout et al., 2019; Ronan et al., 2020). These factors complicate the measurement of EFs and the adequate construction of tests to assess them at an early age. This review also includes results related to variables that interfere with the development and measurement of EFs in children under 36 months old.

The present study offers a scoping review of the literature providing an overview of the progress and difficulties in assessing the three basic EFs (WM, CF, and inhibitory control) in infants younger than 36 months old. The little scarce information existing in the field of assessment and the limited studies attempting to assess and generate tangible measurements of EFs at early ages (Wiebe et al., 2010), as well as the difficulty of establishing a specific assessment method at these ages (questionnaire for parents and teachers, specific tasks, etc.), make necessary detailed and methodical research to provide reliable and evidence-based techniques allowing for the correct identification of difficulties in the EFs before 36 months old.

Method

The present scoping review was conducted following the five-stage process proposed by Arksey and O'Malley (2005). Each stage is described below.

Stage 1. Identifying the research question: The present study aims to answer two questions: What advances have been reported for the evaluation of the three basic EFs in children under 36 months old? And likewise, what challenges have been reported for this age range?

Stage 2. Identifying relevant studies: The search was carried out in the PubMed, Scopus, and Web of Science databases, as well as the digital library of the Autonomous University of Barcelona. The search terms used were development, infant, executive functions, working memory, inhibition or inhibitory control, and shifting or cognitive flexibility. The search commands for each database are shown in Table 1.

Stage 3. Study selection: Original full-text studies were included without date or language limits. Research, with assessment by cross-sectional and longitudinal studies of basic EFs (WM, inhibition, and CF) before 36 months old in a population with typical development, was considered. Additionally, reviewed literature included ADHD, ASD, or other risk factors such as premature birth but without any other underlying pathology. Systematic reviews, conference abstracts, and thesis dissertations were excluded. The selection of the studies was carried out in three phases: (1) The title and abstract of the studies were examined, (2) studies selected for full-text review were independently assessed, and (3) the reviewers met to reach a consensus on the included studies. The considered exclusion criteria were for duplicate studies, age samples (over 36 months old), type of study, and measurement features. Reasons for exclusion were based on the assessment of EFs after 36 months (despite other variables being assessed before 36 months old), samples with an underlying pathology, and assessments that consider temperament instead of EFs (due to the strong relationship with inhibition). The selection process is shown in Fig. 1 through a PRISMA flowchart for scoping reviews.

Table 1 Commands used for the search in each database

Database	Commands
PubMed	((((development) AND (infant)) AND (executive function) AND (working memory)) AND (inhibition OR inhibitory control)) AND (shifting OR cognitive flexibility)
Web of Science	TS=((((Development and infant) and working memory) and inhibition) and shifting)
	TS=((((Development and infant) and working memory) and inhibitory control) and shifting)
	TS=((((Development and infant) and working memory) and inhibitory control) and cognitive flexibility)
	TS=((((Development and infant) and working memory) and inhibition) and cognitive flexibility)
Scopus	TITLE-ABS-KEY ((((development AND infant) AND "working memory") AND inhibition) AND shifting)
	TITLE-ABS-KEY ((((development AND infant) AND "working memory") AND "inhibitory control") AND shifting)
	TITLE-ABS-KEY ((((development AND infant) AND "working memory") AND "inhibitory control") AND "cognitive flexibility")
	TITLE-ABS-KEY ((((development AND infant) AND "working memory") AND inhibition) AND "cognitive flexibility")
Other resources	((((development AND infant) AND "working memory") AND inhibition) AND shifting)
	((((development AND infant) AND "working memory") AND "inhibitory control") AND shifting)
	((((development AND infant) AND "working memory") AND "inhibitory control") AND "cognitive flexibility")
	((((development AND infant) AND "working memory") AND inhibition) AND "cognitive flexibility")

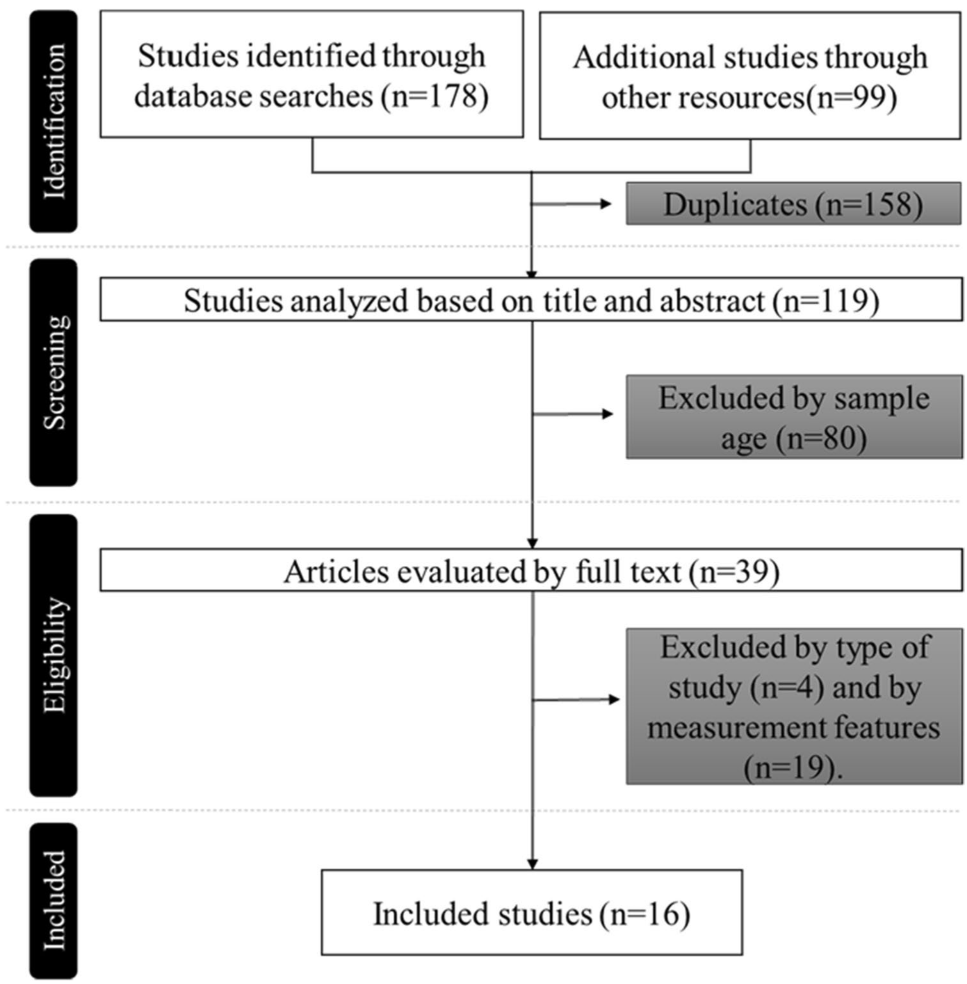

Fig. 1 PRISMA-ScR flowchart

Stage 4. Charting the data: The data are presented in tables, all revised and organized in consensus by two reviewers. General information about the studies is included (e.g., authors, year, ages of participants, type of EFs, task names, main results, factor analysis, and reliability). The results were summarized in four relevant topics to show the advances and challenges of measuring EFs before 36 months old.

