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Review Article

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Early Development of Executive Attention

Conejero A and Rueda MR*

Department of Experimental Psychology & Center for Research on Mind, Brain and Behavior (CIMCYC), Universidad de Granada, Spain

***Corresponding author:** Rueda MR, Department of Experimental Psychology & Center for Research on Mind, Brain and Behavior (CIMCYC), Universidad de Granada, Spain, Tel: +34958249609; E-mail: rorueda@ugr.es

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Abstract

Executive attention (EA) encompasses a variety of attention mechanisms implicated in the control of thoughts and behavior. The emergence of EA skills depends on the maturation of frontal brain structures. Evidence in the past years has shown that frontal brain structures related to EA are already functional in the first months of life and first signs of EA can be observed by the second half of the first year of life. Given the importance of EA to a wide range of developmental outcomes (e.g. academic and professional outcomes, socialization, psychological well-being, etc.), understanding early stages of development is of great interest for the promotion of EA and the prevention of EA-related deficits over the course of development. Despite its relevance, relatively little is known about the development of EA before the preschool years. This paper aims at providing a selective review of the existing literature about the early development of EA. We present the principal measures of EA for infants and toddlers available to date. We also review main findings on behavioral as well as brain mechanisms of EA in infancy and toddlerhood. Finally, we summarize research on early indicators of EA and its implication for the early detection of some developmental disorders.

Keywords: Developmental psychology; Attention; Executive control; Child development; Infant development

Introduction

Attention has to do with a variety of cognitive functions that are essential to carry out almost any common activity in daily life. Attention is a multidimensional construct that refers to a state in which we have an optimal level of activation that allows selecting the information we want to prioritize in order to control the course of our actions. Hence, it serves as a mechanism to control both sensorial input and voluntary actions, by maintaining a state of high sensitivity to incoming information and selecting the most relevant information, as well as regulating thoughts, emotions, and behavior. The role of attention as a mechanism of control is what Posner and colleagues have identified as executive attention (EA) in their Attention Networks Model. This model differenciates three main functions of attention: 1) achieving and maintaining an optimal state of activation (Alerting); 2) orienting to and selecting a particular source of stimulation, either internal or external, for priority processing (Orienting); and 3) voluntarily regulating behavior, particularly in situations that involve conflict between dominant but inappropriate responses and non-dominant course of actions (i.e., novel actions, overcoming automatic tendencies, inhibiting immediate rewards in order to reach future goals, etc.). According to Posner's model, different networks of brain regions are involved in carrying out the three functions of attention [1,2].

Numerous studies have associated EA with the activation of prefrontal brain structures, in particular the anterior cingulate cortex [3]. In fact, the anterior cingulate cortex is considered the main node of the EA network. This region is part of the so-called cingulo-opercular network, responsible of maintaining the mental set (task instructions or goals) associated with the current course of action, and closely linked to the dorsolateral prefrontal network, implicated in switching between mental sets [4]. Also, the neurotransmitter dopamine is thought to have a key role in modulating the activation of the EA network. Low levels of dopamine in prefrontal areas of the brain have been related to difficulties in inhibitory control, attention flexibility and conflict resolution [5].

The concept of EA greatly overlaps with what has been called "Executive Functions". The executive functions construct refers to a number of different cognitive processes involving flexibility in adapting to new environmental demands, monitoring changes in upcoming stimulation and own internal states, and the ability to manage with conflicting information [6], which greatly overlap with EA. However, executive functions is a broader construct that not only includes cognitive processes related to inhibitory control and cognitive flexibility, but also the ability to maintain and manipulate information in memory, what is called working memory [7]. Thus, EA partly corresponds with the concept of executive functions, comprising executive functions under the domains of inhibitory control and cognitive flexibility.

The study of EA has interested to numerous researchers in the field of developmental psychology due to its implication in a wide range of developmental outcomes. EA skills are thought to underlie the development of higher-order cognitive functions, such as planning, problem resolution, and reasoning, which are core functions of fluid intelligence [6]. There is, in fact, a substantial overlap between brain structures associated with general intelligence and those of the EA network [8]. Likely due to the relationship between EA and general intelligence, individual differences in the ability to control attention are associated to school competence [9]. Likewise, EA is thought to be on the basis of the development of self-regulatory skills, sharing common neural substrates [10] and predicting later social adjustment, as well as internalizing and externalizing problems [11].

Although considerable research has focused on the early development of EA during the preschool years, much less attention has

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been paid to development of EA during the first years of life. In this article, we present a selective review[1] of existing research on the development of EA during infancy and toddlerhood, including studies examining early measures of EA skills and longitudinal studies investigating either early predictors of EA skills or developmental changes on this function during the first three years of life.

In the sections that follow, we begin by presenting a general overview of the different experimental paradigms that have been used to investigate EA in the early stages of development. Next, we review existing evidence on the development of EA in early years at both the brain and cognitive levels. Finally, we discuss literature on early signs of EA and their implication for the detection of developmental disorders involving this particular function.

	Infants/Toddlers	Adults
Cognitive Conflict	Shape Stroop task [28]; Baby Stroop [29]	Stroop task [89]
	Young-Child ANT (adapted from [90]).	Flanker task [91]
		Attention Network Test [92]
	Spatial Conflict task [30]}	Simon task [93]
Flexibility	A-Not B task [12]	Task switching paradigm [94]
	Detour Reaching task [23]	
	Shifting task [17]	
	Reverse Categorization task [26]	Wisconsin Cards Sorting Test [95]
	Dimension Card Sorting Test [70]	
Error monitoring	Arithmetic errors [20]	Any of the conflict or inhibitory control tasks adjusting difficulty to provoke the commission of errors.
	Unexpected action ending [21]	
	Errors in building simple animal puzzles [27]	
Inhibitory control	Anti-saccade paradigm [14]	Anti-saccade paradigm [96]
	Freeze-Frame task [16]	Go-No Go [98]
	Walk-in-a-line [97]	Stop-Signal [99]
Self-regulation	Snack Delay task [28]	Academic Delay of Gratification scale [101]
	Delay of Gratification [100]	

Table 1: Summary of Executive Attention measures for infants and toddlers and equivalent adults' measures.

