Attention in Early Development FREE

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Summary

Attention is a complex construct that shows development throughout the life span and undergoes significant changes over the first years of life. The complexity of attentional processes is described by the different systems and brain network theorized to describe the construct (i.e., alerting, orienting, executive attention, and sustained attention).

Evidence of the development of attention in infancy comes from several behavioral paradigms—primarily focused on the analysis of infants' eye gaze—physiological measures, and neuroimaging techniques. Many of the changes in attention rely upon the structural and functional development of brain areas involved in attention processes. Behavioral and physiological signs mark the development of attention and are identifiable very early in life.

The investigation of the typical development of attention is pivotal for the understanding of atypical trajectories that characterize many neurodevelopmental disorders. The individuation of alterations in early visual attention processes may be utilized to guide intervention programs aimed at improving attention and other cognitive domains.

Keywords: visual attention, attentional systems, infancy, looking behavior, EEG/ERP, fNIRS, fMRI, ADHD, ASD

Subjects: Developmental Psychology

Attention Definition and Subtypes

Attention refers to a complex set of behavioral and cognitive processes that allow a discrete aspect of information to be enhanced while ignoring other perceptible information. The organization of attention has been described with different systems to capture the complexity of attentional processes. Posner and Petersen (1990) described the classic model of attention that includes the systems of alerting, orienting, and executive attention. Imaging data have supported the presence in the adult brain of these three networks (Fan et al., 2005), which represent the neural substrate of the functionality of the attentional systems (Posner & Fan, 2007).

Alerting is defined as achieving and maintaining a state of high sensitivity to incoming stimuli. This function has been linked to the thalamic as well as frontal and parietal regions of brain cortex (Fan et al., 2005). Orienting implies the alignment of attention with a selection of information from the sensory signals. This function can occur with (i.e., overt attention) or without (i.e., covert attention) eye movements accompanying the shift of attention. A further distinction of the orienting process is based on the object of attention, which can be a particular location in the space—that is, spatial attention—or a specific object and/or its features—that is, object-based attention (Colombo, 2001).

The orienting system seems to activate both posterior brain areas, which include the superior parietal lobe and temporal parietal junction, and the frontal eye fields (Corbetta & Shulman, 2002). Executive attention involves mechanisms for monitoring and resolving conflict among thoughts, feelings, and responses. This attentional system is usually investigated with tasks that involve conflicts (e.g., the Stroop task) and activate midline frontal areas (anterior cingulate) and the lateral prefrontal cortex (Botvinick et al., 2001; Fan et al., 2005).

Posner and colleagues (1988) suggested that anterior brain areas (i.e., the frontal cortex and its connections with the limbic system) are involved in mechanisms of sustained attention. This attentional system is also referred to as the anterior attention network to distinguish it from the posterior attention network involved in visuo-spatial orienting tasks (for a review see Colombo, 1995). Sustained attention is closely related to the alertness system, which refers to the state of arousal during cognitive processing. The brain-controlled sleep-wake system, metabolic systems, as well as motivation and cognitive processing have a modulatory effect on sustained attention (Oken et al., 2006).

Measures of Attention

Looking behavior was the first measure utilized to investigate infants' cognitive abilities, including the development of attention. The first measure of attention based on looking-time behavior was introduced by Leslie B. Cohen (1972). Two types of attention were identified from the use of infant-controlled paradigms. Black and white checkboards varying for size and number were presented to 4-month-old infants to investigate the degree of complexity that visual stimuli could have to elicit attentive responses. Each stimulus was presented for the duration of the infant's attention to the screen. The latency between presentations provided a measure of the attention-getting process, whereas the duration of the looking behavior was considered as a measure of attention-holding (Cohen, 1972).

The habituation/dishabituation procedure has been used to investigate infants' attention processing. The paradigm relies on the reduction of looking duration and participant's disengagement when subsequent presentations of the same stimulus occur (i.e., habituation). The recovery of responsiveness to a new stimulus following habituation is referred as dishabituation phase. The paradigm was used to investigate the mechanism with which infants' attention habituates and how this process is modulated by the characteristics of the stimuli. It is worth noting that looking behavior is not an exclusive measure of visual attention; rather, it reflects a variety of underlying cognitive processes (Aslin, 2007). Looking behavior is related to the time needed to collect information and generate a mental representation of a stimulus, but it is not sufficient to draw conclusions on the development of specific attentional processes.

