COMPARABLE PERFORMANCE ON LOOKING AND REACHING VERSIONS OF THE A-NOT-B TASK AT 8 MONTHS OF AGE

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The neuropsychological model of A-not-B performance focuses on the maturation of the frontal lobe and the development of skills associated with working memory, inhibition, and attention. These cognitive skills are essential for A-not-B performance regardless of the search modality required to exhibit object knowledge. This study used a within-subjects design to examine 8-month-old infants' performance on looking and reaching versions of the A-not-B task. In both Experiment 1 (n = 62) and Experiment 2 (n = 47), there were no differences in A-not-B performance on looking and reaching versions of the task. These data suggest that the looking and reaching versions of the A-not-B task measure comparable cognitive abilities at 8 months of age.

object permanence A-not-B task frontal lobe working memory inhibition attention

Piaget's notions of object permanence have inspired a wealth of research concerning the development of object concept and, specifically, the A-not-B reaching error. The situations under which the A-not-B error occurs have been subject to meta-analyses (Marcovitch & Zelazo, in press; Wellman, Cross, & Bartsch, 1986) and the explanations for this

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INFANT BEHAVIOR & DEVELOPMENT 22 (2), 1999, 221–235
ISSN 0163-6383

counter-intuitive search behavior have been numerous. One account for the A-not-B error is the neuropsychological perspective (e.g., Bell & Fox, 1992, 1997; Diamond, 1990a, 1990b, 1991). This viewpoint focuses on the maturation of the dorsolateral prefrontal cortex (DLPC) and corresponding skills of working memory and inhibitory control as being major contributors to A-not-B object permanence performance (Diamond, Prevor, Callender, & Druin, 1997; Diamond, Cruttenden, & Neiderman, 1994). Thus, not only do infants need to keep the current location of a hidden object in working memory throughout different manipulations of a hiding site, but they must also inhibit reaching back toward a previously rewarded hiding site when they see the object being hidden in a different spatial location. While this neuropsychological perspective has been used to explain A-not-B performance in the classic reaching task, it may also be useful for explaining task performance under other response modalities. The goal of this study was to examine infants' performance on a looking version of the A-not-B task relative to the same infants' performance on the classic reaching version.

Diamond (1991) has proposed that the concepts of object and space are understood by infants long before they can actually be demonstrated. Thus, she has suggested that the reaching behaviors associated with the demonstration of object permanence are evident only with maturation of the DLPC. In anecdotal information, Diamond (1990a, 1991) has noted that a few infants will sometimes look at the correct "B" hiding location during the A-not-B task while reaching toward the incorrect "A" location. She has interpreted this behavior as indicating that, contrary to Piaget's notion, infants actually do understand object permanence but are unable to display that knowledge with their reaching behaviors.

Contrary to the Piagetian notion that young infants lack knowledge about how objects exist in the physical world, Baillargeon (1995) has contended that young infants do have a great deal of understanding. Using a violation-of-expectation paradigm, Baillargeon has compared infant gaze duration to "possible" and "impossible" events and demonstrated that 8-month-old infants look longer at the "impossible event," where an object is retrieved from one location after having been hidden at a different location (Baillargeon & Graber, 1988). Baillargeon has shown that infants as young as 5 months of age look reliably longer at the "impossible event" of a rotating screen that appears to complete a 180-degree drawbridge-like rotation despite the apparent presence of a box in the rotation pathway (Baillargeon, Spelke, & Wasserman, 1985). This finding has been replicated with 3.5- and 4.5-month-old infants (Baillargeon, 1987).

The interpretation of these and similar results usually has focused on the mental representation of the object and the notion that infants must have some understanding of object permanence in order to have a longer gaze duration to the "impossible event" (e.g., Baillargeon, 1987; Baillargeon et al., 1985). A corollary to this finding is that infants may exhibit "advanced" cognitive concepts at an early age under the appropriate conditions. Such conditions usually involve the oculomotor response, which may be "more sensitive" in detecting early cognitive abilities than the reaching response, which requires the coordination of oculomotor responses with gross motor responses (Hofstadter & Reznick, 1996). Indeed, Baillargeon has proposed that infants perform poorly on the classic Piagetian A-not-B reaching task because they have difficulty planning manual means-ends search sequences (Baillargeon, Graber, DeVos, & Black, 1990).