Stage 5. Collecting, summarizing, and reporting the results: The findings are shown in Tables 2 and 3. All the 16 studies included were published between 2004 and 2021 in psychology, development, and childhood journals. Ten studies were cross-sectional, six were longitudinal, and all were published in English. The samples came mostly from a typical development population, one from a population with ASD, one from institutionalized children, and one from bilingual children. Subsequently, the analysis of the results regarding the advances and challenges in the assessment of EFs under 36 months old was divided into four topics: (1) available tasks and scales, (2) the unidimensional model of EFs, (3) variables related to EF measurement, and (4) biological and environmental factors related to EF development.

Results

The search identified 277 studies (Fig. 1), of which 261 were excluded. Hence, only 16 studies that assessed basic EFs under 36 months old were considered (see Tables 2 and 3). Studies include diverse samples of children, such as those born premature or extremely premature, post-institutionalized, infants with ASD, bilingual, monolingual, and typically developing. Other studies included samples consisting of the mother-child dyad or the whole family. The sample's ages range from 5 to 74 months old, although only findings in children younger than 36 months old were considered for this review.

Four topics describe the most relevant findings. The first explains the WM, inhibition, and CF tasks, as well as the two scales reported in the studies. The second addresses evidence suggesting that the unidimensional model can explain better all three basic EFs at these early ages. The third topic details the variables that may influence the measurement of the basic EFs. The last topic summarizes the findings of the variables that demonstrated an influence on the development of the EFs, to understand the complexity of measuring EFs at early ages.

Available Tasks and Scales

For this first topic, sixty-six tasks were examined from the 16 reviewed studies, some of which consisted of an adaptation of tasks described in other studies (see Table 2). Some tasks were assessed as composite scores (including the three basic EFs) and classified under different names (e.g., conflict tasks or cognitive executive function). Table 2 includes all this information organized by authors, type of EFs, task's name including a citation of the study from which the task was obtained, and assessment ages. The following subsection describes the task features for each EF (i.e., WM, inhibition, and CF). Also, a battery and a questionnaire extracted from the literature are described in this review.

Working Memory Tasks

The WM tasks applied at earlier ages were two: hide the pots (or similar names) and hide and seek. These tasks were applied up to the age of 18 months (Garon et al., 2014; Treat et al., 2019), and both tasks required the child to find a toy under or behind some other object. The tools for hiding the toy may be different, but the goal (finding an object) is always the same. For example, a piece of fabric covers the toy for a waiting time (determined by the examiner) making it more complex to find the toy. As in most assessments, several practice trials are performed to proceed with the test. A score is obtained by counting the child's mistakes.

Three studies used the spin-the-pots task, with a similar goal to hide the pots but with more pots and at older ages (Pozzetti et al., 2014; Treat et al., 2019). The task was applied with eight or more pots for children aged 28 months or older. Pozzetti et al. (2014) created an easier version using six pots for younger infants (< 24 months old). Another similar task is the three-box task that was applied by McHarg et al. (2020) for 14-month-old children. These tasks require placing several visually distinct containers on one tray. The examiner invites the child to place objects under the pots in a manner that left two pots empty. A piece of fabric is placed to cover the tray, and the tray is then rotated. Subsequently, the tray is uncovered, and the child is asked to choose one of the pots that contain an object. This is performed until the child finds a given number of objects or fails a maximum number of spins. The way of scoring differs among researchers: Some count errors and perseverations and others only whether or not the child achieves what is expected as a dichotomous measure.

Other tasks described in the reviewed studies were multi-location task, find the toy, multi-location multi-step, delayed alternation, six boxes, and visual attention. Nevertheless, its procedures and goals are similar to the tasks described above. Furthermore, studies revealed that performance on WM tasks improves with age.

Inhibition Tasks

To assess inhibition, tasks were identified in which the children are required to wait for a reward after a delay (inhibiting

Table 2 Executive functions, tasks, and assessment ages by study

Authors	EF	Task's name	Sample
Espy et al. (2004)	In	Delayed response (Jacobson, Wolfe & Jackson 1935)	*n* = 66 TD and 30 PT children 24 to 60 months old
	WM	Delayed alternation (Espy, Kaufmann, McDiarmid et al., 1999)	
	CF	Spatial reversal (Kaufmann, Leckman & Ort, 1989)	
	CF	Spatial reversal with irrelevant color cues (Kaufmann, Leckman & Ort, 1989)	
	WM	Six boxes (Diamond et al., 1997)	
	WM	Visual attention (NEPSY-A, Korkman et al., 1998)	
	In	Children continuous performance task (C-CPT) (Kerns & Rondeau 1998)	
	In	Statue (NEPSY subtest, Korkman et al., 1998)	
	In	Self-control (Lee, Vaughn, & Kopp, 1983)	
Bernier et al. (2010)	CT	Hide the pots (adapted from Hughes and Ensor (2005))	*n* = 80 mother-infant dyads 18 to 26 months old
	CT	Categorization (adapted from Carlson et al. (2004))	
	CT	Spin the pots (Hughes & Ensor, 2005).	
	IC	Delay of gratification (Kochanska et al., 2000).	
	CT	Shape Stroop (Kochanska et al., 2000).	
	CT	Baby Stroop (adapted from Hughes & Ensor, 2005).	
Matte-Gagné and Bernier (2011).	CT	Spin the pots (Hughes & Ensor, 2005)	*n* = 53 mother-infant dyads 24 to 36 months old
	IC	Delay of gratification (Kochanska et al., 2000)	
	CT	Shape Stroop (Kochanska et al., 2000)	
	CT	Baby Stroop (adapted from Hughes and Ensor (2005))	
	CT	Day/night (Gerstad et al., 1994)	
	CT	Dimensional change card sort (DCCS) (Zelazo, 2006)	
	CT	Bear/dragon (Reed et al., 1984)	
Bernier et al. (2012)	CT	Spin the pots (Hughes & Ensor, 2005)	*n* = 62 families 24 to 36 months old
	IC	Delay of gratification (Kochanska et al., 2000)	
	CT	Shape Stroop (Kochanska et al., 2000)	
	CT	Baby Stroop (adapted from Hughes and Ensor (2005))	
	CT	Bear/dragon (Reed, Pien & Rothbart, 1984)	
	CT	Day/night (Gerstad, Hong & Diamond, 1994)	
	CT	Dimensional change card sort (DCCS) (Zelazo, 2006)	
	IC	Delay-of-gratification task (Kochanska et al., 2000)	
Hostinar et al. (2012)	CF	Dimensional change card sort (DCCS) (Zelazo, 2006)	*n* = 60 PI children and 30 NA 28 to 48 months old
	WM	Spin the pots (Hughes & Ensor, 2005)	
	In	Delay of gratification (Mischel, Shoda & Rodriguez, 1989)	
Cuevas and Bell (2014)	CS	A-not-B with invisible displacement (Morash & Bell, 2011)	*n* = 201 children 24, 36, and 48 months old
		Tongue task (Kochanska, Murray, & Harlan, 2000; Wolfe & Bell, 2007)	
		Day/night (Gerstadt, Hong, & Diamond, 1994)	
		Simon says (Carlson, Moses, & Breton, 2002; detailed in Wolfe & Bell (2007))	
		Dimensional change card sort (DCCS) (Zelazo, Frye, & Rapus, 1996)	
		Visual search (Espy & Bull, 2005; Korkman, Kirk, & Kemp, 1998)	
Garon et al. (2014)	WM	Hide and seek (created by the authors Garon et al. (2014))	*n* = 261 children 18-67 months old
	In	Tricky box (created by the authors Garon et al. (2014))	
	CF	Flap book (created by the authors Garon et al. (2014))	
Johansson et al. (2014)	CF	A-not-B task (Piaget, 1954)	*n* = 40 infants 10 months old