A more fine-tuned measure of eye movements can be obtained through eye-tracking tools. Eye trackers estimate the exact point of gaze and track the eye movements over time using the relative position of the corneal reflection and center of the pupil. Similarly, electrooculography provides a physiological measure of the potential difference between two electrodes positioned around the eyes.

Both techniques can be easily implemented with infants to register eye movements and saccades. Saccades are ballistic movements occurring between fixations. Saccades are not sufficient for the control of attention since covert attentional shift can occur even without eye movements. However, attention is necessary for the control of saccades and can shift the goal of a saccade while the saccadic planning is underway. Reflexive saccades are controlled by the visual pathway that goes from the retina to the superior colliculus. This first component of the visual attention system is operational within 3 months of age (Johnson, 1990). On the other hand, voluntary saccades are under the control of attention, involve cortical brain areas (e.g., frontal eye fields, FEF), and emerge later in the first year of life (Richards, 2001a).

Heart rate (HR) activity is another physiological measure utilized in the investigation of infant attention and arousal. Several attention phases have been identified through the analysis of the beats per minute within a single visual fixation and used to distinguish components of infant attention. The HR variations during a look follow a U-shaped pattern. A large deceleration in the HR activity marked the beginning of the attention orienting process (i.e., when the infant is looking at a given stimulus). This initial phase is followed by a sustained lowered HR activity, which characterizes the sustained attention phase. Infants are more engaged in information processing during this deceleration than during other phases of the look. The return of the HR to the pre-stimulus level identified the end of the attentional phase before the infant looks away from the stimulus.

The duration of the orienting and sustained attention periods varied as a function of both stimulus characteristics (e.g., complexity, novelty) and participant’s age (Richards & Casey, 1991). Moreover, individual differences in look duration were related to individual differences in the disengagement of attention and recognition performance. For instance, poor recognition memory in a paired-comparison paradigm was associated with prolonged looking behavior (Colombo et al., 2001). Similarly, the performance of long-looking infants seemed to improve when an increased number of short looks and shift was induced (Jankowski et al., 2001).

The cortical activity associated with the control of saccades and attention has been investigated with electroencephalography (EEG) and event-related potentials (ERPs) recorded on the scalp (Richards, 2000). Pre-saccadic ERPs are of particular interest for the investigation of saccadic planning that precedes eye movements. An early negativity starting up to 1 second before saccade onset and recorded on the vertex seems to reflect the activation of the FEF. A positive slow wave (about 30–300 ms prior to saccade onset) is sometimes recorded on the parietal cortex contralateral to the eye movement.

Another activity contralateral to the eye movement occurs about 10–20 ms prior to saccade, has positive polarity, and is recorded in response to anti-saccades (i.e., saccades with opposite direction to a cue). Positive activity over frontal scalp areas contralateral to the eye movement was shown to develop from 3 to 6 months of age (Richards, 2000). This evidence speaks in favor of an early development of the FEF response in controlling eye movement toward an attended target location. A more accurate localization of the covert orienting process was identified via cortical source analysis. The neural generators of the pre-saccadic ERP component (i.e., P1) were localized in the superior frontal gyrus and showed increased activity in response to cued target locations (Richards, 2005).

The negative central (Nc) component is another ERP often investigated in infant visual attention studies. The Nc appears to be a generic ERP component reflecting attentional engagement, allocation of attentional resources (Ackles & Cook, 2007, 2009; de Haan et al., 2003; Nelson, 1994; Reynolds & Richards, 2005; Richards, 2003a), and sensitivity to both stimulus familiarity (Carver et al., 2003; de Haan & Nelson, 1999; Nelson & Collins, 1992; Nelson & De Haan, 1996; Reynolds & Richards, 2005), and emotional content (de Haan et al., 2004; Grossmann et al., 2007; Xie, McCormick, et al., 2019).