Comparing performance on the classic A-not-B task of object permanence with performance on a violation-of-expectation version of A-not-B, Ahmed and Ruffman (1998) reported that 8- to 12-month-old infants exhibited longer looking times to "impossible events" in the looking paradigm at the delays in which the same infants searched incorrectly on the reaching version of the A-not-B task. The researchers proposed that infant success on the violation paradigm involves a reaction (i.e., recognition memory), while the manual search task involves a deliberate recall (i.e., working memory).

Munakata has attempted to explain these types of findings of enhanced performance on looking versions of the task (i.e., violation-of-expectations paradigm) using the notion of graded representations (Munakata, McClelland, Johnson, & Siegler, 1997). The violation-of-expectations looking version of the task may have a lower threshold of representation relative to the reaching version and, thus, may require a simpler response. According to Munakata, knowledge of object location is graded and embedded in specific behavioral processes. Developmental changes in performance on the A-not-B task result from the fortification of the links between knowledge representation and response output. Thus, when the links are weaker, the easier looking response in the violation-of-expectations paradigm is more evident at younger ages, with the more difficult reaching response requiring stronger links between internal representations and motor responses.

Recently the methodology used in the violation-of-expectations paradigm has come under intense scrutiny. Some developmental researchers have suggested that the methodology may be more appropriate for examining familiarity preferences (Bogartz, Shinsky, & Speaker, 1997) and simple perceptual characteristics of the stimuli (Cohen & Cashon, 1998) than for examining knowledge of the permanence of objects. A looking task that requires the infant to recall where the object is hidden, rather than recognize that a spatial violation has occurred, may be a better comparison to the classic reaching task. From a neuropsychological point of view, the cognitive skills required to "search" on a looking task (i.e., working memory, inhibition, attention) may be similar to those required to "search" on a reaching task.

Indeed, some researchers have hypothesized that the reaching and looking responses required to demonstrate the object concept emerge from the same underlying representation, with the reaching response being more physiologically and psychologically complicated than the direction-of-gaze response that might be used in A-not-B assessments (e.g., Diamond, 1990a, 1991; Hofstadter & Reznick, 1996; Munakata et al., 1997). Thus, when knowledge of object permanence is assessed via looking, infants should exhibit this knowledge at a younger age than Piaget reported. Likewise, older infants should exhibit even more proficient performance on object permanence via looking relative to reaching. From a neuropsychological perspective, however, if working memory and inhibition are essential to task performance, why should these skills be evident only during reaching versions of the task and not during looking versions? To make comparisons between looking and reaching task modalities used in A-not-B assessment, it is necessary to address an additional cognitive skill essential for performance on both looking and reaching tasks. That skill is attention. Nelson and Dukette (1998) have noted that attention and memory share many neural substrates. Although the typical pattern is to study these two cognitive abilities separately, Nelson and Dukette note that it is difficult to study memory in the absence of attention.

Using Schiller's (1985) model of the neuroanatomy of oculomotor control, both Richards (1990; Richards & Hunter, 1998) and Johnson (1990, 1995) have outlined the development of visual attention in early infancy. Both models involve the neural development of infant eye movements and demonstrate how infant saccades develop from being under the external control of environmental stimuli to being under endogenous control with respect to the developing cognitive abilities of the infant, such as memory (Johnson, 1995). For example, following partial cortical involvement in visual attention from the newborn period, the visual pathway involving the frontal eye fields (FEF) develops by 3 months of age to the point where the infant begins to make target-directed saccades (Richards & Hunter, 1998) and anticipatory eye movements (Johnson, 1990). Johnson (1995) also has noted that the development of this pathway allows the infant to learn sequences of looking patterns. This may be particularly important to a looking version of the A-not-B task. In a looking version of the task, the experimenter may hide a toy in one location and, after the infant makes two or more successful looks to the correct location "A," the experimenter will switch and hide the toy in location "B" (e.g., Matthews, Ellis, & Nelson, 1996). It may be that immature visual pathways associated with the FEF allow for the A-not-B error in a looking version of the classic task.