Methods to study the early development of executive attention

Measuring cognitive processes in infants can be challenging for obvious reasons. Infants' impossibility to develop instructed behavior traditionally left babies out of experimental paradigms designed to measure cognitive processes by using reaction time or response accuracy variables. Much less so for frequently used attention control tasks (e.g., Stroop), which involve following instructions to overcome automatic behavior tendencies. Also, language competences at these ages may be insufficient for understanding the rules and instructions typically required by this type of tasks. Finally, researchers need to take into account young children's shorter attention spans, greater distractibility, and the relative facility with which their emotional state can be altered when designing experimental protocols and tasks suitable for children of this age. In an attempt to deal with these challenges, researchers have adapted existing experimental paradigms by simplifying stimuli and making them more child-friendly. Common strategies consist on making tasks more attention-catching with the use of colorful and dynamic stimuli, finding alternative ways to measure performance that do not require complex motor responses (e.g., registering gaze patterns), and including more breaks or shorten the procedures. Table 1 presents a selection of EA tasks appropriate for infants and toddlers and equivalent measures in adults, grouped by the type of process they tax. In the following section, we review the main tasks and measures that have been used for assessing EA in the first three years of life.

Tasks suitable for infants

Probably the most used procedure to study the early development of EA is the A-not-B task [12]. The simplicity of the procedure allows researchers to use this task from very early in development, extending from infancy to early childhood. The task consists on hiding a toy in location A in front of the child sight. Then, after a delay of a few seconds, the experimenter encourages the child to retrieve the toy. Once children learn to retrieve the toy from location A, the toy is hidden in a new location (B). Flexibility of attention is needed in order to adapt to that change and look for the object in the new location B. Thus, perseverative errors (that is, searching for the toy in the previous learned location A) indicate poor cognitive flexibility.

The reaching task [13] represents another example of a lab measure of attention flexibility in infants. In this task, babies are shown an attractive toy in a clear-sided box. The box is opened only in one side that is different from the line of sight in which babies are viewing the toy. In order to success in getting the toy, infants need to inhibit the natural tendency of reaching the toy in a direct way, and detour the box to retrieve the toy by the open side.

In addition to these two tasks, researchers investigating EA in pre-verbal infants have recurred to experimental paradigms based on learning contingencies between stimuli, combined with the registration of looking behavior. This is the case of the anti-saccade paradigm [14], in which the automatic tendency to look at a cued position has to be inhibited. This task has been adapted for use with babies as young as 3

[1] Instead of a systematic review, we carried out a selective review of the literature in which we searched for up-to-date publications in two different online databases: Scopus (Elsevier Co.) and Web of Science (Thomson Reuters). Search terms included "attention", "attention control", "executive functions", "executive control", "inhibitory control", "flexibility", "infancy", "toddlers", "brain development", "cognitive development", "longitudinal", and "developmental disorders". Searches were limited to peer-reviewed articles written in English language and published in ISI-ranked journals.

months of age. As infants cannot be given instructions on how to perform the task, researchers build their tendency to look toward the opposite direction of the cued location by reinforcing them with an animated cartoon that appears every time they look toward the opposite side of the cue. Although this task mainly implicates orienting of attention, it also involves elementary mechanisms of control of attention necessary to inhibit attention to a previously cued location. Thus, these rudimentary mechanisms of control over orienting of attention may lay the foundation for the development of EA mechanisms of control and may be considered as an early indicator of that function.

Likewise, in the visual expectation paradigm [15] a predictable sequence of visual stimuli is shown to infants repeatedly while infant eye movements are recorded. Anticipatory looks, as those occurring prior to the appearance of the stimuli, and reactive looks are coded. Reactive looks are thought to reflect exogenous (stimulus-driven) control of attention, whereas anticipatory looks may involve endogenous (goal-directed) control of attention and are thought to reflect the early functioning of the EA network.

Another task measuring inhibitory control during infancy that is based on learning of contingencies is the so-called freeze-frame task [16]. This task was designed to automatically respond to infants looking behavior with the help of an eye tracking system. Infants have to look to a target stimuli while ignoring other irrelevant stimuli that act as distractors. Babies are rewarded with the animation of the target as long as they look at it, for which they must inhibit looking to the distractors. This task is suitable for preverbal infants and provides a general index of inhibition to distractors, as well as a selective inhibition to distractors (depending on whether target was an engaging stimulus or not) measure that has been related to later performance in conflict tasks.

A similar logic applies to the shifting task designed by Kovács and Mehler [17]. This task was conceived to measure flexibility of attention during infancy. In this task, infants learn first to expect a target stimulus in a certain location as it appears repeatedly in the same side of the screen for a number of consecutive trials. After the first block of trials, the target stimulus appears in a different location as the previous block for a number of trials. Infants able to switch attention reallocate their attention to the new location within a few trials and stop anticipating gaze to the previously reinforced location. Thus, the percentage of perseverating looks to the locations learned in block 1 provides a measure of infant's attentional flexibility (the more perseverations the less attentional flexibility).

Error detection is also a process associated with EA and self-regulation [18]. Regarding the early development of error detection, researchers have mainly employed violation of expectancy tasks based on the habituation paradigm. In this type of tasks, infants' looking time to expected and unexpected events is registered. Researchers assume that infants' longer looking times to unexpected events indicate that they are able to anticipate forthcoming events and learn about objects' features. This idea was applied to test babies' arithmetic knowledge by means of an experimental paradigm in which researchers presented correct and incorrect solutions of simple arithmetic operations (e.g. 1+1=2; 1+1=1; etc.) to infants using puppets as stimuli [19]. As expected, infants looked longer to incorrect solutions. In an attempt to investigate underlying brain mechanisms of error detection in infancy, some studies have incorporated electrophysiological brain measures. For instance, Berger, et al. [20] used the same paradigm designed by Wynn to test the ability of babies between 7 and 9 months of age to detect arithmetic errors, but registering EEG. Reid, et al. [21] designed a task in which babies were shown a model performing a set of common simple actions. Action sequences are completed as expected or in an unexpected way (e.g., the action of eating finish in the ear instead of in the mouth). In both studies, infants showed the frontal activation typically observed in adults and older children following the observation or commission of an error, the error-related negativity (ERN; [22]), indicating that infants are already able of processing errors.

Tasks for infancy development research are limited by the impossibility of using verbal instructions. However, children verbal comprehension and motor skills experiment a great progress during the second and third years of life. The unintelligible babbling that is characteristic of babies gives rise to few words sentences with which children start to express their desires and feelings. Improvements in language are further accompanied by advancements in physical strength and motor coordination that allow children to start walking or employ more refined movements. As we discuss next, these developmental changes lead to qualitative changes in the type of tasks procedures used to tax the development of EA.

Tasks suitable for toddlers

Progressively, toddlers become able to understand simple instructions and follow easy rules, being able to produce some more complex responses, as pushing buttons, ordering objects, selecting by pointing among different options, or answering simple concrete questions. From this age, measuring the control of impulses becomes possible as well, thus different tasks suitable for toddlers have been used to measure EA and self-regulation.