Table 2 (continued)

Authors	EF	Task's name	Sample
Pozzetti et al. (2014)	WM	Spin the pots (Hughes & Ensor, 2005)	*n* = 72 EPT and 73 FT children 24 months old
	In	Snack delay (Kochanska et al., 1996; Kochanska et al., 2000)	
	CF	Reverse categorization (adapted from Carlson et al. (2004))	
	CS	Multi-location multi-step (modified A-not-B task by Zelazo et al. (1998))	
Crivello et al. (2016)	CF	Reverse categorization task (Carlson, 2005; adapted from Carlson et al., 2004)	*n* = 49 BL and 43 ML children 31 months old
	In	Shape Stroop task (Carlson, 2005; adapted from Kochanska et al., 2000)	
	In	Gift delay task (Carlson, 2005; adapted from Kochanska et al. (2000))	
	WM	Multi-location task (Carlson, 2005; adapted from Zelazo et al. (1998))	
Marcovitch et al. (2016)	CF	Looking A-not-B task (Cuevas & Bell, 2017; scoring procedure based on Bell & Adams (1999))	*n* = 390 5 months old infants
Pauen and Bechtel-Kuehne (2016)	CF	Shape and color sort (adapted version of the DCCS of Zelazo (2006))	*n* = 93 children study 1 *n* = 62 children study 2 22 to 24 months old
	In	Forbidden cookie (inspired by the snack delay task by Kochanska et al. (2012))	
	WM	Find the toy (adaptation of the hide-the-pots task by Bernier et al. (2010) and Hughes and Ensor (2005))	
Garon et al. (2018).	WM	Hide and seek (Garon et al., 2014)	*n* = 34 children with ASD and 255 TD 18 to 74 months old
	In	Tricky box (Garon et al., 2014)	
	CF	Flap book (Garon et al., 2014)	
Treat et al. (2019)	WM	Hide-the-pots task (adapted by Bernier et al. (2010); from Hughes and Ensor (2005))	*n* = 55 mother-child dyads 18 to 40 months old
	WM	Spin-the-pots task (Bernier et al., 2010; Hughes & Ensor, 2005)	
	CF	Categorization task (adapted from Carlson et al. (2004) by Bernier et al. (2010))	
	CF	Reverse categorization task (Carlson, 2005)	
	In	Delay-of-gratification task (Kochanska et al., 2000)	
McHarg et al. (2020)	In	Prohibition task (Friedman, Miyake, Robinson, & Hewitt, 2011)	*n* = 416 FB infants 14 months old
	WM	Three boxes task (Miller & Marcovitch, 2015)	
	CF	The ball run task (based on the trucks task developed by Hughes and Ensor (2005))	
Hendry and Holmboe (2021)	CS and regulation	Early Executive Functions Questionnaire (EEFQ) 31 items	*n* = 486 children 8–30 months old

All references in the table are cited in the reviewed studies

WM working memory, *In* inhibition, *CF* cognitive flexibility, *CT* conflict tasks, *CS* composite score (including WM, In, CF), *IC* impulsive control, *TD* typical development, *PT* preterm, *PI* post-institutionalized, *NA* not adopted, *EPT* extremely preterm, *FT* full term, *BL* bilingual, *ML* monolingual, *ASD* autism spectrum disorder, *FB* firstborn

their behavior) or to inhibit a distracting stimulus to follow instructions correctly. The tasks in which the child was required to expect a reward after a delay were gift delay task, delay-of-gratification task, forbidden cookie, snack delay, delayed response, prohibition task, and self-control tasks. Basically, in these tasks, the children are offered a food or object that they like and are instructed to wait before giving it to them. In some studies, the child is asked to wait for a bell to ring, for the examiner to return, or for permission to take the object. As a quantifying assessment, the time the child can control the behavior is measured (Crivello et al., 2016; Treat et al., 2019). An alternative inhibition task, the statue task (Espy et al., 2004), also aims for the child to achieve control of a prohibited behavior (e.g., moving) but

Table 3 Factor analysis, internal structure and reliability, other variables, and main results by study