Johnson (1995; Johnson, Posner, & Rothbart, 1991) noted a developmental shift around 4 months of age when infants begin to use memory abilities in endogenous, target-directed shifts of attention. Although Richards (Richards & Hunter, 1998) reported that these target-directed FEF saccades appear to reach adult-like levels of maturity by 6 to 9 months of age, the additional memory load required by the A-not-B task may make these target-directed saccades less accurate. Indeed, Funahashi has noted FEF involvement in the working memory associated with the oculomotor delayed response task in non-human primates (Funahashi, Bruce, & Goldman-Rakic, 1989, 1993; Funahashi, Chafee, & Goldman-Rakic, 1993). Thus, it appears that there is frontal lobe involvement in both the looking and reaching versions of the task; DLPC in the reaching version and FEF in the looking version. Task modality may *not* be the crucial factor in performance. Frontal lobe maturation may be the determining factor. If that is the case, then there may be little difference between looking and reaching performance on the task.

Recently, two groups of researchers have compared performance on the classic reaching version of the A-not-B task with performance on a looking version of the task. The looking version in each study was very similar to the reaching version of the task and, thus, did not utilize the violation-of-expectations methodology. In a between-subjects design, Hofstadter & Reznick (1996) reported that a cross-sectional group of infants (ages 5, 7, 9, and 11 months) were more likely to search at the correct well on the looking version of the task at each age relative to a same-age group of infants' performance on the reaching version.[1] The same testing apparatus was used for each group of infants, with modifications to prevent the infants in the looking group from touching the wells. Infants did tend to make some search errors, however, during the looking response. Hofstadter and Reznick (1996) suggested looking and reaching may be alternative assessments of the same cognitive construct and, thus, can be considered to be different aspects of the same biological system. Further, they suggested that the pathways from the prefrontal cortex that control reaching may be more vulnerable than the pathways from the prefrontal cortex that control looking.

While Hofstadter and Reznick (1996) reported better performance on a looking version of their object permanence task than on the reaching version, this finding is not consistent with the other study comparing reaching and looking. Matthews et al. (1996) used a longitudinal design to compare healthy preterm and full-term infants' performance on a battery of cognitive measures that included the classic reaching A-not-B task and a looking version of the task. In contrast to Hofstadter and Reznick (1996), these researchers reported that performance on the looking and reaching versions of the object permanence task was essentially the same at each age from approximately 6.5 to 14 months. That is, there was no advantage in performance with the looking version of the task in their longitudinal study. Because of this finding, Matthews et al. (1996) questioned the assumption that looking and reaching in the A-not-B task proceed from different underlying representations. Specifically, they questioned the notion that looking is a more accurate reflection of knowledge, while reaching is contaminated from representations of previous trials.

Thus, the two studies that have compared reaching and looking performance have different outcomes. It may be, however, that the *between-subjects* design used by Hofstadter and Reznick (1996) can explain the results.

There are several accounts in the developmental literature of individual differences in A-not-B performance among same-age infants. In the initial publication of her longitudinal study of A-not-B performance, Diamond (1985) noted that the A-not-B error occurred at a 10-second delay at 12 months of age. A look at her data (Diamond, 1985, table 4, p. 877) reveals a range of 5 to 12 seconds. Bell and Fox (1992) focused on individual differences in frontal lobe development in their longitudinal study and noted a "long delay group" of infants (tolerating a 13-second delay in A-not-B performance at 12 months of age) and a "short delay group" (tolerating a 3-second delay at 12 months of age). There were frontal EEG differences across age (7–12 months) between these two groups of infants.

In another study, Bell and Fox (1997) focused on individual differences in 8-month-old infants' performances on the A-not-B task and again reported frontal EEG differences between infants successful on the A-not-B task and infants making the A-not-B error. Bell and Fox (1997) highlighted the distribution of A-not-B performance among same-age infants (Figure 1, p. 292). Because performance is so variable among same-age infants, it is imperative that the research design examining looking performance relative to reaching performance utilize *within-subjects* methodology.

The purpose of Experiment 1 was to compare 8-month-old infants' performance on the classic reaching version of the A-not-B task with performance on a looking version of the task using a within-subjects research design. Using the neuropsychological model of task performance, it was hypothesized that there would be comparable performance on looking and reaching versions of the task. Although the null hypothesis is difficult to interpret, it is critical for the neuropsychological model. Thus, the plan of action was to implement Experiment 1 to assess looking and reaching performance on the A-not-B task and then to replicate the expected null findings with Experiment 2.