Source analysis studies with infants revealed that the cortical sources of the Nc are localized in the anterior cingulate and other prefrontal regions (Reynolds & Richards, 2005). Moreover, the amplitude of the Nc is modulated by the infants’ attentional status as measured by their heart rate activity. Larger Nc responses were recorded over central and frontal electrodes during HR-defined periods of attention than during inattention (Guy et al., 2016; Reynolds et al., 2010; Reynolds & Richards, 2005, 2009; Richards, 2003a). The Nc amplitude increases in infancy and may reflect the improvement in attention-related activity in the prefrontal cortex (figure 1; Conte et al., 2020; Reynolds & Richards, 2005).

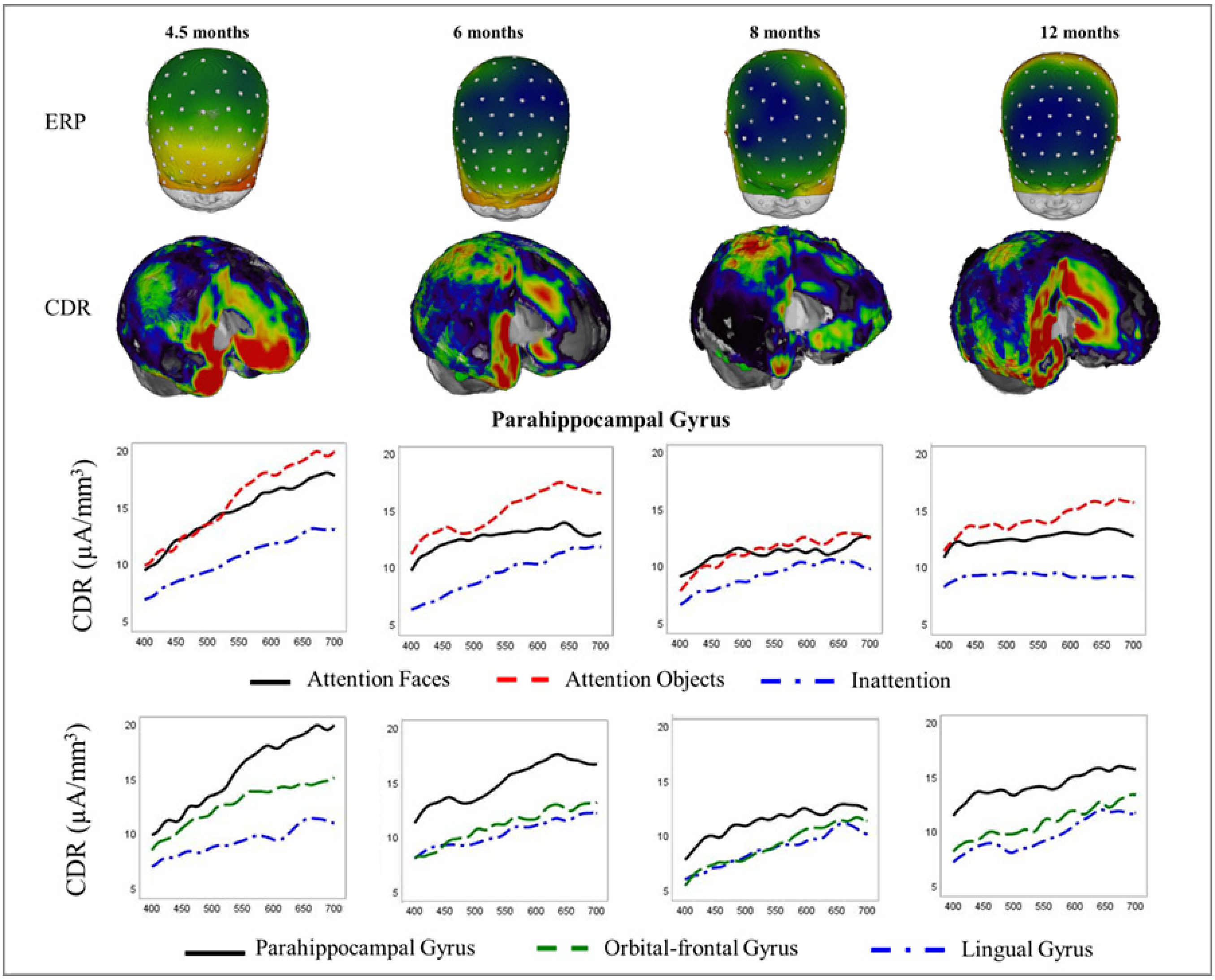

Figure 1. Nc ERP and its source across the first year of life.