Authors	Internal structure and reliability	Other variables included	Main results
Espy et al. (2004)	Three factors were extracted that explain 60.82% of the variance, (1) WM explained 26.59%, (2) inhibitory control 19.39%, and (3) CF 14.84% of the variance. Reliability was not reported.	Emerging mathematical abilities and intellectual ability	WM and inhibitory control predict early arithmetic competence (controlling for child age, maternal education, and the child's vocabulary). Inhibitory control contributed to preschool math skills, even removing the influence of WM and In.
Bernier et al. (2010)	Two factors were obtained that explain 64.7% of the variance; (1) impulse control and (2) conflict EFs. Two averaged standardized scores were calculated. Reliability was not reported.	Maternal sensitivity, maternal mind-mindedness, maternal autonomy support, and general cognitive ability	Maternal sensitivity, mind-mindedness, and autonomy support were related to the child's EFs. Autonomy support was the strongest predictor at each age, independently of general cognitive ability and maternal education. Parent-child relationship influences the development of self-regulatory abilities in the child.
Matte-Gagné and Bernier (2011)	Two factors were obtained that explain a total of 61.7% of the variance; the factors are (1) impulse control and (2) conflict EFs. Low reliability on all tasks was obtained.	Maternal autonomy support and child's expressive vocabulary	Maternal autonomy support was related to the child's expressive vocabulary, conflict EF, and impulse control. The child's language mediated the association between maternal autonomy support and child impulse control, but that was not the case with conflict EFs.
Bernier et al. (2012)	Two factors were extracted that explain a total of 64.8% of the variance, these factors are (1) conflict EFs and (2) impulse control. Reliability was not reported.	Maternal: responsiveness, mind-mindedness, and autonomy support. Quality of parent-child interactions. Children: secure attachment and receptive verbal ability	Parent behavior composite score and child attachment are related to child performance on conflict EF tasks. The child's secure attachment is related to conflict EFs at 3 years old. The child's verbal abilities, previous EFs, socioeconomic status, and parental behavior suggest that secure attachment influences the development of executive control.
Hostinar et al. (2012)	A single common factor was identified that explained 70.8% of the variance. The tasks were highly correlated. The three measures were merged into one composite EF score. Reliability was not reported.	IQ, pre-adoptive experiences, and the institution's physical and social features	IQ was negatively correlated with the length of institutional care. The adopted sample obtained an association between EFs and measures of early deprivation controlling IQ (less time spent in the biological family before placement in an institution and lower quality of physical/social care in institutions), suggesting that this predicts a poorer performance on EFs.
Cuevas and Bell (2014)	One component in 24, 36, and 48 months old (explained 55%, 50%, and 45% of the variance respectively). A composite *z*-score was obtained that explained 45%. Cronbach's interrater reliability in all tasks is more than .90.	Care at 5 months. Verbal ability	Short lookers show higher EF composite scores in comparison with long lookers, even after controlling for verbal ability. Attention style at 5 months old is related to EF scores from 24 to 48 months old.
Garon et al. (2014)	WM, CF, and In obtained 2 factors each and explained 39.09%, 42.69%, and 53.65% of the variance respectively. Reliability was .70 to .93 in all tasks.	Cognitive ability	All EF measures correlated positively with age in months and mental age, showing sensitivity to age differences.

Table 3 (continued)

Authors	Internal structure and reliability	Other variables included	Main results
Johansson et al. (2014)	Factorial analysis and reliability are not reported. Agreement with Cohen's Kappa between coders was .86 and .81 in both reaching and looking responses, respectively.	Temperamental measures: activity level and attention	10-month-olds show individual differences in A-not-B task performance, reflecting variation in temperamental activity level, and maturity of short-term/WM, In, and CF. It also concludes that looking response may be less cognitively demanding than reaching response.
Pozzetti et al. (2014)	Three final factors are extracted: CF, In, and WM explained 19.18%, 16.92%, and 15.76% of the variance respectively. All tasks show limited psychometric validity and reliability.	Cognitive ability and psychomotor function. Questionnaire for parents and medical records	Provided a broad assessment of 3 basic EFs. Preterm infants without significant brain injuries showed some weaknesses in CF compared to controls. CF in preschool ages could be a precursor of deficit in these EFs in older ages. WM did not show differences.
Crivello et al. (2016)	There is no report on factorial analysis or reliability.	Exposure to language (BL and ML). TE and expressive vocabulary	BL children showed advantages in inhibitory control. TE predicts better performance in conflict tasks but not in delay tasks. The authors confirm the relationship between EFs and early bilingualism.
Marcovitch et al. (2016)	There is no report on the factorial analysis. Cronbach's interrater reliability in looking A-not-B task is .99.	Attention (short and long lookers). Percentage of time attending to the puppet and the peak fixation time	Attention is related to emerging object permanence and cognitive flexibility at 5 months old. Children of mothers with less education and shorter peak fixation time have higher object permanence and cognitive flexibility skills.
Pauen and Bechtel-Kuehne (2016)	There is no report on the factorial analysis. Based on previous studies that refer to each task as a component. Interrater agreement with ICC = .96.	Use of tools	From 18 to 24 months old, means-ends involving tools are learned by observing others. Training performance, focusing on tool-relevant information, and the ability to profit from positive feedback improve with age. Set switching and In were associated with better spontaneous transfer performance and less fixation on perceptually salient but functionally irrelevant tool features. WM helps to update information, allowing a faster adaptation of tool choices based on the feedback information.
Garon et al. (2018)	Explained by Garon et al. (2014). All tasks: internal reliability for tasks ranging from .71 to .93	Cognitive ability	Lower scores in 3 basic EFs in children with ASD, showing the moderation of mental and chronological age. It is important to measure simple EFs in very young children with ASD.
Treat et al. (2019)	There is no report on factorial analysis or reliability.	Parental traumatic experiences and harsh parental attitudes	A higher level of the parent's adverse childhood experiences predicts a lower WM performance in their children. Harsh parenting attitudes predict lower inhibitory control in children and are negatively associated with lower CF.

Table 3 (continued)

Authors	Internal structure and reliability	Other variables included	Main results
McHarg et al. (2020)	Two factors are reported: WM and CF. No latent factor was estimated for inhibition. High and perfect interrater reliability in the tasks.	Screen exposure time	Screen exposure at 4 months old appears to be negatively associated with inhibition at 10 months old (above first levels of attention and individual differences in temperament).
Hendry and Holmboe (2021)	A factor called "cognitive executive function" (CEF) explained 36% of the variance and included the In, CF, and WM tasks. The regulation was included since it is of theoretical interest but the EFA scores showed vulnerability to measurement error. Cronbach's alpha for CEF and regulation was in the range of .751 to .876.	Attention focusing and attention shifting	The EEFQ provides a reliable measure for EFs in children of ages ranging from 9 to 30 months old, it has adequate statistical validation processes and is sensitive to age-related changes.

WM working memory, *In* inhibition, *CF* cognitive flexibility, *CF* conflict tasks, *CS* composite score (including WM, In, CF), *IC* impulsive control, *TE* translation equivalents, *ICC* intraclass correlation

includes the interaction of the examiner. This consists of the children standing up and pretending to hold a flag in their hands for 75 s. Every 5 s, the examiner attempts to distract the child by recording any body movement of the child (e.g., eye opening or vocalization). The score is recorded in intervals. Two points are scored per error-free interval: one point if one error is made and zero if two or more errors are made.