EXPERIMENT 1

Method

Participants

Sixty-two healthy 8-month-old infants (33 male, 29 female; 53 Caucasian, 5 African-American, 3 Asian, 1 Hispanic) were participants for this study. Infants were born to middle- and upper-middle-class parents. All parents had at least a high school diploma (mothers: 18% high school diploma, 68% bachelor's degree, 14% graduate degree; fathers: 27% high school diploma, 68% bachelor's degree, 21% graduate degree). Infants were recruited via birth announcements placed in local Columbia, South Carolina newspapers. All infants were born within 3 weeks of their calculated due dates and were healthy at the time of testing. All infants were seen when they were between 8.0 and 8.5 months of age, so that only 2 weeks separated the oldest and youngest infants in the study. One additional infant was recruited for this study but was not included in the analyses because he cried and would not do the looking version of the task. All infants were given a small toy for their participation in the study.

Infants were assessed on both the classic reaching version and a looking version of the A-not-B object permanence task in this within-subjects design. Order of assessment was counter-balanced among infants.

Reaching Version of the A-not-B Task

Details of the reaching assessment are similar to those noted by Bell and Fox (1997). Each infant was tested on the following object permanence scale, adapted from Kermoian and Campos (1988), which was constructed to demonstrate a wide range of individual differences in object permanence performance in 8-month-old infants:

1. *Object partially covered with one cloth.*
2. *Object completely covered with one cloth.*
3. *Object hidden under one of two identical cloths.*
4. *A-not-B with 0 delay.*
5. *A-not-B with 2-second delay.*
6. *A-not-B with 4-second delay.*

The Permanence of Objects scale of the Ordinal Scales of Psychological Development designed by Uzgiris and Hunt (1975) was used as a guide for object permanence scale items 1–3 above. During testing, the infant was seated on the parent's lap at a table. The examiner was seated opposite the infant and offered the infant a small attractive toy, such as a brightly colored rattle or squeaky toy. After the infant manipulated the toy briefly, the examiner removed the toy and administered object permanence scale items 1–3 using the following procedures:

1. *Finding an object that was partially covered:* The examiner placed the toy in front of the child and covered it with one cloth in such a way that a small portion of the object remained visible.
2. *Finding an object that was completely covered:* The examiner placed the toy in front of the child and covered it with one cloth so that it was no longer visible.
3. *Finding an object that was completely covered with a single screen in two places:* The examiner placed the toy under one of two identical cloths.

The examiner signaled the beginning of a trial for each of the first three tasks on the object permanence scale by holding up a toy to attract the infant's attention. The experimenter then administered the task. If the infant's attention was lost during the trial, the examiner regained the attention and proceeded with scale administration. Each infant was required to successfully retrieve the toy from the correct cloth in two out of three trials to be declared competent at a specific object permanence scale item. Infants were rewarded for a correct reach with praise and clapping from the experimenter. They also were allowed to briefly manipulate the toy prior to the next hiding. Infants were not allowed to manipulate the toy after incorrect reaches.

Upon successful completion of object permanence scale item 3 above, the A-not-B procedure began. Items 4–6 of the object permanence scale used in this study employed an A-not-B task procedure modeled after the standard two-location task commonly used in the developmental psychology literature; i.e., identical covers and backgrounds, two hiding locations horizontally oriented, and object hidden at the same location on all A trials and then hidden at the other location on the B trial (Marcovitch & Zelazo, in press; Wellman et al., 1986). For this study, the A-not-B task apparatus was a white, cardboard box that measured 47.5 cm (L) × 22.5 cm (W) × 7.5 cm (D). Embedded in the box were two wells 9.5 cm in diameter, 7.5 cm deep, and 29 cm apart from center to center. White fabric cloths used to cover the wells measured 20 cm square. The box was positioned on an adjustable height table that was raised and lowered so that each individual infant could see inside the hiding wells.

The A-not-B task apparatus was placed in front of the infant on the table so that the center of the apparatus was at midline and the cloths covering each well were within reach of the infant. The examiner was seated on the opposite side of the table facing the infant and parent. A large assembly of toys sized to fit in the apparatus wells was accessible to the experimenter. After two successful retrievals at side A, the toy was then hidden in the opposite well B. Infants who successfully recovered the toy from the B well in two out of three A-A-B trials (i.e., did not make the A-not-B error) were then tested with a 2-second delay. Subsequent delays were initiated until the infant made the A-not-B error in two out of three trials at any given delay. Delay was incremented in 2-second intervals throughout the study. For the present study, each infant was required to successfully retrieve the toy from the B well in two out of three A-A-B trials to be declared competent at a given delay.

