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Attention Demands Influence 10- and 12-Month-Old Infants' Perseverative Behavior

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The present study examined the role of attentional demand on infants' perseverative behavior in a noncommunicative looking version of an A-not-B task. The research aimed at clarifying age-related improvements in the attention process that presumably underlies the development of cognitive control. In a between-subjects design, forty 10-month-olds and forty 12-month-olds were assigned to either a distractor or a no-distractor condition as a means of testing the role of attentional load. The authors used an eye tracker to record infants' looking behavior while they anticipated the reappearance of the target of interest as well as continuously throughout the task. The data demonstrated that 10-month-olds show more perseverative looking than do 12-month-olds and that increased attentional demand leads to more perseverative looking. Correct anticipation, however, was not affected by age or distraction. The results also failed to show that 12-month-olds are better than 10-month-olds at handling the increased attentional demand introduced in the distractor condition, in that the effect of the distractor was not larger for the younger infants. Our results are in line with the theoretical view of cognitive control as dependent on a limited attentional resource, which can explain perseverative behaviors in different tasks and at different ages.

Keywords: attention, cognitive control, gaze tracking, infancy, perseveration

During the first years of life, there is a dramatic development of abilities that enable cognitive control of thoughts and actions, making flexible and goal-oriented behavior possible (Diamond, 2006; Welsh & Pennington, 1988). Early improvements in cognitive control have been related to the maturation of the attention systems, which undergo considerable development during the first year (Ruff & Rothbart, 2001). This development, and especially the development of executive attention (Rothbart & Posner, 2001), lays the foundation for higher cognitive functions (for a review, see Garon, Bryson, & Smith, 2008). Brain substrates of cognitive control, or executive attention, have been shown to be primarily located in frontal areas, although there is also evidence for wide-

spread connections to other areas (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Ruede, Posner, Rothbart, & Davis-Stober, 2004).

The development of cognitive control in infancy is often tested in hide-and-search tasks, such as the A-not-B task (Piaget, 1954). In the classical A-not-B task, an infant watches an experimenter hide an object at location A and is encouraged to search for the hidden object after some delay. After repeatedly hiding the object at location A, the object is hidden at location B. An incorrect search at location A on B trials is termed an A-not-B error, or a perseverative error. Infants younger than 10 months typically commit the perseveration error with a delay between hiding and search of 2–5 s. By 12 months of age, infants can tolerate longer delays and respond correctly on the B trials even after 6- to 10-s delays between hiding and search, a result that has been taken to indicate improved cognitive control (Diamond, 1985; Puschina, Orekhova, & Stroganova, 2005).

Aside from issues concerning the developmental course of cognitive control, the perseverative error as such continues to be of theoretical interest (for reviews, see Marcovitch & Zelazo, 1999; Thelen, Schöner, Scheier, & Smith, 2001; Wellman, Cross, & Bartsch, 1986). According to Piaget's (1954) original notion of object permanence, infants believe that the object's appearance is solely contingent on their own action. Alternative explanations for the perseverative error have been suggested, spurring a lively debate (see Marcovitch & Zelazo, 2009, target article with commentaries). In Diamond's (e.g., Diamond, 1990; Diamond, Crutenden, & Neiderman, 1994; Diamond & Doar, 1989) influential

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account, infants perseverate because they have difficulties overcoming a previous successful response. To perform correctly on the B trials, they have to keep the location of the hidden object in working memory and inhibit reaching toward the previously correct location; that is, the two systems coact in determining behavior. In competing process accounts (e.g., hierarchical competing systems model; Marcovitch & Zelazo, 2009; dynamic field theory; Clearfield, Dineva, Smith, Diedrich, & Thelen, 2009; parallel distributed processing model, Munakata, 1998, 2001), the perseverative error is instead understood as a conflict between different systems, in which the competition leads to correct or perseverative behavior in an all-or-nothing fashion. For example, in Munakata's (1998, 2001) parallel distributed processing model, latent memory traces of location A compete with active memory traces (or working memory) of location B. Thus, a core issue in the theoretical debate on infants' perseverative behavior concerns the role of inhibition. More specifically, the debate concerns whether the strength of the mental representation of the B location relative to the strength of the stored information on the A location is sufficient to cause perseveration or whether lack of inhibition of a prepotent response is also necessary (see Marcovitch & Zelazo, 2009).

Another important discussion within the A-not-B literature concerns the role of motor behavior. Studies comparing infants' performance in looking and reaching versions of the A-not-B task have directly or indirectly addressed the importance of these two response modalities (Bell & Adams, 1999; Cuevas & Bell, 2010; Hofstadter & Reznick, 1996; Matthews, Ellis, & Nelson, 1996). Without directly describing the role of inhibition in looking versions of the A-not-B task, Cuevas and Bell (2010) concluded that the underlying attentional and cognitive abilities are essentially the same in looking and reaching versions of the task. In their study, infants performed better on the looking task than the reaching task between 5 and 8 months of age, whereas by 9 months the infants' performance was equivalent across the two tasks. They attributed these findings to slower maturation of the reaching system compared with the visual system, such that cognitive abilities become integrated with the latter system at an earlier age. Thus, it is plausible that in early development, a reaching response is more demanding than a looking response. To reach for an object, one must know where it is, how it is moving, how big it is, and what shape it has. A visual response only requires a representation of the position and motion of the object (Spelke & von Hofsten, 2001).