As in infancy research, the A-not-B task has been widely used to test attention flexibility in toddlerhood. Concerned about the low difficulty that the original task represents for toddlers, experimenters made an effort for making the task challenging enough for two-year-olds by either increasing the delay [23], or including additional possible locations and introducing some means actions necessary to retrieve the toy from a special device [24]. Despite these modifications, the A-not-B a task does not demand too much cognitive flexibility for children older that 24 months, not being sensitive enough for measuring individual differences in flexibility beyond this age [25], and some evidence suggests that the reverse categorization task [26] may be a better choice for toddlers. In the reverse categorization task, children have to classify a number of blocks according to its size: big blocks in a big bucket, small blocks in a small bucket. After sorting a number of blocks according to this simple rule, the sorting rule is reversed and children are asked to put big blocks in the small bucket and small blocks in the big one. Errors after changing the rule, similarly to errors in the A-not-B task, indicate low flexibility.

As we mentioned in the previous section, there are some studies that have observed the ability of infants to detect errors. A recent study has also investigated error detection in 16-18 months old toddlers using a novel paradigm in which children observe animal puzzles being completed on the screen either in a correct or in an incorrect way [27]. The study shows that toddlers' brain activity increases in response to errors, showing an ERN-like component with a burst of oscillatory activity in theta (4-7 Hz) range. Interestingly, results also show that the amplitude of toddlers' brain response to errors is partially predicted by socio-economic status of the family, suggesting an important vulnerability of the executive attention network to early experience.

The ability to resolve cognitive conflict can also be examined at this age. Diverse authors have ideated different Stroop-like conflict tasks that are suitable for toddlers. Kochanska et al. [28] in their shape-stroop task employed a set of three cards depicting three different fruits. Fruits are represented in both big and small sizes in a way that small fruits are embedded inside the picture of a different big fruit (e.g., a card with a small banana inside a big apple). Children are asked to point to a particular small fruit (e.g., the small banana). A card with the same fruit the experimenter asks for but in the large size, is placed next. Toddlers have to inhibit the prepotent response of pointing to the big fruit, which is more prominent, and search for the small one. Another example of an adapted Stroop paradigm for children of this age was provided by Hughes and Ensor [29]. These authors created the baby stroop task in which toddlers are required to feed a mummy doll with a "baby" spoon and a baby doll with a "mummy" spoon. Children have to manage the incongruence between doll size and spoon size and avoid the natural tendency of pairing objects by size.

Gerardi-Caulton [30] also adapted a conflict paradigm, the spatial conflict task, for use with toddlers. This task is based on the Simon effect, which refers to a delay in reaction time (RT) usually found when the mapping between the stimulus location (either left or right) and the response hand is inconsistent. Unlike the previously described tasks, Gerardi-Caulton's adaptation of the spatial conflict task provides a RT-based measure of conflict, and it is normally performed in a touch-screen device. In the toddler adaptation of the task, children are told to select the response button matching a target stimulus' identity, usually a funny cartoon representing an animal. Response buttons, which represent "houses" of two different cartoons (e.g., a bunny and a turtle), are located either on the right or left of the screen and the target appears either just above the matching response (e.g. a bunny appears just above the bunny house; spatial compatible trial) or in the opposite side (e.g., a bunny appears just above the turtle house; spatial incompatible trial). As in the adult version of the task, incompatible trials are responded with higher proportion of errors and slower reactions times. Also, a conflict index can be calculated by subtracting percentage of errors or RT in compatible from incompatible trials. The greater the conflict effect the poorer efficiency of EA inhibiting the dominant but incorrect response tendency.

Measuring behavioral self-regulation also becomes easier from the second year of age on. Self-regulation tasks characteristically involve suppressing impulses towards some appetitive stimuli. Both the snack delay and gift delay tasks are part of the inhibitory control battery developed by Kochanska, et al. [28], and are frequently used measures of behavioral self-regulation. In the snack delay task, the experimenter locates a tempting snack (usually a cracker) under a transparent cup and asks children to wait until s/he rings the bell before taking the snack. In four consecutive trials the delay to the ring of the bell is progressively increased from 5 to 20 seconds. Children who patiently wait during the entire trial and do not make gestures as to approach the snack get the maximum score, whereas eating the snack or even touching it before the experimenter rings the bell cause lower scores. On the other hand, the gift delay task measures the ability of children to override the impulse of opening a wrapped gift. In this task, the experimenter gives a wrapped gift to children but leaves the room for some minutes with the excuse of looking for a bow to put on it. The experimenter asks the child to wait while s/he returns without opening the gift. As in the snack delay task, being unable to wait and peeking the gift is indicative of poor self-regulation.

Finally, another task measuring self-regulation in toddlers is the so-called walk-in-a-line-slowly [31]. In this task, toddlers have to inhibit the impulse of walking without any restrictions. Children are asked to walk toward their mum following a line painted in the floor as slow as possible. The time that children spend on walking along the line is registered. A child who typically fails in this task normally runs right toward the mum, not necessarily following the line.

Reviewed tasks constitute good examples of the efforts researchers made to address EA development in early years. Developing sensitive measures of EA suitable for infants and toddlers is still a big challenge. Much work remains to be done with regard to the validation and reliability of these tasks as early measures of EA. Infants and toddlers' limited motor and verbal comprehension skills call for designing relatively simple experimental paradigms that seem not to represent high EA demands. Furthermore, some tasks rely on children's ability to learn about contingencies, making unclear whether individual differences in performing these tasks are completely attributable to differences on executive skills. Future studies may try to disentangle the processes involved in particular tasks and examine which are the ones most directly associated with performance of well-established EA tasks later in development.

Development of Executive Attention during Infancy and Toddlerhood

Early development of the EA network

For many years, the study of executive functions was limited to older children and adults due to the belief that brain structures in the prefrontal cortex subtending this function did not become functional until later developmental stages [32]. Thanks to the introduction of neuroimaging technology together with novel child-appropriate methods in developmental research, we currently know that the development of executive skills occurs much earlier than was previously thought [33].

EA brain networks are present in infants by term, including fronto-parietal and cingulo-opercular circuits, which already show a connectivity pattern that in some aspects is similar to that observed in adults [34]. The development of brain networks occurs throughout a segregation-integration process in which short-range connections decrease within the network whereas longer-range connections between distant brain regions increase with age [35,36]. There is some evidence that this process is already taking place in neonates and is explained by both synaptic pruning and the myelination of white matter [37]. Particularly, the first two years of life may be key for the development of the EA network. A rapid exponential myelination growth takes place over frontal areas about the 6th month of life [38]. Cortical grey volume also increases substantially in the first two years of life, with a faster growth of frontal structures during the second year of age [39,40]. There is also an increment in the thalamo-cortical connections during the first two years of life that has been related to toddlers' working memory skills and general cognitive development [41]. These structural changes correspond to the restructuring of the network configuration, leading to more efficient and stronger connections that has been also related to a general increase in the modularity of the different brain networks in toddlerhood [37].

