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Eighteen-month-olds' ability to make gaze predictions following distraction or a long delay

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ABSTRACT

The abilities to flexibly allocate attention, select between conflicting stimuli, and make anticipatory gaze movements are important for young children's exploration and learning about their environment. These abilities constitute voluntary control of attention and show marked improvements in the second year of a child's life. Here we investigate the effects of visual distraction and delay on 18-month-olds' ability to predict the location of an occluded target in an experiment that requires switching of attention, and compare their performance to that of adults. Our results demonstrate that by 18 months of age children can readily overcome a previously learned response, even under a condition that involves visual distraction, but have difficulties with correctly updating their prediction when presented with a longer time delay. Further, the experiment shows that, overall, the 18-month-olds' allocation of visual attention is similar to that of adults, the primary difference being that adults demonstrate a superior ability to maintain attention on task and update their predictions over a longer time period.

1. Introduction

In the first years of life, the development of attentional control provides an important mechanism for children's exploration and learning about their environment. Attentional control involves the ability to flexibly allocate attention and suppress conflicting stimuli that interfere with the task at hand. The early development of this ability has been suggested to underpin the development of more complex skills, such as emotional and social regulation (Posner, Rothbart, Sheese, & Voelker, 2012) executive functions (e.g., working memory and inhibition; see Garon, Bryson, & Smith, 2008 for a review), and language development (Salley, Panneton, & Colombo, 2012). Further, deficits in the early development of attentional control may be related to increased risk for developmental disorders (e.g., attention deficit hyperactivity disorder and autism spectrum disorder) (Johnson, 2012).

It is generally believed that brain maturation and increased functional connectivity are accompanying developmental improvements in behavioral control of attention. Resting-state fMRI studies indicate that the neural networks, supporting basic forms of attention control, become functional in infancy. They show a strong increase in connectivity over the first 2 years of life, and follow different developmental trajectories (Gao et al., 2013, 2009; Uddin, Supekar, & Menon, 2010). Functional connectivity between brain areas that support resolution of attentional conflict, such as the suppression of interfering stimuli (e.g., connectivity between the frontal cortex and anterior cingulate gyrus), emerges after 6 months of age and has a protracted development that lasts throughout childhood (Petersen & Posner, 2012; Posner & Fan, 2008).

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One method to study attentional control in infancy and toddlerhood is the assessment of anticipatory gaze, that is, gaze shifts occurring prior to the presentation of an event or stimulus. Studies measuring eye movements have shown that infants can make anticipatory gaze shifts around 4–9 months of age (Johnson, Posner, & Rothbart, 1991; Nelson, 1971; Sheese, Rothbart, Posner, White, & Fraundorf, 2008), depending on the difficulty of the task. In contrast to reactive gaze shifts, anticipatory eye movements are generally thought to rely on voluntary attentional processes and to be an early marker of attentional control. By the end of the first year infants demonstrate improvements in their ability to resolve visual attentional conflict as seen in their enhanced performance on tasks that involve switching gaze response, such as in looking versions of the A-not-B task (e.g., Cuevas & Bell, 2010; Watanabe, Forssman, Green, Bohlin, & von Hofsten, 2012). The A-not-B task requires the ability to cope with conflicting mental representations (i.e., previous hiding location vs. current hiding location) and the suppression of a previously learned response in favor of an updated prediction. Thus, successful performance includes flexibly shifting direction of attention when the target's hiding location is switched from location A to location B, which in turn has been associated with increased activation in the frontal and parietal areas in infancy (Baird et al., 2002; Cuevas & Bell, 2011). Studies using manual search versions of the A-not-B task have shown that by the end of the first year and throughout toddlerhood, children are increasingly able to deal with longer delays between hiding and searching (Marcovitch & Zelazo, 1999), or increasing conflict (Schutte, Spencer, & Schöner, 2003), but they can still be found to make search errors on this task at pre-school age (Espy, Kaufmann, McDiarmid, & Glisky, 1999).

In a recent study (Watanabe et al., 2012), we used a looking version of the A-not-B task to assess 10- and 12-month-old infants' ability to correctly anticipate the reappearance of a hidden target during both pre- (A) and post-switch (B) trials. By using eye-tracking we were able to measure the infants' visual attention to both the correct and incorrect location quantitatively throughout the task. The study showed that an age-related improvement in attentional control takes place between 10 and 12 months of age. This age-related improvement was particularly reflected in less perseverative anticipatory looking (i.e., less anticipatory looking at the incorrect hiding location on the B trials) in the older age group. In one condition the infants were presented with a visual distractor that preceded the reappearance of the target on the B trials and thereby increased the level of attentional conflict of the task. The infants in the visual distractor condition showed more perseverative anticipatory looking compared to the infants in the control condition where no visual distractor was presented. The result also indicated that the 12-month-olds were better than the 10-month-olds at handling the distractor, but also that older infants' ability to overcome distraction was not yet sufficiently developed. This finding suggests that attentional control and the ability to overcome attentional conflict is still under development by the end of the first year. Thus, to further our understanding of this development it would be fruitful to further examine the developmental course of this ability. Current research suggests that marked improvements in the ability to control attention take place between 18 and 24 months of age (Clohessy, Posner, & Rothbart, 2001; Garon et al., 2008; Posner et al., 2012). In line with Colombo's (2001) view, that research on cognitive development gains from focusing on age periods where rapid improvements take place, in the present study we focus on 18-month-old children's ability to control attention and we contrast our results to that from adults and from our previous study on infants.

For the current study we adapted our previously used looking version of the A-not-B task (Watanabe et al., 2012), which included a control and visual distractor condition. Eighteen-month-old children's and adult's anticipatory looking, on four A (pre-switch) and two B (post-switch) trials, was examined following a 3.5 s hiding delay. The A trials were identical, whereas a visually distracting stimulus was added in the visual distractor condition on the B trials. In addition, we included a long delay condition where the duration of the target's hiding delay was extended to 10 s on the B trials. The purpose of adding a longer delay was to assess how the increased time needed to keep information in mind (i.e., the target's correct hiding location) would affect the participants' allocation of anticipatory looking. We presumed that this condition would be more challenging for the participants in terms of working memory demand compared to the control condition. Working memory is an ability that is closely linked to attentional control and these two cognitive processes rely on overlapping brain regions (e.g., parietal and prefrontal cortex) (Corbetta & Shulman, 2002; McNab & Klingberg, 2008). Whereas attentional control is important for selecting between and suppressing conflicting information, working memory is necessary for actively maintaining and retaining information (Kastner et al., 2007). To our knowledge, no previous study has examined how both distraction and an increase in time delay affect 18-month-olds' ability to make correct anticipatory gaze predictions on a task that requires the ability to control visual attention.

Considering our previous findings from 10- to 12-month-olds (Watanabe et al., 2012), we expected the 18-month-olds to correctly anticipate the target's location on the A trials and also on the B trials in the control condition (i.e., a 3.5 s empty hiding interval). In the same study Watanabe et al. (2012) found that the introduction of a distractor deteriorated anticipatory looking performance in 10–12-month-olds. We used the same distractor in the present study to investigate whether the ability to suppress this conflict has matured by 18 months of age. In the long delay condition, we predicted the 18-month-olds to display less accurate anticipatory looking on B trials compared to the children in the control condition. This could be revealed in both more perseverative anticipatory looking and/or less correct anticipatory looking. Finally, given the central role of the maturation of the attentional control system for the current task we expected that the adults would outperform the 18-month-olds across trials (A and B) and conditions. By comparing how the allocation of attention is managed for adults and for children at the age when they presumably are starting to master the task we hope to improve our understanding of the development of attentional control.