The interpretation of Cuevas and Bell (2010) regarding the role of task demands is arguably in line with the findings of Berger (2004, 2010), who showed that high motor demands lead to more perseverative behavior in 13-month-olds than do low motor demands. Berger's (2010) findings also suggest a gradual development of infants' ability to reach correctly, where infants, for example, hesitate before they reach, which is in contrast to descriptions of the perseverative error as a dichotomous phenomenon. Berger's interpretation of performance as being dependent on available attentional resources, where high motor or cognitive demands can tax infants' limited resources, is consistent with theories of executive attention in infants (Boudreau & Bushnell, 2000) and adults (Engle, 2002; Kahneman, 1973; Kane & Engle, 2002). The notion of limited attentional resources implies that perseverative behavior may be produced by a number of factors related to task difficulty. Factors, such as overlearning of re-

sponses, that make inhibition difficult and introduce competing information or extraneous stimulation will all challenge the limited attentional resources and therefore influence performance.

Aim of the Present Study

In the present study, we used a gaze-tracking measure of 10- and 12-month-olds' performance in a noncommunicative looking version of an A-not-B task. Gaze tracking is a well-established method and has been used in several studies to measure the direction and time course of infants' gaze as they look at various events (e.g., Baillargeon, 2004; Falck-Ytter, Gredebäck & von Hofsten, 2006; Johnson & Shuwairi, 2009; Kochukhova & Gredebäck, 2007; for a review, see Gredebäck, Johnson, & von Hofsten, 2010). The aim of the study was to clarify age effects in the attention processes that underlie the development of cognitive control (Garon et al., 2008). Just observing an object hiding and reappearing reduces motor involvement substantially. Therefore, our method, which requires only minor motor involvement, should be more sensitive to the role of memory and shifting of visual attention. By tracking the infants' gaze, we are also able to measure their visual attention to location A and location B quantitatively throughout the task, which is an advantage compared with previous looking and reaching studies on the A-not-B paradigm that only measure the final behavior. The end of the first year has often been pointed out as a developmental period in which control of attention emerges (Ruff & Rothbart, 2001). The choice of this age period in the present study is in line with the view of Colombo (2001), who suggested that research on cognitive development profits from studying change across periods of rapid development.

In the present study, we used a between-subjects design with regard to age (10- and 12-month-olds) and condition (whether or not a distractor was presented during the B trials). The infants viewed film clips in which an object (a Mickey Mouse figure) disappeared behind one of two identical occluders to the left or right (A or B). After Mickey had been hiding for 3.5 s, an auditory cue signaled that Mickey would soon reappear. Our method allowed us to observe changes in gaze direction immediately after the object's disappearance and later on during the delay period before its reappearance. Anticipatory gaze movements are made when infants direct their gaze to a location before the object reappears, and these gaze movements are thought to represent cognitive control of attention (Sheese, Rothbart, Posner, White, & Fraundorf, 2008). We expected that the 10- and 12-month-olds would anticipate Mickey's reappearance during the A trials, as younger infants have demonstrated the ability to anticipate the reappearance of occluded objects (Gredebäck & von Hofsten, 2007). Therefore, attention (and gaze) would be directed to the A occluder following the cue signal on the A trials.

Perseveration during B trials in this task would be expressed as looking at the A occluder in response to the auditory signal, and correct anticipation would be indicated by looking at the B occluder. However, as we used a continuous measure of gaze, there is also a possibility of obtaining a nonpreferential gaze response with varying amounts of looking at both occluders during a single trial. As a means of testing the role of attentional load in the control of anticipatory gazing, we included a condition with a visual distractor during the B trials in addition to a condition with just an empty time interval. This way of manipulating the atten-

tional demand is congruent with the notion of interference control as an inherent aspect of executive attention (Engle, 2002; Kane & Engle, 2002; Rothbart & Posner, 2001) as well as with Berger's (2004, 2010) notion of limited attentional resources. Because distraction increases the attentional effort needed to solve the task, we expected an effect of distraction, both in terms of more looking at the A occluder and less looking at the B occluder in both age groups. With regard to development, we hypothesized that the 12-month-olds would have developed more attentional resources than the 10-month-olds and thus show less perseverative looking in both conditions; the 12-month-olds were expected to look less at the A occluder and more at the B occluder than the 10-month-olds. The question of whether the development of attentional resources between 10 and 12 months would allow the older infants to better resist interference was left open. Such a developmental effect would be evident if the effect of distraction was larger for the younger than for the older infants. During the first B trial, we used an extended time period (9 s) between the cue and the object's reappearance. This long B trial preceded the second (short) B trial to allow exploration of the infant's attention strategies in anticipation of Mickey's reappearance without the influence of learning. Whether the predicted effect of distraction and age stated above would be seen beyond the first time period was an exploratory issue. Generally, looking time to both the A and the B occluder was expected to decrease over time with waning anticipation of Mickey's reappearance.

Method

Participants

Forty 10-month-olds ($M = 304.63$ days, $SD = 7.08$ days, 21 girls and 19 boys) and forty 12-month-olds who were born full term were included in the study ($M = 359.20$ days, $SD = 5.47$ days, 21 girls and 19 boys). An additional 43 infants participated in the study but were excluded because of fussiness (15), low gestational age (> 2 weeks before expected birth date; 2), or insufficient looking ($< 50\%$ of the experimental session; 26). All infants were born in Sweden and lived in the area of a university town in central Sweden. In most families, at least one parent had a college education.

Apparatus and Stimuli

The experiment was conducted in a quiet and dimly lit room. Videos were presented on a 17-in. monitor that was part of a cornea reflection eye-tracking system (Tobii T120, Tobii Technology, Sweden). The system records the reflection of near infrared light from the pupil and cornea of both eyes at 60 Hz. The infants were seated at a distance of 60 cm from the monitor. At this distance, the display subtended a $30^\circ \times 24^\circ$ visual angle.