Apart from the structural changes within the EA network, studies utilizing electroencephalography (EEG) suggest that this network becomes functional during the first year of life. EEG and event-related potentials (ERP) provide direct measures of the neural activity with great temporal resolution, which has been used to investigate functional developmental changes of brain circuits. Studies about the early development of functional brain activity usually report a negative ERP component in fronto-central areas over the scalp labelled Nc (Negative central), which is observed about 350–650 ms after a stimulus onset, and appears to have a source or activation in the ACC [42]. This ERP component has been widely investigated in the field of early development of attention as can be observed from a few weeks after birth [43]. Larger amplitudes of the Nc are thought to reflect attention engagement because its amplitude increases in response to novel stimuli [44], incongruence [45] or during attentiveness periods [46].

Earlier in this article, we alluded to a negative component named ERN that has been generally described between 100-200 ms over the frontal midline being associated with error processing in adults [47]. This ERP component can be observed not only after the commission of errors, but also in response to perceived errors or even in the absence of awareness about perceiving the error [48-55]. As we previously mentioned, a fronto-central negative component comparable to the adults' ERN is also observed in infants and toddlers [21,22,56,57]. In all these studies, infants and toddlers' brain responses were functionally equivalent to that observed in adults in the same experimental paradigm with the only difference that babies' ERP effects occurred later (about 350–650 ms) and were more extended in time. This ERN-like component observed in infants and toddlers is seen as a precursor for the later adult ERN, being associated with the activation of the ACC [51] the main node of the EA brain network. This suggests that the EA network is already functional as early as by the end of the first year of life.

The study of brain's oscillatory activation in different frequencies, particularly in theta band, has also provided a useful tool for understanding infants' EA development. Theta band comprises frequencies in a range between 4–7 Hz and has been related to cognitive control [52]. Recent research suggests that frontal theta is an important mechanism supporting changes in white matter fibbers. Evidence from animal and human studies show increases in myelination and connectivity following bursts of frontal theta that are mediated by activation of the protease calpain [53]. Frontal theta activation in young children may thus be an important mechanism promoting the development of optimal structural connections between regions within the EA network. Indeed, there is an increase in theta power during infancy that might underlie the development of cortical pathways associated with the shift from the primarily exogenous to the more internally controlled attention observed by the end of the first year of life [55,56]. As mentioned earlier, a recent study investigating neural mechanisms of error detection in toddlers found a significant increase of frontal theta power associated with the processing of errors, suggesting that evoked theta power may also serve as a neural marker of early EA skills [27].

In summary, brain circuits underlying the executive control of attention start to be functional from very early on. Of course, this does not mean that we are not to expect great further functional and structural changes of the EA network later in development. On the contrary, the development of the EA network follows a protracted trajectory that extends throughout childhood well into adulthood. However, important changes in brain structure and function support the observed cognitive and behavioral changes occurring during the first three years of life. Studies investigating the development of prefrontal structures in early years rarely extend beyond the second year of life. Further longitudinal studies exploring brain development throughout the life-span may serve to understand the importance of brain changes during infancy and toddlerhood for future brain development. Including cognitive measures may also help establishing a relationship between brain structural and functional changes and maturation of EA skills.

Development of executive attention: behavioral evidence

Along with the development of the EA brain network in the first years of life there are improvements in the ability of infants and toddlers to control attention. There is some evidence suggesting that primary mechanisms of attention control start to develop from early infancy. At about the third-to-forth month of age, babies already show some endogenous control of attention [56]. Before that age, babies' attention is considered as essentially reactive, responding preferentially to exogenous events and relying in low-level arousal mechanisms [57]. In line with this form of attention, young infants commonly show difficulties disengaging attention from objects, even after they become uninteresting or boring [58]. This phenomenon has been labeled as "obligatory attention" or "sticky fixation" and is explained as a result of the prominent role that the superior colliculus, a sub-cortical structure involved in visual attention, may have in the reallocation of attention at this age [59]. The voluntary control attention may require the maturation of prefrontal brain structures with the potential to inhibit the colliculus, such as the frontal eye fields, which might facilitate the disengagement of attention from already explored objects. By 3 months of age, babies are able to disengage attention from a central stimulus [60], significantly diminishing the time they need to disengage between 4 and 6 months of age [61]. Infants from 6 months of age regulate their attention differently according to whether the stimuli are boring (habituating more rapidly) or engaging (increasing the time they expend looking at it), also reflecting an initial endogenous control of attention [62].

Another early indicator of EA in infancy is the ability of infants to deploy attention according to internal expectations or task goals. By 4 months of age, infants learn to anticipate their attention to the location in which a particular stimulus embedded in a fixed sequence will appear [63]. This is thought to reflect EA given that it requires orienting attention voluntarily toward a particular location according to a repeated sequence of locations. Anticipating the location of the upcoming stimuli requires monitoring the sequence of locations, which in adults has been shown to depend on attentional resources. In fact, the proportion of anticipatory looks that babies produce during the task is associated with genes that regulate the levels of dopamine in frontal brain structures related to EA network [64]. Another piece of evidence indicating the early development of attentional inhibition during the end of the first year of life comes from studies showing that 9 months old infants are also able to inhibit attention to irrelevant stimuli that try to distract them from a target stimulus in the so-called freeze-frame task [16].

About the end of the first year of life children become more flexible at both cognitive and behavioral levels. By this age, infants performing the A-not-B task are able to inhibit searching for a toy in the location in which the toy was initially hidden and learn to retrieve it from a new location [23]. Similarly, 7-months olds can redirect attention from a previously rewarded location (e.g., with an animated cartoon) to a new one [17]. Further improvements in attention flexibility are observed in the performance of the detour-reaching task at this age [23]. Babies are able to inhibit directly reaching a toy presented in a transparent box (open by only one side) to detour the box and retrieve the toy by the open side instead.

During toddlerhood, the development of EA capabilities becomes more apparent. By two years of age, children are able to overcome a more sophisticated version of the detour-reaching task that requires performing a means-action before they can reach the desired object [65]. The enhancement in EA also results in improved performance in a set of executive function tasks that children failed before that age, such as a multiple hiding locations in the A-not-B task or the forbidden toy task [66]. All these changes in EA are accompanied with an increase in self-regulation skills. Infants self-regulatory strategies are focused on reducing reactivity levels and mainly rely on the use of simple mechanisms to reduce distress such as disengagement of attention and distraction (e.g., looking away from distressful stimuli) and self-comforting [67]. However, toddlers not only try to regulate their reactivity levels but also try to self-regulate actions in order to behave according to goals and social demands. This means that toddlers potentially can adjust their behavior to follow simple rules, first with some external help (caregivers guidance), but later, about two years of age, becoming more independent and self-regulated as long as their inhibitory control capabilities get more efficient [68].