Source: Reprinted from Conte et al. (2020).

Several neuroimaging techniques have been implemented to investigate the neural basis of attention in infancy. The EEG is an infant-friendly technique that provides information on attentional processing with high temporal resolution. The development of infant attention has been studied through the investigation of stimulus-locked neural responses (i.e., ERPs), frequency-band oscillations, and functional connectivity between brain areas included in attention networks.

An increase in theta synchronization accompanied by an attenuation of alpha synchronization were recorded during HR-defined periods of sustained attention. The increased theta response started at 8 months and was well established by 10 months of age. Similarly, changes in the alpha-band response started at about 10 months of age and were well established by the end of the first year of life. Source analysis procedures identified the orbital frontal, temporal pole, and ventral temporal regions as neural generators of the theta synchronization. The precuneus, prefrontal cortex, and inferior parietal gyrus were likely the generators of the alpha activity during sustained attention (Xie et al., 2017). These brain areas are part of the default mode network (DMN) in the adult brain.

Connectivity analyses replicated the result of an attenuation of the activity in the DMN during sustained attention. Furthermore, a decrease in the functional connectivity has been reported in the dorsal attention network. Overall, an increase in the strength of functional connectivity of the attentional network characterized the brain development of the second half of the first year of life (Xie, Mallin, & Richards, 2019).

Functional near infrared spectroscopy (fNIRS) is another neuroimaging technique utilized with pediatric populations to understand the functional changes in the infant's brain. Changes in the hemodynamic response occurring in the brain during cognitive processing are measured via optodes positioned on the scalp. Differences in the absorption and scattering of near-infrared light produced by oxyhemoglobin and deoxyhemoglobin changes is used to index the underlying brain function. This technique was implemented to investigate the development of the DMN in infants and toddlers. Results suggested a gradual increase of DMN connectivity between the first and second year of life. These changes over time did not occur in other brain networks (Bulgarelli et al., 2020).

Evidence from EEG, source analysis, and fNIRS studies investigated the neural changes that characterized the development of attention. These techniques contributed to the understanding of cortical attentional processes but are limited in the investigation of subcortical areas. Functional magnetic resonance imaging (fMRI) has the potential to overcome this limitation and investigate brain-wide attentional processes. However, conducting fMRI research with awake infants is challenging for multiple reasons and requires important variations to the commonly used adult protocols (Ellis, Skalaban, Yates, Bejjanki, et al., 2020). For these reasons fMRI evidence in infancy is limited.

Nonetheless, in Ellis et al. (2020), the brain activity in stimulus-driven attentional processes was investigated in 3- to 12-month-old infants. Results showed that frontoparietal (MFG/IFG) and cingulo-opercular (i.e., ACC and basal ganglia) regions were recruited to support stimulus-driven attention in infants. Similar regions were active when adults performed stimulus-driven attentional tasks, suggesting that the functionality of frontal areas in the first year of life is more mature than previously thought (Ellis, Skalaban, Yates, & Turk-Browne, 2020).

Attention Development

Attention develops across the life span, but important changes occur in infancy. The simplest and first-to-develop form of attention is alertness. Alert state refers to the period in which infants are awake and ready to process information. The attainment of the alert state develops late in the gestational period and frequently occurs around 2 to 3 months of age (Colombo, 2001). Alertness in early infancy is mainly initiated by exogenous events and controlled by subcortical pathways. Specifically, the ascending noradrenergic system is linked to the alertness for stimulus input and may be stimulated during common caregiving activities (e.g., rocking the infant). Research with adults showed that increased alertness was linked to an increased activity in the locus coeruleus (Aston-Jones & Cohen, 2005). The locus coeruleus is a brainstem structure and the primary site for the synthesis of the norepinephrine, which is the major neurotransmitter in the infant and adult alerting system (Richards, 2001b).

Another distinctive type of attention involves the orienting and shifting of attention to a particular spatial area of the visual field. Prior behavioral studies have suggested that the orienting system undergoes dramatic changes in the first few months of life and becomes well established by the second half of the first year (Mallin & Richards, 2012; Richards & Hunter, 2002).