The infants were presented with six short movie clips, interleaved with short attention-grabbing stimuli. The six movie clips were based on the A-not-B paradigm and consisted of four A trials followed by two B trials. A between-subjects design was used in that half the infants in each age group were assigned to a distractor condition during the B trials, whereas the A trials were the same across all participants. At the beginning of each trial, an attractive object, Mickey Mouse (subtending a $3.3^\circ \times 5.2^\circ$ visual angle), was first positioned at the center of the display (the first picture in

Figure 1a). Then Mickey disappeared, accompanied by an upbeat instrumental melody (in major), behind one of two occluders (A and B, subtending a $8.6^\circ \times 7.2^\circ$ visual angle; the second picture in Figure 1a). While Mickey was hiding behind the occluder (the third picture in Figure 1a), no sounds were present. Following a brief delay, a sound cue (a chime) was presented, and shortly thereafter Mickey reappeared (the fourth picture in Figure 1a) accompanied by the same melody as presented previously. The A and B occluders were located at the left and right side of the center, and their locations were counterbalanced across participants. The space between the occluders subtended a horizontal visual angle of 8.9° . Schematic screen images of the movies are presented in Figure 1a, and a schematic time course of the experimental trials is presented in Figure 1b–f.

A trials. During the first four movies (the A trials), Mickey disappeared completely behind occluder A after 5.5 s. After 3.5 s from the disappearance of Mickey, a sound cue was presented. One second after the sound cue, Mickey reappeared from behind occluder A and went back to the center of the display (see Figure 1b). Please note that for the 12-month-olds, Mickey reappeared 2 s after the sound cue. However, in the analyses, the same time window was used (1 s after cue) for anticipatory gaze for both 10- and 12-month-olds to make the comparisons equivalent.¹

B trials. The four A trials were followed by a long and then a short B trial. In the B trials, Mickey disappeared behind the opposite occluder (B) as compared with the A trials. During the long B trial (see Figure 1c–d), the time intervals for Mickey's disappearance and presentation of the sound cue were the same as during the A trials. However, in the long B trial, Mickey did not reappear until 9 s after the sound cue was presented. During the last trial, the short B trial (see Figure 1e–f), the time intervals for Mickey's disappearance, presentation of the sound cue and Mickey's reappearance were the same as in the A trials.

Distractor and no-distractor condition. In the distractor condition (see Figure 1d and 1f), a bouncing ball (the fifth picture in Figure 1a) was presented in the center of the display for 2 s, 0.5 s after the disappearance of Mickey during the B trials. In the no-distractor condition, this bouncing ball was not presented (see Figure 1c and 1e).

Procedure

Families living in the area of a university town in central Sweden and with infants of appropriate age were contacted in writing with a letter describing the study and an invitation to participate. Parents who decided to participate were contacted by telephone, and an appointment was made. Once in the lab, the parent(s) received a verbal description of the study and signed a consent form. The study was approved by the ethics committee of the Research Council in the Humanities and Social Sciences and

¹ The testing of 10-month-olds preceded the testing of 12-month-olds in the present study. Before collecting the 12-month-olds' data, we made a methodological change, so that Mickey reappeared from the occluder 2 s after the sound cue. This methodological change was made to enable analyses of anticipatory gaze during a longer time window and to ensure that a 1-s time window would be sufficient for capturing anticipatory gaze. The conclusions from the analyses with a 1-s time window did not differ from the conclusions based on a 2-s time window.