Using a procedure similar to that of Diamond (1985) and Bell and Fox (1992, 1997), a distractor was employed after each hiding of the toy to break visual fixation to the hidden object. For scale items 1–3 and for the no-delay condition of A-not-B, the mother held the infant's hands while the experimenter called the infant's name to briefly divert the infant's gaze from the hiding site. Immediately after diverting the infant's gaze the examiner asked, "Where's the toy?" Under delay conditions, the mother held the infant's hands while the experimenter called the infant's name, clapped her hands, and counted out the delay period to divert the infant's gaze from the well. After the delay period the experimenter asked, "Where's the toy?" This question was the cue to the mother to release her infant's hands and permit her child to search. Diamond (1985) has argued that a distractor is necessary because visual fixation to the correct well can be used to simplify the A-not-B task. Thus, the "no delay" scale item 4 did have a slight delay as the infant's gaze was broken from the hiding site and the question asked.

Object permanence testing was stopped after the infant failed two out of three trials at a particular task on the object permanence scale or until the infant achieved success on two out of three trials at 4-second delay. Uzgiris and Hunt (1975) have demonstrated the ordinal nature of object permanence items 1–3 above, and Diamond (1985) has shown that the range of delay producing the A-not-B error in any one infant at a particular testing session is small. Infants were assigned a score equal to the highest level completed on the object permanence scale. For example, an infant whose highest level of performance was success on A-not-B (i.e., there was *no* A-not-B error) with "0 delay" received a score of 4.

While behavioral coding was necessarily accomplished by the experimenter during the course of assessment (i.e., the pattern of hidings was dependent on infant performance), additional coding of the reaching object permanence scale was done from the videotape of the laboratory session by the second author and a graduate research assistant. This additional coding was accomplished as a reliability check on the pattern of hidings used by the experimenter and involved coding of each infant's performance by both coders. The percentage of agreement between the two coders for the 62 infants in the study was 95%. The three disagreements in coding were discussed by the authors, with final determination of object permanence reaching score made by the first author.

Looking Version of the A-not-B Task

In this version of the task, the infant "searched" for the hidden toy with eyes rather than hands. The testing apparatus was a table measuring 90 cm (L) $\times$ 60 cm (W) $\times$ 75 cm (H), and the hiding sites were two bright orange and blue plastic tubs that measured 17 cm in diameter and 11 cm deep. The infant sat on the parent's lap 1.1 m from the edge of the testing table while the experimenter manipulated a mechanical toy and hid it under one of the two bright orange and blue plastic tubs.

After the toy was hidden, the infant's gaze to the hiding site was broken and brought to midline by the experimenter's calling the infant's name. The direction of the infant's first eye movement after being brought to midline was scored as either correct or incorrect. The experimenter administered the task identically to the administration of the reaching version of the task. The only difference was that the infant's eye movements were used as the performance behavior, as opposed to the infant's reaching and uncovering one of the wells. The video camera was placed behind and above the experimenter's head and focused so as to maintain a close-up view of the infant's face.

The following scale was used to assess performance on the looking version of the scale:

1. *Object partially covered with one tub.*
2. *Object completely covered with one tub.*
3. *Object hidden under one of two identical tubs.*
4. *A-not-B with 0 delay.*
5. *A-not-B with 2-second delay.*
6. *A-not-B with 4-second delay.*

The examiner signaled the beginning of a trial for each of the items on the looking object permanence scale by holding up a moving, noise-making mechanical toy to attract the infant's attention. These types of toys were needed to maintain the infant's attention to the task. Because infants were not allowed to manipulate the toys themselves, the visual experience they received from the toy had to provide the impetus to continue to search for the toy. After gaining the infant's attention, the experimenter then administered the task. If the infant's attention was lost during the trial, the examiner regained the attention and proceeded with scale administration. Each infant was required to successfully make an eye movement toward the correct tub in two out of three trials to be declared competent at a specific object permanence scale item. Infants were rewarded for a correct eye movement with praise and clapping from the experimenter. After an incorrect eye movement, the experimenter sighed and blandly told the infant, "It's over here."