Later, between the second and the third year of life, children become more and more competent in resolving cognitive conflict. Using the child-friendly version of the spatial conflict task described earlier, Gerardi-Caulton [30] compared performance of children of 24, 30 and 36 months of age. Children's proficiency resolving spatial conflict increases with age within this are range, first by making fewer errors and then by resolving the cognitive conflict faster.

Between the second and third years of age children become increasingly skilled in inhibitory control and attention flexibility. At two years of age, children are able to switch between different rules in a simplified version of the dimensional sorting task that includes only distracting information (e.g., a target stimulus does not match with the distractor stimuli in any relevant category, either shape or color) instead of conflicting information (e.g., the target stimulus match with a distractor in a relevant category) [69]. It won't be until the third year of life that some children will be able to complete the original dimension card-sorting test, although they still make a big proportion of perseverative errors [70]. It has been shown that children who perform better activate prefrontal areas to a greater extend than children performing poorer during the task [71].

In parallel to enhancements in inhibition and conflict resolution, there are significant improvements in self-regulation between the second and the third year of age. Whereas self-regulation in *don't contexts* (that is, when children are required to inhibit certain behavior) seems to develops more rapidly, the increase in the ability to in self-regulate in contexts where children are required to sustain an unpleasant activity is specially noticeable between the second and third year of life [68].

All in all, during the first three years of life, huge changes are observed in the ability of children to resolve different EA-related tasks that reflect the development of the EA network. Over the next section, we discuss how individual differences in the early development of EA may predict later EA skills and related outcomes.

Early signs of Executive Attention as a Predictor of Developmental Outcomes

Increasing research indicates that EA plays a key role in children's social adjustment and academic performance [72], being also affected in a range of developmental disorders such as autistic disorders or ADHD [73]. Therefore, the early detection of EA deficits is going to be important for prevention and early intervention. Nonetheless, longitudinal studies from infancy and toddlerhood that extend over childhood are relatively scarce. In the following lines, we review studies that have tried to examine the predictive power of early measures of EA.

Early predictors of EA

Some early measures of attentional processes may be indicative of later EA skills. One of these measures is the duration of infants' attention fixations when encoding a stimulus. According to the duration of attentional fixations, infants can be divided in two different attentional styles: short-lookers and long-lookers. Shorter fixations are thought to reflect a more efficient cognitive processing. In fact, long-lookers usually have more difficulty in disengaging attention compared to short-lookers [74]. Infants classified as short-lookers by 5 months of age also exhibit better EA skills (e.g., inhibitory control, attention flexibility, conflict resolution) than long-lookers by 2, 3 and 4 years of age [75]. Further, the duration of fixations at 7 and 12 months of age also predicts shifting and working memory skills at 11 years of age [76]. Likewise, shorter duration of fixations during infancy is related to better inhibitory control in adolescence [77]. Overall, although not a direct measure of EA, duration of fixations seems to be a quite reliable predictor of EA development.

Similarly, attention focusing in infancy has been associated with later development of EA. Infants' levels of focused attention in a free-play context are associated with less distractibility by 4 years of age [78]. A more recent study found that sustained attention of children during free play at 12 month of age also predicts both children's attention flexibility in the A-not-B task and effortful control by 2 years of age [79]. Additionally, focused attention by 9 months of age predicts inhibitory control (measured with a battery of behavioral tasks such as the snack delay task) by 24 months, although no longer predicts inhibitory control later, by 33 months of age [28].

Early individual differences in inhibitory control also predict later EA. Holmboe, et al, [16] found that the ability of children to resolve cognitive conflict in a spatial conflict task at 2 years of age is predicted by their ability to inhibit attention to distractors at 9 months of age. Interestingly, they also showed that infants who differentially inhibit attention depending on the interest of the target (i.e., infants who inhibit attention to distractors in a greater proportion when engaging targets are presented compared to boring targets, reflecting a more endogenous control of attention) are the ones that resolve spatial conflict more efficiently later by 2 years of age. Similarly, toddlers who demonstrate greater inhibitory control skills by 14 months of age, waiting longer to touch a toy that they were asked not to touch, also show better general EA skills at 17 years of age [80].

Early executive attention in relation to social and behavioral adjustment

Early measures of EA in infancy and toddlerhood can also serve as early indicators of later social outcomes and behavioral adjustment, predicting academic competence and psychological well-being. It has been shown that the habituation rate at 4 months of age accounts for higher intelligence at 18 months and 8 years of age, as well as for less behavioral problems by 3 years of age and greater academic achievement at 14 years [81]. This is explained in terms of a system of cascades in which early attention development would have an indirect effect on academic outcomes at 14 years of age, as it would be mediated by intelligence and the reduced presence of behavior problems during childhood. In line with these results, it has been shown that selective attention at 7–12 months of age predicts general intelligence and academic achievement at age 21 years [82].

Researchers have also observed that toddlers' "hot" and "cool" executive control skills might predict different developmental outcomes [83]. Hot executive control refers to regulation that occurs in emotional arousing contexts or highly motivating situations (e.g., resist eating a tempting snack), and is closely related to self-regulation. In contrast, cool executive control refers to attentional control exerted in order to select stimuli in the presence of distractors, or responses in the presence of more dominant courses of action in neutral contexts. Mulder and colleagues found that cool executive skills (e.g., performance in a visual search task or working memory tasks) at 24 months of age predict academic performance and less behavioral problems at age 3 years, whereas hot executive skills (e.g., performance in the snack delay) predicted reduced rates of behavioral problems. Thus, although related, hot and cool executive control might have similar but separate developmental courses from very early on.

Early executive attention deficits and developmental disorders

The just reviewed longitudinal data suggest that measuring EA in infancy might be useful for the early detection of risk for deficits in EA and developmental disorders. It has been shown that children diagnosed with autism show difficulties to disengage attention [84]. Longer latencies to disengage are associated with the higher risk of developing autism by 3 years of age [85]. However, before 12 months of age seems too early to forecast the later development of autism with this task because only children with impairments in disengaging attention at the end of the first year of life who continue to show these impairments during the second year were later diagnosed with autism [86].