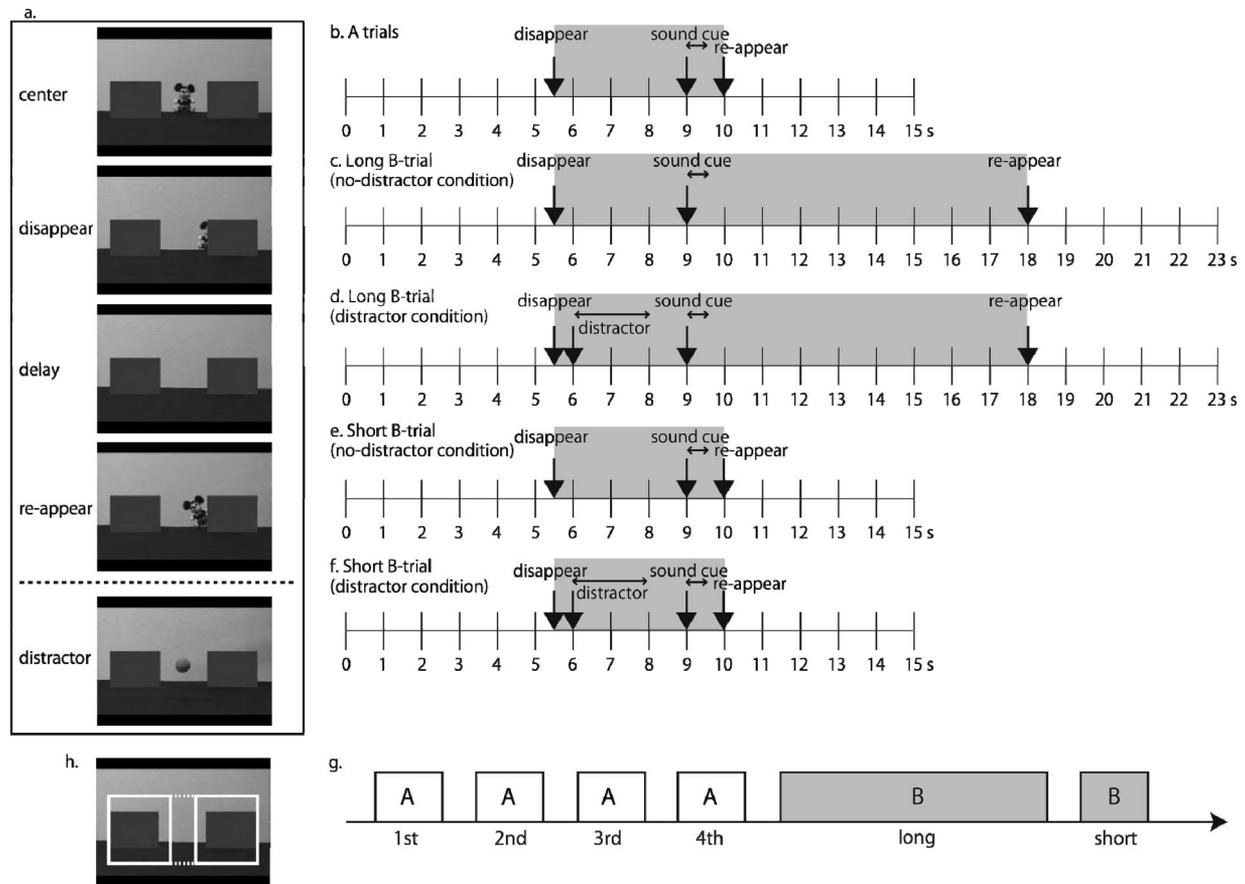


Figure 1. Schematic screen images (a); schematic diagram of A trials (b); schematic diagram of the long B trial in the no-distractor (c) and distractor condition (d); schematic diagram of the second B trial in the no-distractor (e) and distractor condition (f); schematic diagram of the procedure (g); and the center, left, and right areas of interest (h). Note that, in the experiments of 12-month-olds, Mickey reappeared from the occluder 2 s after the sound cue was presented.

was conducted in accordance with ethical standards specified in the 1964 Declaration of Helsinki.

During the experiment, the infant sat in a baby car seat on his or her parent's lap in front of the monitor. Before the experiment started, a calibration procedure was carried out. During the calibration, expanding-contracting checkerboard patterned spheres with accompanying sounds appeared, one at the time, on each of the five calibration points (four in the corners and one in the center of the screen). Any unsuccessfully calibrated points were recalibrated. The experimental session started immediately after a successful calibration procedure, and the infants were presented with the movie clips, which all together were about 2.5 min in duration. Each infant spent approximately 15 min in the lab and received a token worth \$13 as compensation.

Data Analysis

Definition of areas of interest. Three areas of interest (AOI) were defined in order to determine each infant's looking time in these areas during the experiment. These AOIs consisted of a center, left, and right area (see Figure 1h). The left AOI and right

AOI covered the left and right occluder, respectively (subtending a horizontal visual angle of 11.8° and a vertical visual angle of 12.8°). The right and left AOIs were somewhat larger than the actual size of the occluders, taking into account that the infants often anticipated the reappearance of Mickey by looking at the border of the occluder. Between the left and right AOIs was the center AOI (subtending a horizontal visual angle of 2.8° and a vertical angle of 12.8°).

Illustration of raw data. Mean looking time data over successive 500-ms periods was averaged for the 10-month-olds for each AOI area (i.e., center, right, and left), for each trial (i.e., the average of the A trials, the long B trial, and the short B trial) (see Figure 2). The purpose was to give a visualization of what the raw data looked like continuously throughout the task. Because the pattern of the continuous looking throughout the task was similar in the two age groups, data for one age group suffice for purposes

² We have also analyzed the infants' looking time based on a proportional measure, but the conclusion based on these analyses do not differ from the conclusions we draw with the present measure of infants' looking time.