The tasks shape Stroop task, children's continuous performance task (C-CPT), and tricky-box task (Crivello et al., 2016; Espy et al., 2004) had a more complex goal, requiring the child to inhibit a distractor stimulus to achieve an instruction. The shape Stroop task consists of two phases: In the first phase (identification phase), the examiner introduces to the child three pictures with large fruits (i.e., apple, banana, and orange) and three pictures with the same fruits but smaller and placed below the large ones. Afterward, the small fruits are removed, and the children are asked to point to each fruit by telling the name and size, and feedback is given when they do it correctly. In the second phase (Stroop phase), the small pictures are placed below the large pictures but without matching them, and again, the child is asked to point to each fruit by telling the name and size; however, no feedback is given in this phase. The number of attempts to identify the small fruits in this Stroop phase is recorded. Regarding the C-CPT task, this is a computerized task in which the child is presented with images and sounds of several animals for 3 min. The sound of the animal should not match the image. After a familiarization phase, the child is instructed to press the button only when the animal (e.g., sheep) is visually presented, regardless of the sound it makes. Commission errors are scored, as they better measure poor modulation of response inhibition. For the tricky-box task, two identical but different-colored boxes are used. Each box has two red levers at the top and two transparent doors at the bottom. Behind the doors, there is a hidden toy. In one of the boxes, each lever lifts the door just below it. In the other box (conflicting), each lever lifted the opposite door. The above three tasks respond to a more complex inhibitory control.

Cognitive Flexibility Tasks

A commonly used task for assessing EFs at early ages is the A-not-B task, which is often used to assess the rudimentary form of CF. The search pattern necessary for this task develops from 5 months old in its simplest form and is more complex at 7 or 8 months old. A study with a sample of 10-month-old children allows differentiation of A-not-B responses in reaching and looking modalities (Johansson et al., 2014). The reaching response refers to when the child's first response is to touch one of the presented screens. The looking response refers to the first look toward one of the screens for at least three frames (> 100 ms). This study supports that the looking modality in the A-not-B task is less cognitively demanding than the reaching modality. In the same context, Marcovitch et al. (2016) applied the A-not-B task to 5-month-old children; however, a limitation emerged as the A-not-B task could be inadequate for this age because the rule to stop the activity might be too strict. Hence, it might be more appropriate to measure object permanence and not CF at the age of 5 months old. The authors concluded that more research should be carried out considering recent studies on EFs for this age group and their relationship with other skills, such as language.

In addition to the A-not-B task, CF was assessed with tasks that require classification, such as the categorization task, the reverse categorization task, the DCCS scale, and shape and color sort (Pauen & Bechtel-Kuehne, 2016; Treat et al., 2019). These tasks have multiple procedures, depending on the child's age. The simplest is when the child must sort toys according to some feature (e.g., size) into the appropriate pot. A more complex version requires children to sort toys in the opposite pot. Sorting can also be done by asking the child to select and sort specific cards (e.g., stars and trucks) among many different cards. The most complicated is to sort items by color and shape. The simplest version of this task was applied to children up to 17 months old, and the most complex was up to 24 months old. However, as in the previous EF measures, performance on these tasks improves with age.

Other tasks such as ball run task, flap book, spatial reversal, and spatial reversal with irrelevant color cues were applied to assess CF. However, the most relevant are those mentioned above.

Battery and Questionnaire to Assess EFs

Garon et al. (2014) developed a battery, which assesses WM, inhibition, and CF in pre-schoolers. They applied the battery to a sample of 261 children ranging from 18 to 67 months old. Authors showed that all EF measures were positively correlated with chronological and mental age. Moreover, the test was shown to be sensitive to age differences between 18 and 67 months old. Additionally, it was observed that developmental evolution was not the same among the three basic EFs. The factor structure of the three basic EFs resulted in two factors for each one; for WM, the factors were holding-in-mind and updating-in-mind. Regarding CF, the factors were task set and task switch. Finally, for inhibition, the factors were simple and complex inhibition. Reliability ranged from .70 to .93 in all tasks. The authors concluded that the early development of simple EFs (e.g., holding-in-mind, task set, and simple inhibition) is faster during the preschool stage and decelerates with age. Complex inhibition and CF task shift showed slight acceleration as age increases, while WM holding-in-mind shows deceleration. Therefore it seems that WM updating-in-mind exhibits a more gradual development than inhibition and CF.

The Early Executive Function Questionnaire (EEFQ) aimed to assess EF in children aged between 9 and 30 months old (Hendry & Holmboe, 2021). The exploratory factor analysis (EFA) and the confirmatory factor analysis (CFA) identified one factor for cognitive EFs with adequate psychometric properties which included the three basic EFs (WM, In, and CF). They called the factor "cognitive executive function" (CEF). Additionally, Cronbach's alpha for CEF was .751. Authors studied regulation as another factor because it was theoretically important but did not obtain sufficient statistical support.

It is important to note that none of the selected studies in this contribution used BRIEF-P or Stanford Binet-5 to assess EFs; therefore, they were not described in this section. However, the usefulness of both tests to assess EFs from 24 months of life should be emphasized.

The Unidimensional Model of EFs

The factor structure most reported in the review responds to the unidimensional model, in which WM, inhibition, and CF constitute the common components of EFs. This common score has been referred to as conflict EFs (Bernier et al., 2012; Matte-Gagné & Bernier, 2011), composite score (Cuevas & Bell, 2014; Hostinar et al., 2012), or cognitive executive function (Hendry & Holmboe, 2021). Table 3 shows the results related to internal structure and reliability (when reported in the study), as well as other variables analyzed and the main findings of each study.

Garon et al. (2014) demonstrated that a common EF factor contains the three basic EFs, which are separated into two factors characterized by simple and complex tasks. These authors suggest that EFs before 36 months old may have different developmental trajectories that can be assessed with simple and complex tasks (Garon et al., 2014, 2018). Although, some studies showed 3 latent dimensions, separating WM, inhibition, and CF (McHarg et al., 2020; Pozzetti et al., 2014), the unidimensional model was more reported. Moreover, the unidimensional model has been obtained with an adequate sample size (200 or more participants) necessary for any AFE and CFA. Regarding reliability, many studies do not report it, and those that report internal consistency reliability showed a Cronbach's alpha above .70, whereas others only indicate that it was low or limited. Nonetheless, interrater reliability was reported in five studies showing adequate values from .86 to .99. In summary, the unidimensional model appears to be consistent in studies of EFs before 36 months old. However, it should be considered that the factor structure and psychometric features should be reported in the studies to reinforce the support for this model.

Variables Related to EF Measurement

One of the challenges of measuring EFs is the difficulty of separating the measurement from other processes involved in EFs. In this review, attention, object permanence, and language were associated with EF measures.