Two sub-systems constitute the attention-orienting network. These refer to the “where” system, which selects and moves visual attention to a spatial location (i.e., spatial attention), and the “what” system, which involves attentional mechanisms that lead to the identification of patterns and objects (i.e., object-based attention; Ungerleider & Mishkin, 1982). Behavioral measures and neuroimaging techniques have been utilized in the investigation of the development of the spatial orienting network. Infants gain the abilities to track a moving object, detect an exogenous change in the environment, covertly orient their attention to a location, and voluntarily shift their attention and fixation to an interesting stimulus in their first few months of life.

A significant development in the smooth pursuit tracking occurs between birth and 3–4 months of age (Colombo, 2001; Von Hofsten & Rosander, 1997). Moreover, infants show different patterns of stimulus tracking as a function of infants’ high and low level of arousal when the stimulus speed increases to the highest velocity (Richards & Holley, 1999). The study of infants’ anticipatory saccades suggests the development of cortical eye movement planning pathways in the orienting network during infancy.

Anticipatory saccade was investigated with the visual expectation paradigm (VExP) developed by Haith and colleagues (Haith et al., 1988). In the VExP the stimuli are presented in a sequence following an inherent rule. An anticipatory saccade or look is identified as an eye movement made toward the next stimulus location either before or during the first few hundred milliseconds of the next stimulus presentation. Infants as young as 3 months showed an increased number of anticipatory saccades once they learned the sequence of presentation (Haith & McCarty, 1990). However, the measurement of anticipatory saccade is more reliable and shows important changes in the second half of the first year (Csibra et al., 2001; Rose et al., 2002).

The orienting network was found to impact infants’ ERP responses involved in the early visual processing of stimuli. Richards (2000, 2005) examined 3-, 4.5-, and 6-month-old infants’ P1 and N1 responses to valid, invalid, and neutral trials in a spatial cueing paradigm. Infants at 4.5 and 6 months showed larger P1 and N1 responses for the valid trials than the invalid and neutral trials. The validity effect on these ERP components suggests a facilitation effect of attention orienting on the early visual processing of a stimulus.

Richards (2000, 2005) did not find the validity effect in 3-month-old infants, which suggests that the function of this portion of the orienting network might be immature or difficult to be detected with ERP measures at 3 months. Moreover, variability in the stimulus onset asynchrony (SOA) modulated infants’ neural responses. Short SOA elicited larger P1 and N1 responses to the neural than invalid trials, suggesting the presence of a processing cost effect in that condition. The processing cost effect may be due to the cost of shifting spatial attention to an irrelevant or incongruent location triggered by the invalid cue (Xie & Richards, 2016).

Infant neural responses have been investigated during the saccade planning. Pre-saccadic ERP effects were visible at 4.5 months of age but not earlier. This result suggests that the part of the orienting network responsible for the top-down control of spatial attention may be immature early in life. This finding is comparable to the amplitude increase during pre-saccadic activity from 3 to 6 months (Richards, 2000, 2005). The development of the pre-saccadic ERP component indicates the rapid changes in the orienting network underlying top-down control of spatial attention from 3 to 6 months of age.

The "what" system leads to object recognition and perception (Webster & Ungerleider, 1998); thus, it is often referred as object attention. Infants younger than 2 months of age scan visual stimuli less extensively and show a bias toward the scanning of the external contours of stimuli (Maurer, 1983; Maurer & Salapatek, 1976). The length of familiarization is crucial when the development of object attention and recognition is investigated in infancy. For instance, 3.5-month-old infants preferred the familiar object after 30 seconds of familiarization, while 4.5- and 6.5-month-old infants showed a novelty preference after a similar familiarization procedure (Rose et al., 1982). In addition, less extensive visual scanning between 3 and 6 months of age is linked to a worse recognition performance, possibly because infants rely on local elements or features of visual stimuli (Colombo et al., 2001). Therefore, performing short visual fixations during familiarization seemed to improve recognition memory during subsequent stimulus exposure. This pattern of visual exploration was associated with specific neural responses of the late slow wave (LSW) ERP component over temporal and frontal channels (de Haan, 2007). Short-looking infants between 6 and 7.5 months of age showed larger LSWs to novel compared to familiar objects. On the other hand, the LSW was not modulated by stimulus type in long-looking infants (Reynolds et al., 2011).