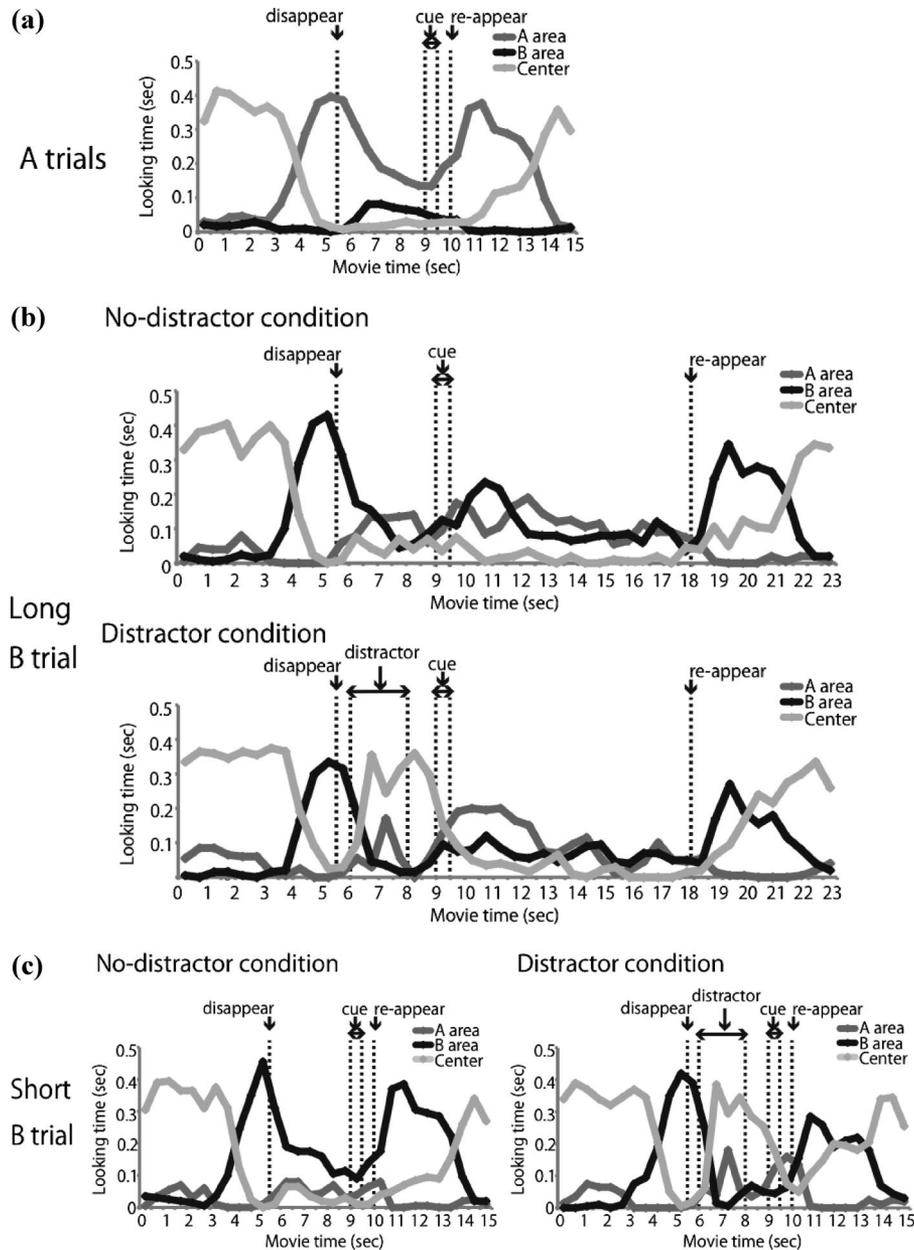


Figure 2. Raw data for 10-month-olds' looking in each area of interest (A, B, and C), (a) during the A trials, (b) during the long B trial for the infants in the no-distractor and the distractor condition, and (c) during the short B trial for the infants in the no-distractor condition and the distractor condition.

of illustration, and only graphs for 10-month-olds are presented. In the main analyses, the infants' mean looking time was used at AOIs for occluder A and B during the A and B trials.

Infants' performance during the A trials. Infants' mean looking time was used at the defined AOIs for occluder A and B during the A trials 1 s after presentation of the sound cue that preceded Mickey's reappearance.² Looking mainly to the A occluder during these trials shows that the infants understand the task and do anticipate the reappearance of Mickey. Furthermore, we wanted to establish the equivalence of performance in the different groups (age and assigned conditions).

Infants' performance during the B trials. First, the infants' looking at the defined AOIs for occluders A and B was analyzed during 1 s before presentation of the cue signal that preceded Mickey's reappearance (i.e., during the time window 8–9 s). This was done to clarify any differences in looking between the age groups and conditions and also to clarify whether the infants fixated their gaze on any of the areas before presentation of the cue signal.

Second, to examine the effect of the visual distractor on the 10- and 12-month-olds' performance during both B trials, the infants' mean looking time was analyzed at the defined AOIs for occluders

A and B during the time window 9–10 s (i.e., 1 s after presentation of the sound cue that preceded Mickey’s reappearance). Third, to clarify changes in attentional strategies during the long B trial, the 10- and 12-month-olds’ mean looking time was analyzed at the defined AOIs for occluders A and B during the time period (9 s) that followed presentation of the sound cue and preceded Mickey’s reappearance. This time period was divided into three time intervals: early time interval (9–12 s, i.e., 0–3 s after presentation of the sound cue), middle time interval (12–15 s, i.e., 3–6 s after presentation of the sound cue), and late time interval (15–18 s, i.e., 6–9 s after presentation of the sound cue).

Results

Figure 2 illustrates raw data for 10-month-olds mean looking time data in each AOI (A area, B area, and C area) during the A trials, the long B trial, and the short B trial. The reason for only showing the data from the 10-month-olds is that their general looking pattern throughout the experiment was similar to that of the 12-month-olds. The only relevant difference in looking is the age effect that we found in relation to anticipatory gaze during the B trials, in which the 12-month-olds showed less looking at the A area. This age effect is illustrated in Figure 3 (top and bottom panel), and relevant analyses are presented below in the sections on anticipatory looking during B trials. For the A trials, it can be seen in Figure 2 that the infants looked at the center of the screen at the stimulus onset, and then transferred their gaze to the oc-

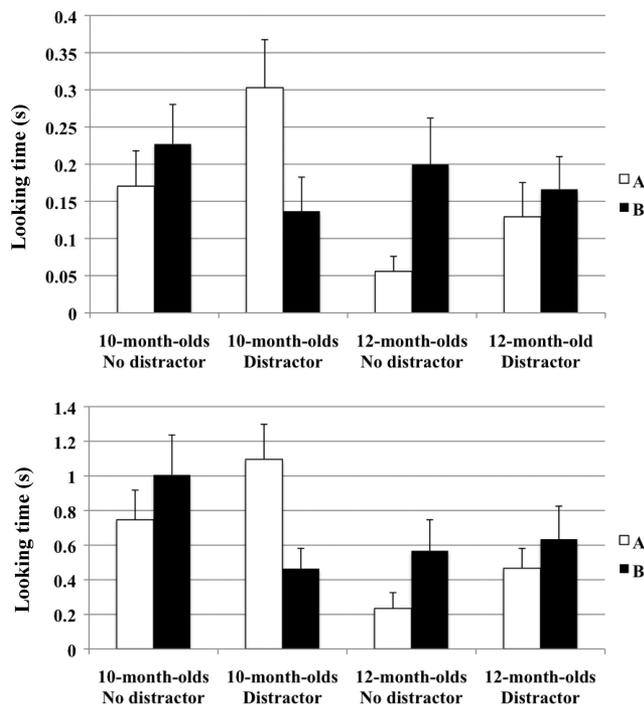


Figure 3. Mean looking time (in seconds) and standard error during 1 s following the sound cue during the B trials (top panel). The white and black bars indicate the A area and the B area, respectively. Mean looking time (in seconds) and standard error during 3 s following the sound cue during the first time interval (0–3 s) in the first B trial (bottom panel). The white and black bars indicate the A area and the B area, respectively.

cluder behind which Mickey disappeared. During the delay period that followed Mickey’s disappearance, the mean looking time to the correct occluder decreased, and the infants demonstrated gaze shifts by looking at the incorrect occluder and the center of the screen as well. The figure also illustrates where the infants looked following the sound cue and how they transferred their gaze to the center of the screen during the post-reappearance period when Mickey moved to the center of the screen.