First, there is a relationship between EFs and attention. Cuevas and Bell (2014) demonstrated that the type of attention used at 5 months old is potentially associated with EFs at older ages. The authors classified the participants according to attention style in short lookers (SL) and long lookers (LL) as reported by Colombo et al. (1991). They found that SL process information faster than LL since they encode global features, while LL tend to encode more localized features. Subsequently, they assessed the EFs of the same participants at 24, 36, and 48 months old, showing that SL scored higher on EFs throughout early childhood compared to LL, even when controlling verbal intelligence in the comparison. Likewise, Marcovitch et al. (2016) also included attention for 5-month-old children in two measures: (a) the percentage of looking time that was spent focusing on a puppet over the entire task and (b) the length of the longest look that was recorded. The most relevant of their results were as follows: (a) Attention is a predictor of the location of an object when it is hidden from the child's view. (b) Maternal education is associated with the child's maximum focus time on the object; for example, children of mothers who did not complete university or technical school present lower focus time. (c) Babies who hold attention for longer periods find the correct hiding place more often because the longer time of holding attention allows them to encode a greater amount of information, including the location of the hidden object. And, (d) at 7 months old, the child can relate the location of an object to its features; however, separate coding of features and location occurs at earlier ages.

Second, locating hidden objects is tied to the development of object permanence; however, when multiple locations are used to hide objects, the EFs are practiced (Marcovitch et al., 2016). This shows that difficulties in developing object permanence reflect deficiencies in inhibition and WM. For example, Pauen and Bechtel-Kuehne (2016) studied how tool use is associated with the development of EFs. They used Bechtel et al.'s (2013) tool selection task, which requires a transparent box with a tube and a ball (reward), as well as three sticks (tool) of different appearances and lengths. The sticks must be inserted through the tube, but only the longest one can reach the ball to drop it down a ramp and for the child to get it. First of all, the examiner inserts each tool into the apparatus in three consecutive attempts, from the shortest to the longest stick, showing the child that only the longest stick pushed the ball out of the tube (learning about the tool by observing others). The task continues with a training phase, which consists of several trials in which the child selects a tool for the examiner to insert into the tube and provides feedback to the child (learning about the tool based on feedback). Finally, there is a transfer phase in which the examiner replaces the training tools with new sticks and provides instruction to the child allowing 7 to 12 trials (transfer of tool knowledge to new situations). Their study found that children at 18, 20, 22, and 24 months old chose the correct tool after seeing another person apply it, increasing substantially the performance as the age group was older, especially between 20 (45%) and 22 months old (63%). Children who scored higher on WM made fewer perceptual errors after feedback; for example, those who waited longer before starting to eat the cookie in the inhibition task chose the wrong tool less frequently than those who did not wait; also, in CF, it was observed that switching skills helped to shift children's perspective from paying attention on perceptually salient information toward paying attention on functionally relevant information. The results revealed that EFs are likely to impact the knowledge transfer of tools in young children.

Finally, language is an important variable related to EF development. Language skills operate as a support tool to inhibit impulsive responses, improve self-control, and have adequate social interaction (Matte-Gagné & Bernier, 2011). Several of the reviewed studies included a measure of verbal ability, language, or vocabulary to control for the influence on EFs (Bernier et al., 2012; Cuevas & Bell, 2014). The instructions of the EF tasks should also be adapted to the level of verbal development of children at this age.

Biological and Environmental Factors Related to EF Development

The review shows that basic EFs before 36 months old are influenced by variables such as prematurity, ASD, parenting, attachment, adverse early life experiences, bilingualism, and screen exposure. The findings about these variables are described below.

Premature birth is a relevant risk factor associated with EF difficulties and neurodevelopmental disorders. Pozzetti et al. (2014) studied this condition in children without significant brain damage and assessed the three basic EFs at 24 months old. The authors compared 72 premature infants and 73 as controls, finding that premature infants without significant brain damage have adequate cognitive development with difficulties only in CF which could be a precursor to deficits in young children. These difficulties could become more evident as they reach school age, when they are subjected to more complex tasks and the demands of the environment increase, resulting in academic and behavioral problems. Espy et al. (2004) considered a single sample that included typically developing children and premature children at 28 weeks gestation or more but without significant brain damage. They made this decision to increase the variability of performance by including children more likely to experience later mathematical difficulties. In their study, they determined that WM and inhibition could predict math skills later in development. However, the authors considered the limitation that the sample included children born preterm, as their findings might have differed with a more homogeneous sample.

Among the studies reviewed, only one included a sample of children with ASD in the age group of interest. Garon et al. (2018) applied their EF battery to 34 children with ASD and compared them with 255 children with typical development. Their results showed deficits in children with ASD in all the basic EFs assessed which were more evident when the tasks were appropriate for their level of development. These authors observed significant deficits in cognitive flexibility and inhibition rather than in WM, regardless of age. This implies that these ability deficits are not only observed in children with ASD but are also evident at early ages in the preschool period. The two abilities that most distinguished the groups were inhibition (simple and complex phase) and CF (simple and complex phase). In WM, the simple phase score had a slightly higher load than the complex phase, indicating that these deficits may be associated with developmental delays and not specifically with ASD symptomatology. Although deficits in inhibition were observed, CF was the one that best marked the severity of the symptoms in children with ASD. The study concluded that these measures could be candidates for endophenotypes, which would be an important line of research to further understand neurodevelopmental disorders.

The parent-child interaction and the quality of the environment at an early age also influence EFs. A favorable environment can have a positive impact, while an unfavorable one can have a negative structural and functional influence (Bernier et al., 2010; Bernier et al., 2012). Maternal care, specifically mind-mindedness, sensitivity, and autonomy support appear to influence conflict EF tasks, operating as a central mechanism in both cognitive and behavioral psychophysiological regulation, being maternal autonomy support the most important predictive factor of EFs at all ages (Bernier et al., 2010). Individual differences and aspects related to the family (e.g., stressful parenting or lack of opportunities) or the child's verbal ability can affect the development of EFs (Matte-Gagné & Bernier, 2011). The longitudinal study of Bernier et al. (2012) looked at possible links between the quality of early care environment and EFs later in life and demonstrated that parenting and secure attachment were linked to conflict tasks at the age of three, even when taking into account socioeconomic status, child's language, and previous performance on conflict tasks. Authors argued that the association between conflicting EFs and secure attachment is mainly attributable to two mechanisms: (1) the independent use of regulation strategies learned during emotionally evocative child-caregiver interactions and (2) more advanced psychobiological regulation, which supports the development of neural systems that underlie children's ability to regulate thoughts and behaviors (Bernier et al., 2012). This is because care is presented in a harmonious environment, reducing negative emotional stimulation, which can affect physiological processes such as parasympathetic responses and cortisol reactivity. Parents' early traumatic experiences could also impact the quality of care and as a consequence influence child EFs, specifically on lower performance in WM and inhibitory control scores due to harsh parenting attitudes (Treat et al., 2019).