Hierarchical patterns have been utilized to better investigate the global and local processing in 6-month-old infants. Hierarchical patterns are composed of smaller figures (local elements) arranged to create larger figures (global elements). The experimental manipulation involved a change between the familiarized and novel stimuli in the global aspects of the stimuli (i.e., novel-global) or in the local elements (i.e., novel-local). Results suggested significant differences in LSW amplitude to novel-global stimuli for short-looking infants while novel-local stimuli elicited LSW amplitude changes in long-looking infants. These findings suggested that individual differences in looking behavior were characterized by different neural responses. Moreover, short-lookers seemed to process global stimulus properties before details, while an opposite pattern characterized the performance of long-lookers (Guy et al., 2013).

Another ERP component frequently investigated in infancy and linked to attentional processing is the Nc. In particular, the Nc responses have been investigated in relation to physiological measures of attention, that is, HR-defined period of attention and inattention. Differences in Nc amplitude were found based on infants' states of attention as measured by their HR activity. Nc was greater in amplitude during attention than during inattention and increased in amplitude between 4.5 and 7.5 months of age (Reynolds et al., 2011). Moreover, the exploration of the preferred stimulus in visual paired comparison tasks was associated with larger Nc responses (Reynolds et al., 2010).

Activity of the Nc component has been extensively investigated in response to face stimuli. Larger Nc responses to an infant's mother's face than a stranger's face have been reported in 6-month-old infants (de Haan & Nelson, 1997, 1999; Webb et al., 2005). Moreover, the salience and emotional content of a face modulated the Nc activity (Nelson & de Haan, 1996; Xie, McCormick, et al., 2019). Overall, the Nc seems to reflect attentional processes that are modulated by the familiarity, recognition, and emotional content of the stimulus.

Attention and Neurodevelopmental Disorders

Visual attention processes are impaired in a variety of neurodevelopmental disorders (e.g., Autism Spectrum Disorder [ASD], attention-deficit hyperactivity disorder [ADHD]). A possible explanation lies in the narrowing effect that attention exerts on the sensory input that is further processed. For this reason, attention is targeted in interventions that aim at altering the trajectory of neurodevelopmental disorders.

Sustained attention deficits are common in both ADHD (Rubia, 2011; Willcutt et al., 2005) and ASD (Corbett & Constantine, 2006; Garretson et al., 1990). These two neurodevelopmental disorders are often diagnosed in comorbidity, with attentional deficits occurring in a range from 28% to 87% across research samples (Frazier et al., 2001; Mansour et al., 2017; Pondé et al., 2010; Simonoff et al., 2008). At the neural level, children with ADHD and children with ASD share deficits in fronto–striato–parietal attention networks and show abnormalities in suppressing the default mode network (DMN; Christakou et al., 2013).

A large body of research has used neuroimaging techniques to examine the neurobiological substrates that underlie attention development in populations with neurodevelopmental disorders. Resting-state functional connectivity MRI (rs-fcMRI) is an fMRI technique that measures spontaneous high-amplitude and low-frequency (< 0.1 Hz) blood-oxygen-level-dependent (BOLD) signal changes when a participant is at rest (Power et al., 2010). This technique has been implemented in the investigation of resting-state functional networks in both typically developing populations and in neurodevelopmental disorders.

A resting-state functional network refers to the co-activation of brain regions—even in the absence of direct structural connectivity between them—during a task-free or resting condition. Resting-state functional networks are usually observed through changes in blood flow inside the brain when a participant is not preforming an explicit task (Fox & Greicius, 2010). Gao and collaborators (2015) examined the development of nine functional networks in the first year of life. Results suggested that the overall maturation of primary sensorimotor/auditory and vision networks was adult-like at birth and showed minimal changes during the first year of life. The attention/default-mode networks were relatively immature at birth and showed substantial changes within the first year of life, while the executive control networks were far from being adult-like even at the end of the first year (Gao et al., 2015).

Many rs-fcMRI studies focused on the default mode network (DMN). Brain regions of the DMN show high activation when participants are at wakeful rest (Buckner et al., 2008), while they become deactivated during goal-directed tasks that increase attentional demand (Raichle & Snyder, 2007). The role of the DMN in sustained attention has been investigated in adults and children. However, the limited applicability of fMRI studies to awake infants has limited the investigation of the relations between the DMN and attention development early in life.