The task table was placed in front of the infant so that the center of the table (marked with a piece of clear tape) was at the infant's midline and the tubs covering each well were equidistant from midline. Two clear pieces of tape marked where the centers of the tubs should be when placed upside down over the A and B hiding sites. These markers positioned the tubs 35 cm apart. The experimenter was seated on the opposite side of the table facing the infant and parent. A large assembly of mechanical toys sized to fit under the tubs was accessible to the experimenter. Just as in the reaching version of the task, after two successful retrievals at side A, the toy was then hidden under the opposite tub B. Infants who successfully made an eye movement toward the toy at side B in two out of three A-A-B trials (i.e., did not make the A-not-B error) were then tested with a 2-second delay. Subsequent delays were initiated until the infant made the A-not-B error in two out of three A-A-B trials at any given delay. Delay was incremented in 2-second intervals throughout the study.

A distractor, calling the infant's name, was employed during the delay to break visual fixation to the correct tub. The distractor was essential during the looking version as the infant must disengage fixation before the eye movement can be made back to the hiding site. Under delay conditions, it was unnecessary for the mother to hold the infant's hands because the distance from the infant to the tubs was 1.1 m. None of the infants strained toward the hiding tubs. Immediately after diverting the infant's gaze, the examiner used the same verbal distractor used for the reaching version by asking, "Where's the toy?" Under delay conditions, the experimenter called the infant's name, clapped hands, and counted out the delay period to keep the infant's gaze from the well. After the delay period the experimenter asked, "Where's the toy?", and the infant was permitted to search (i.e., make an eye movement toward a well). For the present study, each infant was required to successfully make an eye movement toward the B well in two out of three A-A-B trials to be declared competent at a given delay. Object permanence testing on the looking version was stopped after the infant failed two out of three trials at a particular task on the object permanence scale or until the infant achieved success on two out of three trials at 4-second delay. Infants were assigned a score equal to the highest level completed on the object permanence scale. For example, an infant whose highest level of performance was success on looking A-not-B with "0 delay" received a score of 4.

While behavioral coding was necessarily accomplished by the experimenter in the course of assessment (i.e., the pattern of hidings was dependent on infant performance), additional coding of the looking object permanence scale was done from the videotape of the laboratory session by the second author and a graduate research assistant. This additional coding was accomplished as a reliability check on the pattern of hidings used by the experimenter and involved coding of each infant's performance by both coders. The percentage of agreement between the two coders for the 62 infants in the study was 94%. The four disagreements in coding were discussed by the authors, with final determination of object permanence looking score made by the first author.

TABLE 1
Proportion of Correct Responses (and SE) on Nonreversal and Reversal Trials

	Look condition	*Reach condition*
Experiment 1 (n = 62)		
Nonreversal (*A*)	.55 (.003)	.57 (.003)
Reversal (*B*)	.38 (.005)	.36 (.004)
Experiment 2 (n = 47)		
Nonreversal (*A*)	.45 (.003)	.57 (.004)
Reversal (*B*)	.26 (.005)	.37 (.005)

Results

The results of a paired samples t-test showed no difference in performance on the reaching version of the A-not-B object permanence task (M = 3.11, SE = .12) and the looking version of the task (M = 3.02, SE = .14), $t(61) = .50$, $p = .62$. The distribution of these reaching data had the mode at scale item 3, the A-not-B error.

This contrasts with the Bell and Fox (1997) study with 8-month-old infants, where the mode was at scale item 4, success on A-not-B at 0 delay. The procedural difference between these two studies was the employment of the distractor during the "0 delay" condition in this study. Bell and Fox (1997) began to employ the distractor and break the gaze to the hiding sites at the 2-second delay condition. The distractor necessarily had to be employed in this study at the 0-delay condition in order to make the reaching version of the task as similar to the looking version as possible. During the looking version, the infant's gaze had to be diverted from the hiding wells and brought to midline so that the direction of the first eye movement could be recorded.

Inspection of the infants' performance on each individual A or B hiding allowed analysis of the correct responses on nonreversal (A) and reversal (B) trials (e.g., Hofstadter & Reznick, 1996). The results of a paired samples t-test showed no difference in proportion of correct responses on nonreversal (A) trials for the looking and reaching versions of the task, $t(61) = -.59$, $p = .56$. There was also no difference in proportion of correct responses on reversal (B) trials for the looking and reaching versions, $t(61) = .23$, $p = .82$. These data can be seen in Table 1.