For the long and short B trial, the mean looking time data illustrate where the 10-month-olds in both the no-distractor and distractor condition looked. The infants in the distractor condition had more looking time at the center of the screen when the visual distractor was presented. However, the data also show gaze shifts during the time preceding the cue signal; that is, the infants did not just fixate their gaze on one particular area. During the 9 s that followed the sound cue in the long B trial, the infants’ looking to the specified AOIs decreased. Decreased looking means that infants looked somewhere else at the screen or outside the screen, which could indicate that they had lost interest in the movie.

Infants’ Performance During the A Trials

To examine the 10- and 12-month-olds’ anticipatory looking during the A trials, we analyzed looking time during 1 s following the sound cue in the first four A trials in a $2 \times 2 \times 2 \times 4$ mixed repeated measures analysis of variance (ANOVA), with age group (between factor; 10 months vs. 12 months), condition (between factor; no-distractor vs. distractor during the B trials that followed), area (within factor; A area vs. B area), and trial (within factor; A1 vs. A2 vs. A3 vs. A4) as independent variables.

Only the main effect of area was significant ($M_A = .30$ s, $M_B = .08$ s), $F(1, 38) = 44.40$, $p = .000$; partial $\eta^2 = .37$ (all other F s < 2.09 , p s $> .15$). This result demonstrates, as expected, that the participants in both age groups anticipated Mickey’s reappearance from occluder A during the four A trials.

Infants’ Performance During the B Trials

Infants’ looking before the cue. To clarify that the infants did not fixate their gaze on any of the areas before presentation of the cue signal, we analyzed the infants’ looking time 1 s before presentation of the sound cue during both B trials. A $2 \times 2 \times 2$ mixed repeated measures ANOVA was carried out, with age (between factor; 10-month-olds vs. 12-month-olds), condition (between factor; no-distractor vs. distractor), and area (within factor; A vs. B) as independent variables. Only the main effect of condition was significant ($total\ looking_{no\ distractor} = .28$ s, $total\ looking_{distractor} = .14$ s), $F(1, 76) = 7.20$, $p = .009$, partial $\eta^2 = .09$ (all other F s < 3.33 , p s $> .07$) (main effect of area, $p = .072$). These results show that infants in the no-distractor condition had higher total looking time at occluders A and B together during the 1 s that preceded the cue signal. They also show that there were no effects of age or condition on preferential looking or fixation on either occluder (A or B) during the time period before presentation of the cue signal that preceded Mickey’s reappearance.

Anticipatory looking 1 s following the cue. To examine the infants’ anticipatory looking during the B trials, we analyzed the infants looking 1 s following the sound. A $2 \times 2 \times 2 \times 2$ mixed repeated measures ANOVA, with age (between factor; 10-month-

olds vs. 12-month-olds), condition (between factor; no distractor vs. distractor), area (within factor; A vs. B), and trial (within factor; B1 vs. B2) as independent variables, was carried out. We found a significant main effect of age group, $F(1, 76) = 4.72, p = .033$, partial $\eta^2 = .06$, and a borderline significant main effect of trial, $F(1, 76) = 3.86, p = .053$, partial $\eta^2 = .05$. This indicates that the 10-month-olds ($M_{10\text{-months}} = .84$ s) had higher overall looking time than did the 12-month-olds ($M_{12\text{-months}} = .55$ s) and that the infants' mean looking time was higher during the 1-s time window in the first B trial ($M_{\text{first B trial}} = .39$ s) compared with the second B trial ($M_{\text{second B trial}} = .30$).

Furthermore, the ANOVA also revealed a significant interaction between area and condition, $F(1, 76) = 4.93, p = .029$, partial $\eta^2 = .06$. To understand the interaction and to test the effect of the distractor, we performed planned comparisons of looking time at occluder A and occluder B between conditions. The result showed that the participants in the distractor condition looked significantly more at the A occluder ($M_{\text{no distractor}} = .11$ s, $M_{\text{distractor}} = .22$ s), $t(78) = 2.08, p = .041$, but there was no significant difference in looking at the B occluder ($M_{\text{no distractor}} = .21$ s, $M_{\text{distractor}} = .15$ s), $t(78) = 1.21, p = .231$; see Figure 3 (top panel).³ The ANOVA also showed a borderline significant interaction between area and age group, $F(1, 76) = 3.83, p = .054$, partial $\eta^2 = .05$. There were no other main effects or interactions ($F_s < 1.11, p_s > .30$). To test our hypothesis of an age effect, we conducted planned comparisons of looking time at occluder A and occluder B between age groups. The results explained the interaction and showed that the 10-month-olds looked more at occluder A than did the 12-month-olds ($M_{10\text{ months}} = .24$ s, $M_{12\text{ months}} = .09$ s), $t(78) = 2.99, p = .004$, but there was no significant difference between age groups in looking time at occluder B ($M_{10\text{ months}} = .18$ s, $M_{12\text{ months}} = .18$ s), $t(78) = 0.20, p = .984$.