Likewise, adverse experiences in a child's first year of life can negatively influence child development. Hostinar et al. (2012) showed that post-adopted children with early life deprivation have lower performance in EFs, even after controlling for intelligence quotient (IQ) as a covariate. Specifically, the amount of time children spend in their biological family before being placed for adoption and the physical and social quality of the orphanage environment (reported by the parents and an expert from the adoption agency) influence the EF composite (WM, inhibition, and CF). These authors showed that even at the age of 2.5 years old, difficulties in EFs due to exposure to these experiences can manifest.

Proficiency in two languages may be a protective factor for EFs. Likewise, bilingualism may predict the development of EFs at later ages. Translation equivalents (TEs) are lexical representations of the same concept in different languages, which predict cognitive benefits in bilingual children. Increased TEs predicted stronger EF mechanisms, particularly in conflict tasks. In monolinguals, there was no relationship between increased vocabulary and conflict EF tasks, supporting that bilingualism produces this cognitive advantage. Bilinguals also showed superior selective attention and inhibitory control, because they must focus their attention on one language while ignoring the other (Crivello et al., 2016).

Finally, exposure to screens is associated with lower scores in inhibition (considering the response time to the prohibition task with a 5-s delay); this difference is not observed in WM or CF, suggesting a longitudinal association between exposure to screens and inhibition only. These results were observed even with other risk variables such as parental mental health problems or relationship difficulties (McHarg et al., 2020). Table 4 shows the variables that influence specific EFs (WM, inhibition, CF, or composite score).

Discussion

This review highlights the advances and challenges in the study of EFs before 36 months old. The study of EFs at early ages has great research potential; however, it has only been

Table 4 Variables influencing basic EFs

Variables influencing EFs	Basic EFs			
	CS/CT	WM	In	CF
Preterm birth				✓
ASD			✓	✓
The severity of symptoms in ASD				✓
Maternal autonomy support	✓			
Parent's early traumatic experiences		✓		
Secure attachment	✓			
Parenting (moderated by language)			✓	
The amount of time children spend in their biological family before being placed for adoption	✓			
The physical and social quality of the orphanage environment	✓			
Bilingualism	✓			
The number of translation equivalents	✓			
Exposure to screens			✓	
Object permanence development		✓	✓	
Short lookers (fast and efficient information processing)	✓			

WM working memory, *In* inhibition, *CF* cognitive flexibility, *CF* conflict tasks, *CS* composite score (including WM, In, CF)

understood in greater depth in recent decades. Nonetheless, there is still much to be known about its development in the first years of life due to the challenges of observing, measuring, and differentiating it from other constructs (García-Molina et al., 2009; Tirapu-Ustárroz et al., 2002).

The following points are discussed in this section: (1) the existing measures to assess the three basic EFs, (2) the evidence in favor of the unidimensional model before 36 months old, (3) the relevant findings relevant to understanding the complexity of measuring these three EFs at early ages, and (4) the benefits for the study of neurodevelopmental disorders at early ages. In each of the above points, the advances and challenges extracted from the review are presented.

Regarding the existing measures and scales, 66 tasks were identified that allowed measuring EFs before 36 months old. There are current efforts by researchers to adapt the tasks to simpler versions for application to children at younger ages (Pozzetti et al., 2014). Nevertheless, more complex tasks have been successfully applied at older ages. The tasks for each EF have common goals, such as finding an object, controlling behavior, or being able to switch from one task to another (WM, inhibition, and CF respectively). Describing and applying the simple and complex tasks would allow for longitudinal studies to explain the development process of these basic EFs from very early ages. The diversity of tasks described generates the challenge of carrying out strict validation processes; however, they are not always reported in the publications. The process of test standardization is necessary to obtain more reliable results. However, EF tasks are reliable and can be applied to large samples (Mulder et al., 2014). Another challenge for correct assessment is to understand which of these basic EFs develops first and what influence they have on each other, as well as their impact on different populations. For example, Garon et al. (2018) reported a greater impact on CF in their ASD sample. Therefore, it has been found essential to develop sensitive and validated measurements of EF in longitudinal studies (Diamond, 2015). In this review, the battery of Garon et al. (2014) showed sensitivity from 1.5 to 5 years old, and the questionnaire of Hendry and Holmboe (2021) showed sensitivity from 9 to 30 months old. As previously mentioned, studies with samples of children younger than 36 months old are complicated to carry out, so it is essential to work on increasing the number of these younger participants. For instance, two studies in our review, that aim to describe psychometric properties, have 261 (Garon et al., 2014) and 486 participants (Hendry & Holmboe, 2021). The other studies were not intended to show psychometric properties, some of them had large samples (Cuevas & Bell, 2014; Garon et al., 2018; Marcovitch et al., 2016; McHarg et al., 2020; Pauen & Bechtel-Kuehne, 2016; Pozzetti et al., 2014), and the rest had samples of less than 100 participants (see Table 2). On a sample of more than two thousand 2-year-old children, a battery divided the EFs into hot and cool, meeting psychometric quality, and predictive and convergent validity (Mulder et al., 2014). The adequate platforms and data collection procedures can allow for bigger samples to corroborate the structure of EF measurements. The review identified three tests that showed statistical evidence on the assessment of EFs at the ages relevant for our study (Garon et al., 2014; Gioia et al., 2016; Hendry & Holmboe, 2021), one was a battery of tasks, and the rest are questionnaires for caregivers. However, some EF tasks require an individual application and specific devices, hindering the accessibility for large samples (Johansson et al., 2014; Pozzetti et al., 2014).

Concerning the second discussion point, there is evidence of the use of specific tasks to measure the three basic EFs before 36 months old which applied factorial analysis to corroborate the internal structure and correlations between observed variables and thus reduce variables to factors (see Table 3). Most of the reviewed studies showed common scores for WM, CF, and inhibition, which were referred to as conflict tasks or composite scores (Bernier et al., 2012; Matte-Gagné & Bernier, 2011). Though, other research still divides the three basic EFs (McHarg et al., 2020; Pozzetti et al., 2014). This discrepancy reflects the challenges in measuring EFs. The unidimensional model seems to better explain EFs at these ages (Karr et al., 2018; Rose, 2022). Several studies reported a factor structure to divide EFs into hot and cool (Goldstein & Naglieri, 2014; Zelazo, 2020). The challenge here is to continue analyzing the factorial model that is reported in literature, especially in studies with large samples. Challenges also include well-documented validation processes, and assessments of the evolution over time (Hunter & Sparrow, 2012). Again, researchers are encouraged to report all EFA data as well as internal, external, and interrater reliability.