Hofstadter and Reznick (1996) reported that their 7-month-old infants reached correctly 31% of the time on reversal trials. Their 9-month-old infants reached correctly 40% of the time on the reversals. The reaching performance of the infants in the current study (36%) is comparable to those data. In their gaze condition, however, Hofstadter and Reznick (1996) reported that their 7-month-old infants looked correctly 51% of the time on reversal trials and their 9-month-old infants 59% of the time. That is much better than the looking performance of the infants in the current study. Our infants performed at 38% on looking reversal trials, although their performance on looking nonreversal trials was 55%. True to the traditional pattern of errors on the A-not-B task, the infants in the current study performed at a higher level on the nonreversal (A) trials than the reversal (B) trials for both the looking, $t(61) = 3.88$, $p < .001$, and reaching, $t(61) = 4.85$, $p < .001$, versions of the task.

Because the null hypothesis is difficult to interpret, Experiment 2 was designed as an attempt at replication of Experiment 1. Combining the second data set with that from Experiment 1 would also allow for more powerful analyses of the data.

EXPERIMENT 2

Method

Participants

Forty-seven healthy 8-month-old infants (25 male, 22 female; 43 Caucasian, 1 African-American, 1 Asian, 1 Hispanic, 1 Native American) were participants for this study. Infants were born to middle- and upper-middle-class parents. All parents had at least a high school diploma (mothers: 4% high school diploma, 17% some college, 64% bachelor's degree, 15% graduate degree; fathers: 4% high school diploma, 13% some college, 43% bachelor's degree, 40% graduate degree). Infants were recruited via birth announcements placed in local Blacksburg and Christiansburg, Virginia newspapers. The infants were healthy at the time of testing. All infants were seen when they were between 8.0 and 8.5 months of age, so that only 2 weeks separated the oldest and youngest infants in the study. Three additional infants were recruited for this study but were not included in the analyses. Two of the infants cried during the looking task and one was omitted from analyses due to experimenter error during the looking task. All parents were paid for their infant's participation in the study.

Reaching Version of the A-not-B Task

The procedures and scoring were identical to that in Experiment 1. Additional coding of the reaching object permanence scale was done from the videotape of the laboratory session by the graduate research assistant who had coded the videotapes in Experiment 1 and an undergraduate coder. Each infant's performance was assessed by both coders. The percentage of agreement between the two coders was 96%. The two disagreements in coding were discussed by the authors, with final determination of object permanence reaching score made by the first author.

Looking Version of the A-not-B Task

The procedures and scoring were identical to that in Experiment 1. Additional coding of the looking object permanence scale was done from the videotape of the laboratory session by a graduate research assistant who had coded the videotapes in Experiment 1 and an undergraduate coder. Each infant's performance was assessed by both coders. The percentage of agreement between the two coders was 96%. The two disagreements in coding were discussed by the authors, with final determination of object permanence reaching score made by the first author.

Results

The results of a paired samples t-test showed no difference in performance on the reaching version of the object permanence task ($M = 3.02$, $SE = .15$) and the looking version of the task ($M = 2.70$, $SE = .13$), $t(46) = 1.64$, $p = .11$.

The results of a paired samples t-test showed no difference in proportion of correct responses on reversal (B) trials for the looking and reaching versions of the task, $t(46) = -1.59$, $p = .12$. There was, however, a difference in proportion of correct responses on nonreversal (A) trials for the looking and reaching versions, $t(46) = 2.65$, $p = .01$. These data can be seen in Table 1. Despite the lower performance on the nonreversal (A) trials in the looking version, relative to the reaching performance in Experiment 2 as well as relative to the looking performance in Experiment 1, the traditional pattern of errors on the A-not-B task was still evident. The infants in Experiment 2 performed at a higher level on the nonreversal (A) trials than the reversal (B) trials for both the looking, $t(46) = 4.65$, $p < .001$, and reaching, $t(46) = 4.33$, $p < .001$, versions of the task.