Anticipatory looking during the extended time period. We explored the infant's attention strategies in anticipation of Mickey's reappearance during the extended time period (9 s) in the first (long) B trial. The extended time period (9 s) that followed the sound cue was divided into three time intervals, and the infants' mean looking time was entered into a $2 \times 2 \times 2 \times 3$ mixed repeated measures ANOVA, with age (between factor; 10-month-olds vs. 12-month-olds), condition (between factor; no distractor vs. distractor), area (within factor; A vs. B), and time interval (within factor; 0–3 s vs. 3–6 s vs. 6–9 s) as independent variables. The ANOVA revealed significant main effects of time interval, $F(1, 76) = 25.46, p = .00$, partial $\eta^2 = .25$, $M_{0-3} = 1.33$ s, $M_{3-6} = 0.90$ s, $M_{6-9} = 0.77$ s, and age group, $F(1, 76) = 5.66, p = .029$, partial $\eta^2 = .07$, $M_{10\text{ months}} = 1.33$ s, $M_{12\text{ months}} = 0.90$ s. These results show that looking decreased over time and that the 10-month-olds' overall looking time was higher than the 12-month-olds' overall looking time.

The ANOVA also showed a significant interaction between time interval and age group, $F(1, 76) = 7.83, p = .007$, partial $\eta^2 = .09$, and a borderline significant interaction between time interval, condition, area, and age group, $F(1, 76) = 3.61, p = .061$, partial $\eta^2 = .05$ (all other $F_s < 2.09, p_s > .15$). These effects were followed up by analyses related to our hypotheses. First, the research question concerning a possible larger effect of distraction for the 10-month-olds was tested using $2 \times 2 \times 2$ mixed repeated measures ANOVAs for each time interval, with condition, age group, and area as independent variables. This interaction was not

significant in any of the three time intervals ($F_s < 1.84, p_s > .17$). Second, we performed planned comparisons of looking time at occluder A and occluder B during the three time intervals between conditions to test the effect of the distractor. The results showed nonsignificant effects for all intervals, although there was a tendency for infants in the distractor condition to have higher looking time at occluder A than infants in the no-distractor condition in the first time interval (0–3 s), $M_{\text{no distractor}} = 0.49$ s, $M_{\text{distractor}} = 0.78$ s, $t(78) = 1.78, p = .079$ (all other $t_s < 1.28, p_s > .20$; see Figure 3, bottom panel). Third, we tested the effect of age using planned comparisons of looking time at occluder A and B during the three time intervals. The 10-month-olds were found to have higher looking time at occluder A in the first (0–3 s), $M_{10\text{ months}} = 0.92$ s, $M_{12\text{ months}} = 0.35$ s, $t(78) = 3.72, p = .000$, and middle (3–6 s), $M_{10\text{ months}} = 0.68$ s, $M_{12\text{ months}} = 0.38$ s, $t(78) = 2.07, p = .042$, time interval (all other $t_s < .74, p_s > .46$). These analyses show that there was no significant effect to indicate that the older infants manage the distractor better than the younger infants. The 10-month-olds showed more perseverative looking than did the 12-month-olds during the first 6 s of the extended time period. There was no significant difference in looking at the B occluder as an effect of distraction or age.

Discussion

We used a gaze-tracking measure and examined 10- and 12-month-olds' performance in a modified A-not-B task in the present study. We found that (a) as expected, the infants correctly anticipated Mickey's reappearance during the A trials, which demonstrates that they remembered Mickey's hiding location; (b) the 10-month-olds showed more perseverative looking than did the 12-month-olds directly after the cue signals in the B trials (shown during the first 6 s in the extended time period in the first B trial); (c) the infants in the distractor condition displayed more perseverative looking following the sound cue in the B trials compared with the infants in the no-distractor condition; and (d) unexpectedly, the absolute amount of correct anticipation was not affected by age or distraction.

The Infants Anticipated the Objects Reappearance During the A Trials

The infants clearly anticipated Mickey's reappearance at both 10 and 12 months of age during the A trials. The absence of an age

³ One reviewer pointed out that the infants in the distractor condition may have been pulled to looking toward the A area during the presentation of the distractor and that this could explain why the infants in the distractor condition had higher looking time at A following the sound cue. To address this concern, we performed correlations between looking time at area A during the time window 6–8 s (when the distractor was presented in the distractor condition) with looking time at area A following the sound cue (i.e., time window 9–10 s) for the infants in the distractor and no-distractor condition, respectively, during the B trials. None of the correlations were significant ($r_s < .14, p_s > .41$). These results show that the infants' looking at area A during the 6- to 8-s time window was not associated with looking at area A following the sound cue. More specifically, this indicates that the infants in the distractor condition were not pulled to looking toward area A during the presentation of the distractor and that this cannot explain their higher looking time at area A following the sound cue.

effect suggests that there is no developmental difference in the ability to remember and anticipate an object's reappearance during this age span. As there were no trial effects, it seems that the infants understood, rather than learned, where Mickey would reappear. We believe that the infants' correct anticipation of Mickey's reappearance during the A trials can be related to the early development of object representation (Gredebäck & von Hofsten, 2007). Studies of infants' representation of occluded objects have shown that 4-month-olds can learn to predict their reappearance (Johnson & Shuwairi, 2009) and that this ability has improved significantly by 6 months of age (Kochukhova & Gredebäck, 2007).