Also, there is some evidence showing that the duration of attention fixations in infancy significantly predict hyperactivity-inattention symptomatology. Infants classified as long-lookers show a greater proportion of hyperactivity-inattention symptoms between 3 and 4 years of age [87]. Likewise, sustained attention between the first and the second year of life is also a predictor of hyperactivity symptoms observed at 3 years of age [88-101]. These results suggest that individual differences in the development of attention may serve to detect attention deficit disorders as early as by infancy, such as autistic spectrum disorders or attention deficit disorders. Measuring early indicators of executive processes in infancy and toddlerhood can help to identify first signs of alterations in EA. This may also promote prevention by facilitating targeted interventions starting as early as the first year of life. However, existing research mostly involves small sample sizes, and their conclusions very often rely on correlational analyses. Future studies will benefit from increasing sample sizes in order to get higher statistical power, performing appropriated statistical analyses for establishing the predictive value of early measures of EA, exploring developmental trajectories by means of longitudinal researches, and testing a-priori theoretical models (e.g., structural equation modeling, multilevel regression analyses).

Conclusions

Although most the investigation has focused on studying the development of EA from the preschool years onwards, increasing research shows that it is possible to study EA from earlier in development. First signs of EA are already observable from the first year of life. Also, research in the field of cognitive neuroscience is showing that the EA network is functional as early as form infancy. Structural changes undergoing in the prefrontal cortex during the early years are in fact related to the development of EA skills over infancy and toddlerhood. There is also a growing body of literature aiming at predicting later EA and related developmental outcomes, including longitudinal research on the development of EA functions and its implication for later academic achievement, social adjustment, and different developmental disorders.

Despite the rising interest on the development of EA in the first years of life, available research is relatively limited. In the last years, an increasing number of studies adopt longitudinal approaches to address cognitive development. However, there are still few age equivalent measures that could be used from infancy onwards. The development of age equivalent measures for the different EA processes (i.e., conflict processing, inhibitory control, switching) would be necessary in order to expand our understanding of individual differences in developmental trajectories of EA. Furthermore, exploring more robust and adjusted statistical methods to analyze data, together with the increase of sample sizes may lead to stronger models predicting EA development.

Research on the early development of EA has important practical implications. Developing reliable tools to predict the development of executive attention from infancy is key to the early detection of difficulties involving EA. Future research including children at risk for diverse developmental disorders is likely to provide insights for the identification or early signs of dysfunctions in EA, which would allow an earlier start of interventions to prevent or palliate EA-related disorders. Besides, more extensive longitudinal research would be needed to examine individual differences in developmental trajectories. This type of research will very likely help to identify not only individual profiles of children at risk of EA difficulties, but also the constitutional (i.e., temperament, genes, gene x environment interactions) and environmental factors that may serve as protective factors for the optimal development of this fundamental cognitive function.

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References

1. Posner MI, Petersen SE (1990) The attention system of the human brain. Annu Rev Neurosci 13: 25-42.
2. Petersen SE, Posner MI (2012) The attention system of the human brain: 20 years after. Annu Rev Neurosci 35: 73-89.