Xu and collaborators (2017) measured the hemodynamic response in the prefrontal cortex (PFC) of 5- to 6-month-old infants via functional near-infrared spectroscopy (fNIRS). Results revealed that the decreased PFC response was of larger magnitude for stimuli with salient features, suggesting the involvement of the PFC in attention tasks (Xu et al., 2017). These results provide important knowledge about the early development of attentional networks, the activity of which may be dysfunctional in children with ADHD.

Specifically, the interactions between the DMN and the cognitive control network have been studied in ADHD children (for a review, see Posner et al., 2014). The DMN and cognitive control network have opposite responses to attentional demands, that is, the activity in the cognitive control network increases as attentional demands increase, while the activity in the DMN is reduced. Several studies found a lack of or absence in temporal segregation between the cognitive control network and DMN in children and adolescents with ADHD when compared to controls (Cao et al., 2009; Sun et al., 2012).

Functional connectivity patterns have been investigated through rs-fcMRI in children with ADHD, those with ASD, and typically developing controls (TDC). Increased functional connectivity was found in the ASD group compared with TDC, and in the ADHD group compared with both ASD and TDC groups. Increased functional connectivity in the limbic and sensory-motor areas characterized the brain response of children with ASD, whereas increased functional connectivity in the frontal and temporal lobes, frontoparietal network, and ventral attention network differentiated the response of children with ADHD and TDC. Machine learning algorithms accurately discriminated among the three groups (Jung et al., 2019).

The development of attention networks in individuals with ASD is characterized by an early hyper-connectivity between regions of the dorsal (DAN) and ventral (VAN) attention networks, followed by a hypo-connectivity in adults. Children with ASD showed increased connectivity between attention and sensory networks, which may reflect reduced functional specialization and network segregation compared to controls. In adulthood the DAN regions seemed to be hypo-connected with extra-network regions, reflecting an immature specialization of the attention network in ASD (Farrant & Uddin, 2016).

Brain functional connectivity has been investigated in infants at high risk for developing ASD, defined as having at least one sibling with a diagnosis of ASD. Functional brain imaging was acquired during natural sleep in high- and low-risk infants at 12 and 24 months of age and analyzed considering 13 putative brain networks. Functional connectivity results were associated with measures of restrictive behavior. Results revealed that high scores for restricted behavior were associated with resting-state patterns in the DMN, DAN, and frontoparietal control network (FPC). Altered dynamics between these networks may provide a possible mechanism for limited cognitive flexibility and rigid and repetitive behaviors and interests in infants at high-risk for ASD (McKinnon et al., 2019).

Additional evidence of atypical development of visual attention comes from behavioral studies with infants at high risk for ASD. Infant siblings of children with autism showed longer latencies to disengage from a central visual stimulus to orient to the periphery (i.e., disengagement effect). The temporal gap preceding the peripheral stimulus facilitated less their reaction times (i.e., facilitation effect) relative to the control group. These results speak in favor of an atypical profile of visual attention in infants at high-risk for ASD (Elsabbagh et al., 2009).

Conclusive inference on early behavioral markers of autism can be drawn only from prospective studies that follow infants who are later diagnosed with ASD. Findings suggested that a difficulty in disengaging attention at 12 months is predictive of social-communicative impairments at 24 months of age. Attention disengagement at 6 months did not show to be predictive of later diagnosis. However, latency to disengage attention from two competing visual stimuli became longer between 6 and 12 months of age in infants who developed ASD relative to controls (Zwaigenbaum et al., 2005).

Overall, both behavioral and neural findings seem to suggest alterations in early visual attention processes in pediatric populations with and at-risk for neurodevelopmental disorders. Future work can determine the effect of targeted visual attention interventions on changing atypical developmental trajectories and producing generalized improvement across multiple cognitive domains.

Conclusion

The development of visual attention is characterized by significant changes in the first year of life and continues across the life span. Behavioral evidence of visual attention development can be identified as early as 2 months of age. The functional activity of neural networks involved in attentional processes increases in the second half of the first year of life and shows adult-like activity around 12 months of age.

Attention networks associated with high-order cognitive functions (e.g., executive control) are rudimental in infancy and require prolonged development over the life span. Nonetheless, the investigation of the developmental pattern of attention could shed light on early atypical manifestations that later characterize the phenotype of several neurodevelopmental disorders.

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