Effect of Age During the B Trials

In contrast to the A trials, correct anticipation during the B trials is more attention demanding, as it requires the ability to shift the focus of attention and to hold the objects' new location active in memory. As predicted, we found differences in perseverative looking between 10 and 12 months of age, such that the younger infants looked more at the previously correct location (A). This difference in performance between the age groups was found to last over the first 6 s of the extended time period. It was interpreted to reflect the development of the roots of executive control, emerging at the end of the first year (Ruff & Rothbart, 2001). Interestingly, however, age effects were not obtained for correct anticipation, as the 12-month-olds did not look significantly longer at the correct location (B) in anticipation of the object. Thus, we only gained partial support for our hypothesis that 12-month-olds would look less at the A area and more at the B area than the 10-month-olds during the B trials. This result requires further interpretation.

We expected reduced attentional competition as an effect of development, which should result in corresponding effects on perseverative looking (A location) and looking at the correct goal (B). This expectation is in line with the all-or-nothing competition presumed in competing process accounts (e.g., Munakata, 1998, 2001). However, the fact that our findings showed independent effects suggests that partly separate mechanisms are involved. In line with Diamond's (2009) view that inhibition and working memory are jointly responsible for A-not-B performance, our interpretation is that the difference in perseverative looking between 10 and 12 months reflects an improved ability to inhibit a gazing response. Diamond (2009) stressed inhibition of habit as an important aspect of correct performance. In the present case, however, motor involvement was low, meaning that it is not so much a question of inhibition of a motor habit. The fact that the age effect lasted up to 6 s indicates that development involved a somewhat protracted direction of attention, rather than a quick response. As to the mechanism responsible for the active maintenance (over relatively brief delays) of information on the new hiding location (i.e., location B), our results suggest little development between 10 and 12 months.

Our finding of nonparallel effects for perseveration and correct behavior is not easily observed in studies on infants' performance in A-not-B tasks, as a dichotomous measure is used in such tasks, in which infants are reinforced for reaching/gazing toward one location only (e.g., Bell & Adams, 1999; Diamond, 1985; Hofstadter & Reznick, 1996; Pushina, Orekhova, & Stroganova, 2005; but see Berger, 2010). Our continuous measure of behavior, which

allowed for the analysis of shifts in gaze and nonpreferential looking, arguably gives a more detailed understanding of infants' attentional processes in the A-not-B task. In line with Berger's (2010) conclusions, our findings suggest that infants' gazing response in a looking version of the A-not-B task is better described as gradual than as dichotomous.

Effect of Distraction/Attentional Demand During the B Trials

The results support the hypothesis that increased attentional demand would result in more perseverative looking, and this is in line with theoretical views claiming that cognitive control is dependent on a limited attentional resource (Berger, 2004, 2010; Boudreau & Bushnell, 2000; Kane & Engle, 2002). This finding shows that the increased attentional demand in the distractor condition, compared with the no-distractor condition, taxes the infants' ability to selectively attend to the correct location and to control anticipatory behavior. Again, however, the effect was observed for perseverative looking and not for correct looking. In line with our above interpretation of the developmental nonparallel effect, we suggest that the effect of distraction was to make inhibition of the response to the cue more difficult, because attentional resources were occupied by the interfering stimulus (cf. Kane & Engle, 2002). An important finding in this context was that the older infants were not better at handling the distraction compared with the younger infants. As can be seen in Figure 3 (top and bottom panel), there is some indication of development with regard to overcoming the effect of the distractor at 12 months, but the effect was not strong enough to yield a significant three-way interaction of age, condition, and area. This suggests that although the ability to overcome habitual responses was better at 12 months of age, the attentional resources available were still insufficient to overcome the brief visual interference.

General Discussion

The abilities to shift focus of attention and actively maintain information in working memory, despite distractions in the environment, are necessary first steps in mastering flexible and goal-directed behavior. As discussed by Rothbart and Posner (2001), these abilities also lay the ground for self-regulation of emotions. When and how these abilities emerge is important for understanding the development of cognitive control in humans. Our findings are in accordance with previous studies using the classical A-not-B and other search tasks showing that important development occurs between 10 and 12 months, and they indicate that examining performance in older children would help us understand the development of attentional resources in relation to resistance to interference. Furthermore, the results suggest that one fruitful research agenda would be to study the interplay of delay and interference in this age range. As has been pointed out by previous researchers, goal-directed behaviors require the integration of several processes, such as attention, memory, perception, and action (Thelen et al., 2001; Thelen & Smith, 1996; von Hofsten, 2003). Our findings do not invalidate the contribution of other cognitive and motor processes, but we suggest that the role of attention demands has been overlooked in most studies on infants' perseverative behavior.

Limitations

Some limitations of our study should be noted. Data from a number of infants had to be discarded due to fussing and insufficient looking, which may mean that the task was not sufficiently interesting. This, in turn, may mean that the results reflect the performance of infants with relatively good sustained attention ability and/or temperamental low irritability. Another issue concerns the fact that a 2-s time window was used to record anticipatory looking in the 12-month-olds, meaning that they waited longer for the reappearance of Mickey than did the 10-month-olds, for whom the wait was 1 s. This may have affected memory for the correct location at the B trials and contributed to the absence of an age effect for correct looking. However, there was no age difference in performance for the A trials, and using the 2-s data for the 12-month-olds did not change the conclusions. Although the independent group design of the study is not a direct limitation, additional information may be obtained using repeated measurement, especially with regard to longitudinal effects.

Conclusion

To summarize, our study demonstrates that increased attention demands lead to more perseverative behavior in infants and suggests that improvements in control of anticipatory behavior between 10 and 12 months of age involve development of an inhibitory process as part of the development of executive attention. Our findings are in accordance with the view that infants' correct or perseverative behavior during an A-not-B task is best described as continuous rather than dichotomous. Our results are consistent with the perspective that the taxing of limited attentional resources is an important factor underlying the perseverative behaviors found in various contexts and age groups (Berger, 2004, 2010; Boudreau & Bushnell, 2000).

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