The third discussion point is the complexity of the development of EFs that influences how researchers measure them. Understanding the influence of environmental variables, in addition to the statistical requirements mentioned earlier, can provide insight into whether the tasks truly assess what they are intended to assess. Variables such as socioeconomic level, maternal education, history of neurodevelopmental disorders in the family, limited opportunities, conditions of adversity, bilingualism, child temperament, IQ, language, and early trauma can influence the development of EFs (Motsan et al., 2021; Waters et al., 2021). Related to parenting, factors such as parent-child interaction, the quality of care, the environment in which a child is educated, secure attachment, autonomy support, mind-mindedness, adversities in life, and stress can also influence children's EFs (Brown et al., 2022; Werchan et al., 2022). Therefore, it is relevant to control these variables in early EF research.

One challenge is to separate developmental processes that are highly influential in children's performance, such as language, attention, and temperament. EFs are influenced by knowledge acquired during development, beliefs, norms, and values, which must be taken into account in understanding children's task performance to assess executive functioning (Doebel, 2020). The level of language developed by the child influences the comprehension of the given task. Hence, the less verbal instruction required, the better we can control the child's actual performance. Besides, language has been shown to mediate between inhibitory control and impulsive responses, so it should be taken into account in future studies (Matte-Gagné & Bernier, 2011). Child attention has been shown to have a significant relationship and influence with EFs as early as 5 months old; furthermore, there is evidence that it is related to EF performance at later ages as well (Cuevas & Bell, 2014). This implies that attention should always be considered in the measurement of EFs, not as part of the construct, but as an effective influencing variable. Likewise, the development of the child's attention must be determined in each stage of life with greater specification. Attention, object permanence, and tool use, while not part of the same construct, are precursors to the development of EFs and can be observed at very early ages (Decker et al., 2016; Pauen & Bechtel-Kuehne, 2016). Additionally, temperament, similar to EFs, predicts inhibition outcomes. However, the challenge is to understand how to differentiate the measurement of these variables from a multi-theoretical and multi-method approach (Aguilera Lázaro & Ostrosky-Shejet, 2013; Rocha et al., 2019). It should be considered that to measure EFs, it is necessary to maintain the child's interest, avoid fatigue, provide situations that require reasoning and integration of various sources of information, and consider the procedure, errors, and context (Hoskyn et al., 2017).

Returning to environmental influences, positive parenting favors verbal skills that help develop inhibitory control in the child, a basic skill of executive functioning at an early age. In this way, it has been shown that competent parenting influences infant development since the caregiver is involved in the child's self-regulatory skills (psychophysiological, cognitive, and behavioral) (Matte-Gagné & Bernier, 2011). The genetic influence of these factors and the order of protective importance have yet to be determined. Nonetheless, these findings have shown the importance of including parents in early intervention models. Taking into account that family involvement is crucial for the development of EFs, questionnaires directed to parents/caregivers may provide reliable evidence of children's executive functioning at these early ages (Gioia et al., 2016).

The study conducted in institutionalized children (Hostinar et al., 2012) highlights the need to address aspects that can prevent and reduce the impact of adversity on cognitive development in the short and long term. Extensive practice of a second language appears to be effective in EF development (Crivello et al., 2016). Even minimal exposure to screens appears to decrease executive functioning skills very early in life (McHarg et al., 2020). Parents should be advised to reduce screen use at an early age, especially when screen interaction is not possible.

In recent years, substantial advances in the study of EFs have been made due to neuroimaging technologies (Fiske & Holmboe, 2019). The main difficulties include the complexity of developmental research, such as intergenerational and longitudinal studies with large samples, although this could help to better understand EF behavior (Deater-Deckard, 2014). There may be an endophenotype related to EFs, specifically in the study of ASD (Demetriou et al., 2019; Garon et al., 2018). Nevertheless, hormonal influences have been described in EF development such as cortisol in psychobiological regulation (DePasquale et al., 2021; Feola et al., 2020). These endogenous factors have a strong influence and must be considered separately, but how they interact with environmental variables should be considered. There is still much to be done to understand in greater detail the impact of the environment on EFs, and new theories, innovative measurements, and novel interventions should be developed since there are many factors that can affect them (Doebel, 2020).

Finally, for our fourth discussion point, it remains to be determined with greater precision how performance on EF tasks before 36 months old is related to neurodevelopmental disorders. Until now, ASD assessment has shown significant results because its identification has been achieved at younger ages, but the current differentiation of signs and symptoms between boys and girls leaves much to be discovered regarding the development of EFs in early ages (Garon et al., 2018; Tomaszewski et al., 2020). Future research should focus on understanding the relationship between early EF difficulties with symptoms of risk for neurodevelopmental disorders and, if possible, differentiate them from other impairments. The most plausible one is to analyze the signs and symptoms of risk for neurodevelopmental disorders in children younger than 36 months old and compare them with EF tasks at early ages.

With all this information, we not only provide treatment alternatives or intervention programs but also recommendations for the study of the measurement of EFs at early ages. Intervention should consider changes in different contexts ranging from the inclusion of physiological measures, the promotion of resilience, the reduction of screen use, and the implementation of strategies to reduce adversity or to create healthy parent-child relationships. More longitudinal studies, with large samples and involving gene-environment interaction, are required to obtain firm conclusions about their influence on EFs (Deater-Deckard, 2014; Inguaggiato et al., 2017).

Limitations and Future Research

The interest of researchers in EF development before 36 months old is increasing; hence, new studies must contemplate the earliest stages of EF development. Psychometric research on EF tasks at these ages can allow for a clearer definition of the construct, to have valid measures that explain the evolution of basic EFs. The development of EFs is complex and multifactorial, so future research should control factors such as language, attention, temperament, and other biological, environmental, and social variables that may influence the measurement of EFs before 36 months old. Measuring these functions at early ages can allow early identification and intervention when warning signs for neurodevelopmental disorders appear, preventing and reducing the impact on quality of life and improving the adaptation of the child and family. Some of the study's limitations are related to the diversity of topics that had to be analyzed separately and the lack of studies using the early age range considered in our review. Longitudinal studies with large samples should also be conducted to achieve ecological validity. The inclusion of measurement of the three basic EFs in their simple and complex versions will help to understand how they evolve. Although the unidimensional model appears to explain EFs before 36 months old, it is important to compare studies reporting the bidimensional model of hot and cool EFs. Research with children at risk for neurodevelopmental disorders (even if undiagnosed) will provide a better understanding of behavior before 36 months old.

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Declarations

Competing Interests The authors declare no competing interests.

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