3. Posner MI, Rothbart MK, Sheese BE, Tang Y (2007) The anterior cingulate gyrus and the mechanism of self-regulation. Cogn Affect Behav Neurosci 7: 391-5.
4. Dosenbach NU, Fair DA, Cohen AL, Schlaggar BL, Petersen SE (2008) A dual-networks architecture of top-down control. Trends Cogn Sci 12: 99-105.
5. Posner MI, Rothbart MK, Sheese BE, Voelker P (2012) Control networks and neuromodulators of early development. Dev Psychol 48: 827-35.
6. Diamond A (2013) Executive Functions. Annu Rev Clin Psychol 64: 135-168.
7. Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A (2000) The Unity and Diversity of Executive Functions and Their Contributions to Complex " Frontal Lobe " Tasks: A Latent Variable Analysis. Cogn Psychol 100: 49-100.
8. Duncan J, Seitz RJ, Kolodny J, Bor D, Herzog H, et al. (2000) A neural basis for general intelligence. Science 289: 457-60.
9. Checa P, Rueda MR (2011) Behavioral and Brain Measures of Executive Attention and School Competence in Late Childhood. Dev Neuropsychol 36: 1018-1032.
10. Rothbart MK, Sheese BE, Rueda MR, Posner MI (2011) Developing Mechanisms of Self-Regulation in Early Life. Emot Rev 3: 207-213.
11. Lengua LJ (2003) Associations among emotionality, self-regulation, adjustment problems, and positive adjustment in middle childhood. J Appl Dev Psychol 24: 595-618.
12. Diamond A (1990) The Development and Neural Bases of Higher Cognitive Functions. Ann N Y Acad Sci 608: 267-317.
13. Diamond A (1991) Frontal Lobe Involvement in Cognitive Changes During the First Year of Life. In: Gibson KR, Petersen AC (eds) Brain Maturation and Cognitive Development: Comparative and Cross-cultural Perspectives. Aldine de Gruyter, New York 127-180.
14. Csibra G, Tucker LA, Johnson MH (1998) Neural correlates of saccade planning infants: a high-density ERP study. Int J Psychophysiol 29: 201-15.
15. Canfield RL, Haith MM (1991) Young infants' visual expectations for symmetric and asymmetric stimulus sequences. Dev Psychol 27: 198-208.
16. Holmboe K, Pasco FRM, Csibra G, Tucker LA, Johnson MH (2008) Freeze-Frame: a new infant inhibition task and its relation to frontal cortex tasks during infancy and early childhood. J Exp Child Psychol 100: 89-114.
17. Kovács AM, Mehler J (2009) Cognitive gains in 7-month-old bilingual infants. Proc Natl Acad Sci U S A 106: 6556-6550.
18. Rueda MR, Posner MI, Rothbart MK (2005) The Development of Executive Attention: Contributions to the Emergence of Self-Regulation. Dev Neuropsychol 28: 573-594.
19. Wynn K (1992) Addition and subtraction by human infants. Nature 358: 749-750.
20. Berger A, Tzur G, Posner MI (2006) Infant brains detect arithmetic errors. Proc Natl Acad Sci U S A 103: 12649-12653.
21. Reid VM, Hoehl S, Grigutsch M, Groendahl A, Parise E, et al. (2009) The neural correlates of infant and adult goal prediction: evidence for semantic processing systems. Dev Psychol 45: 620-629.
22. Gehring WJ, Liu Y, Orr JM, Carp J (2011) The Error-Related Negativity (ERN/Ne). Oxford Handb Event-Related Potential Components.
23. Diamond A (1990) Developmental Time Course in Human Infants and Infant Monkeys, and the Neural Bases of, Inhibitory Control in Reaching. Ann N Y Acad Sci 608: 637-676.
24. Zelazo PD, Reznick JS, Spinazzola J (1998) Representational flexibility and response control in a multistep multilocation search task. Dev Psychol 34: 203-214.
25. Carlson SM (2005) Developmentally sensitive measures of executive function in preschool children. Dev Neuropsychol 28: 595-616.
26. Carlson SM, Mandell DJ, Williams L (2004) Executive function and theory of mind: stability and prediction from ages 2 to 3. Dev Psychol 40: 1105-1122.
27. Conejero Á, Guerra S, Abundis-Gutiérrez A, Rueda MR (2016) Frontal theta activation associated with error detection in toddlers: influence of familial socioeconomic status. Dev Sci.
28. Kochanska G, Murray KT, Harlan ET (2000) Effortful control in early childhood: continuity and change, antecedents, and implications for social development. Dev Psychol 36: 220-232.
29. Hughes C, Ensor R (2005) Executive function and theory of mind in 2 year olds: a family affair? Dev Neuropsychol 28: 645-668.
30. Gerardi-Caulton G (2000) Sensitivity to spatial conflict and the development of self-regulation in children 24À36 months of age. Dev Sci 3: 397-404.
31. Maccoby EE, Dowley EM, Hagen JW, Degerman R (1965) Activity level and intellectual functioning in normal preschool children. Child Dev 761-770.
32. Hughes C (2002) Executive functions and development: Emerging themes. Infant Child Dev 11: 201-209.
33. Dehaene-Lambertz G, Spelke ES (2015) The Infancy of the Human Brain. Neuron 88: 93-109.
34. Doria V, Beckmann CF, Arichi T, Merchant N, Groppo M, et al. (2010) Emergence of resting state networks in the preterm human brain. Proc Natl Acad Sci USA 107: 20015-20020.
35. Dosenbach NUF, Nardos B, Cohen AL, Fair DA, Power JD, et al. (2010) Prediction of individual brain maturity using fMRI. Science 329: 1358-1361.
36. Fair DA, Dosenbach NUF, Church JA, Cohen AL, Brahmbhatt S, et al. (2007) Development of distinct control networks through segregation and integration. Proc Natl Acad Sci USA 104: 13507-13512.
37. Huang H, Shu N, Mishra V, Jeon T, Chalak L, et al. (2015) Development of human brain structural networks through infancy and childhood. Cereb Cortex 25: 1389-1404.
38. O'Muircheartaigh J, Dean DC, Ginestet CE, Walker L, Waskiewicz N, et al. (2014) White matter development and early cognition in babies and toddlers. Hum Brain Mapp 35: 4475-4487.
39. Gilmore JH, Shi F, Woolson SL, Knickmeyer RC, Short SJ, et al. (2012) Longitudinal development of cortical and subcortical gray matter from birth to 2 years. Cereb Cortex 22: 2478-2485.
40. Li G, Lin W, Gilmore JH, Shen D (2015) Spatial Patterns, Longitudinal Development, and Hemispheric Asymmetries of Cortical Thickness in Infants from Birth to 2 Years of Age. J Neurosci 35: 9150-9162.
41. Alcauter S, Lin W, Smith JK, Short SJ, Goldman BD, et al. (2014) Development of thalamocortical connectivity during infancy and its cognitive correlations. J Neurosci 34: 9067-9075.
42. Oakes L, Cashon C, Casasola M, Rakison D (2011) Infant perception and cognition: Recent advances, emerging theories, and future directions. Infant Percept Cogn Recent Adv Emerg Theor Futur Dir.
43. Reynolds GD (2015) Infant visual attention and object recognition. Behav Brain Res 285: 34-43.
44. Carver LJ, Meltzoff AN, Dawson G (2006) Event-related potential (ERP) indices of infants' recognition of familiar and unfamiliar objects in two and three dimensions. Dev Sci 9: 51-62.
45. Hyde DC, Jones BL, Flom R, Porter CL (2011) Neural signatures of face-voice synchrony in 5-month-old human infants. Dev Psychobiol 53: 359-370.
46. Richards JE (2003) Attention affects the recognition of briefly presented visual stimuli in infants: an ERP study. Dev Sci 6: 312-328.
47. Pailing PE, Segalowitz SJ, Dywan J, Davies PL (2002) Error negativity and response control. Psychophysiol 39: 198-206.
48. Bates AT, Patel TP, Liddle PF (2005) External Behavior Monitoring Mirrors Internal Behavior Monitoring Error-Related Negativity for Observed Errors. J Psychophysiol 19: 281-288.
49. Mesika D, Tzur G, Berger A (2014) Electrophysiological evidence for automatic processing of erroneous stimuli. Neuropsychologia 59: 85-92.
50. Nieuwenhuis S, Ridderinkhof KR, Blom J, Band GPH, Kok A (2001) Error-related brain potentials are differentially related to awareness of

response errors: evidence from an antisaccade task. Psychophysiol 38: 752-760.

51. Dehaene S, Posner MI, Tucker DM (1994) Localization of a Neural System for Error Detection and Compensation. Psychol Sci 5: 303-305.
52. Cavanagh JF, Frank MJ (2014) Frontal theta as a mechanism for cognitive control. Trends Cogn Sci 18: 414-421.
53. Posner MI, Tang Y-Y, Lynch G (2014) Mechanisms of white matter change induced by meditation training. Front Psychol 5: 1220.
54. Stroganova TA, Orekhova EV, Posikera IN (1998) Externally and internally controlled attention in infants: an EEG study. Int J Psychophysiol 30: 339-351.
55. Stroganova TA, Orekhova EV, Posikera IN (1999) EEG alpha rhythm in infants. Clin Neurophysiol 110: 997-1012.
56. Colombo J (2001) The development of visual attention in infancy. Annu Rev Psychol 52: 337-367.
57. Posner MI, Rothbart MK, Rueda MR (2013) Developing Attention and Self-Regulation in Infancy and Childhood. In: Neural Circuit Dev. Funct Brain Elsevier 395-411.
58. Hood BM, Atkinson J (1993) Disengaging visual attention in the infant and adult. Infant Behav Dev 16: 405-422.
59. Johnson MH, Posner MI, Rothbart MK (1991) Components of visual orienting in early infancy: contingency learning, anticipatory looking, and disengaging. J Cogn Neurosci 3: 335-344.
60. Atkinson J, Hood B, Wattam-Bell J, Braddick O (1992) Changes in Infants' Ability to Switch Visual Attention in the First Three Months of Life. Perception 21: 643-653.
61. Hunnius S, Geuze RH, van Geert P (2006) Associations between the developmental trajectories of visual scanning and disengagement of attention in infants. Infant Behav Dev 29: 108-125.
62. Courage ML, Reynolds GD, Richards JE (2006) Infants' attention to patterned stimuli: developmental change from 3 to 12 months of age. Child Dev 77: 680-695.
63. Clohessy AB, Posner MI, Rothbart MK (2001) Development of the functional visual field. Acta Psychol (Amst) 106: 51-68.
64. Voelker P, Sheese BE, Rothbart MK, Posner MI (2009) Variations in catechol-O-methyltransferase gene interact with parenting to influence attention in early development. Neuroscience 164: 121-130.
65. McGuigan N, Núñez M (2006) Executive functioning by 18-24-month-old children: effects of inhibition, working memory demands and narrative in a novel detour-reaching task. Infant Child Dev 15: 519-542.
66. Miller SE, Marcovitch S (2015) Examining Executive Function in the Second Year of Life: Coherence , Stability , and Relations to Joint Attention and Language. Dev Psychol 51: 101-114.
67. Rothbart MK, Ziaie H, O'Boyle C (1992) Self-regulation and emotion in infancy. New Dir Child Dev 1992: 7-23.
68. Kochanska G, Coy KC, Murray KT (2001) The development of self-regulation in the first four years of life. Child Dev 72: 1091-1111.
69. Blakey E, Visser I, Carroll DJ (2016) Different Executive Functions Support Different Kinds of Cognitive Flexibility: Evidence From 2-, 3-, and 4-Year-Olds. Child Dev 87: 513-526.
70. Zelazo PD, Frye D, Rapus T (1996) An age-related dissociation between knowing rules and using them. Cogn Dev 11: 37-63.
71. Moriguchi Y, Hiraki K (2009) Neural origin of cognitive shifting in young children. Proc Natl Acad Sci USA 106: 6017-6021.
72. Rueda MR, Checa P, Rothbart MK (2010) Contributions of Attentional Control to Socioemotional and Academic Development. Early Educ Dev 21: 744-764.
73. Margari L, Craig F, Margari F, Legrottaglie AR, Palumbi R, et al. (2016) A review of executive function deficits in autism spectrum disorder and attention-deficit/hyperactivity disorder. Neuropsychiatr Dis Treat 12: 1191.
74. Frick JE, Colombo J, Saxon TF (1999) Individual and developmental differences in disengagement of fixation in early infancy. Child Dev 70: 537-48.
75. Cuevas K, Bell MA (2014) Infant attention and early childhood executive function. Child Dev 85: 397-404.
76. Rose SA, Feldman JF, Jankowski JJ (2012) Implications of Infant Cognition for Executive Functions at Age 11. Psychol Sci 23: 1345-1355.
77. Sigman M, Cohen SE, Beckwith L (1997) Why does infant attention predict adolescent intelligence? Infant Behav Dev 20: 133-140.
78. Ruff HA, Lawson KR (1990) Development of sustained, focused attention in young children during free play. Dev Psychol 26: 85-93.
79. Johansson M, Marciszko C, Gredebäck G, Nyström P, Bohlin G (2015) Sustained attention in infancy as a longitudinal predictor of self-regulatory functions. Infant Behav Dev 41: 1-11.
80. Friedman NP, Miyake A, Robinson JL, Hewitt JK (2011) Developmental trajectories in toddlers' self-restraint predict individual differences in executive functions 14 years later: A behavioral genetic analysis. Dev Psychol 47: 1410-1430.
81. Bornstein MH, Hahn C, Wolke D (2013) Systems and Cascades in Cognitive Development and Academic Achievement. Child Dev 84: 154-162.
82. Fagan JF, Holland CR, Wheeler K (2007) The prediction, from infancy, of adult IQ and achievement. Intelligence 35: 225-231.
83. Mulder H, Hoofs H, Verhagen J, Van der Veen I, Leseman PPM (2014) Psychometric properties and convergent and predictive validity of an executive function test battery for two-year-olds. Front Psychol.
84. Landry R, Bryson SE (2004) Impaired disengagement of attention in young children with autism. J Child Psychol Psychiatry Allied Discip 45: 1115-1122.
85. Elsabbagh M, Fernandes J, Jane Webb S, Dawson G, Charman T, et al. (2013) Disengagement of visual attention in infancy is associated with emerging autism in toddlerhood. Biol Psychiatry 74: 189-194.
86. Sacrey L-AAR, Bryson SE, Zwaigenbaum L (2013) Prospective examination of visual attention during play in infants at high-risk for autism spectrum disorder: a longitudinal study from 6 to 36 months of age. Behav Brain Res 256: 441-450.
87. Papageorgiou KA, Smith TJ, Wu R, Johnson MH, Kirkham NZ, et al. (2014) Individual Differences in Infant Fixation Duration Relate to Attention and Behavioral Control in Childhood. Psychol Sci 25: 1371-1379.
88. Lawson KR, Ruff H (2004) Early attention and negative emotionality predict later cognitive and behavioural function. Int J Behav Dev 28: 157-165.
89. Stroop JR (1935) Studies of interference in serial verbal reactions. J Exp Psychol 18: 643-662.
90. Rueda MR, Fan J, McCandliss BD, Halparin JD, Gruber DB, et al. (2004) Development of attentional networks in childhood. Neuropsychologia 42: 1029-1040.
91. Eriksen BA, Eriksen CW (1974) Effects of noise letters upon the identification of a target letter in a nonsearch task. Percept Psychophys 16: 143-149.
92. Fan J, McCandliss BD, Sommer T, Raz A, Posner MI (2002) Testing the efficiency and independence of attentional networks. J Cogn Neurosci 14: 340-347.
93. Simon JR (1990) The effects of an irrelevant directional cue on human information processing. Adv Psychol 65: 31-86.
94. Jersild AT (1927) Mental set and shift. Arch Psychol.
95. Grant DA, Berg E (1948) A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. J Exp Psychol 38: 404-411.
96. Hallett PE (1978) Primary and secondary saccades to goals defined by instructions. Vision Res 18: 1279-1296.
97. Kochanska G, Murray KT, Coy KC (1997) Inhibitory control as a contributor to conscience in childhood: from toddler to early school age. Child Dev 68: 263-277.
98. Mostofsky SH, Schafer JG, Abrams MT, Goldberg MC, Flower AA, et al. (2003) fMRI evidence that the neural basis of response inhibition is task-dependent. Cogn Brain Res 17: 419-430.

99. Verbruggen F, Logan GD (2008) Response inhibition in the stop-signal paradigm. Trends Cogn Sci 12: 418-424.

100. Mischel W, Metzner R (1962) Preference for delayed reward as a function of age, intelligence, and length of delay interval. J Abnorm Soc Psychol 64: 425-431.

101. Bembenutty H, Karabenick SA (1998) Academic delay of gratification. Learn Individ Differ 10: 329-346.