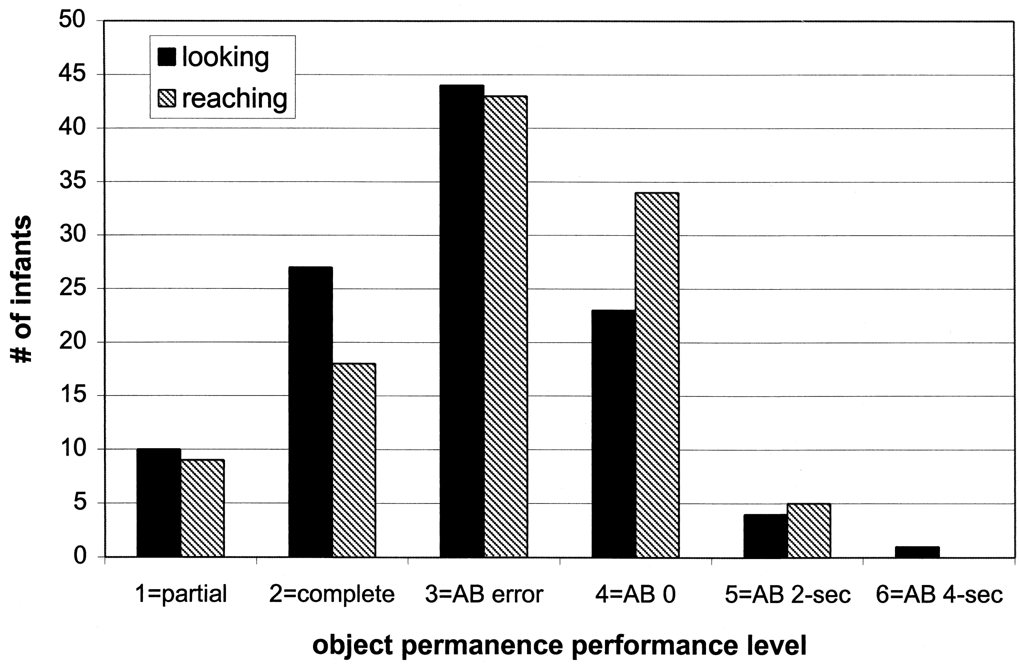

FIGURE 1
Individual infant performance for Experiments 1 and 2 combined on the looking and reaching versions of the object permanence scale. X axis represents items on the object permanence scale. Y axis represents the number of infants whose best performance was at each scale item. (*Note:* n = 109.)

COMBINED RESULTS FROM EXPERIMENTS 1 & 2

The data from Experiment 2 replicated the results of Experiment 1 in that there was no difference in performance on the reaching and looking versions of the object permanence task. For a more powerful assessment of tasks, the two data sets were combined and analyzed with a repeated-measures MANOVA with object permanence score as the dependent variable. Condition (look, reach) was the within-subjects factor and group (Experiment 1, Experiment 2) was the between-subjects factor. There were no main effects for condition ($F(1,107) = 2.21$, $p = .14$) or group ($F(1,107) = 2.31$, $p = .14$) and no condition by group interaction ($F(1,107) = .63$, $p = .43$). The combined data can be seen in Figure 1. Thus, in both experiments 8-month-old infants exhibited no difference in performance level on the looking and reaching versions of the object permanence task using a within-subjects research design.

The two data sets were also combined for repeated-measures MANOVA analysis using proportion of correct trials as the dependent variable. Condition (look, reach) and trial type (nonreversal, reversal) were the within-subjects factors and group (Experiment 1, Experiment 2) was the between-subjects factor. There was a main effect for trial type (Wilks = .564, approx. $F(1,107) = 82.60$, $p <$ .001), indicating the lower performance on the reversal trials, typical of the A-not-B error. There were no other main effects or interactions. Specifically, there was no main effect or interaction associated with condition (look, reach), all F's < 3.11, all p's $> .08$.

Performance of individual infants on the looking and reaching scales was examined. In the combined data set, 26 infants (24%) had duplicate scores on the looking and reaching versions of the task. Thirty-seven infants (34%) scored higher on the looking version relative to the reaching version and 46 infants (42%) scored higher on the reaching version of the task. Further examination revealed that 80 infants (73%) in the combined sample had looking and reaching scores that were within one scale level of each other. Twelve infants (11%) scored higher on the looking version relative to the reaching version by at least two scale levels and 17 infants (16%) scored higher on the reaching version by at least two scale levels.

DISCUSSION

The prediction that 8-month-old infants would have comparable performance on looking and reaching versions of the A-not-B task was based on a neuropsychological model of infant cognition. That model has two components that explain why infants in this pair of studies performed similarly on looking and reaching versions of the A-not-B task.

First, both versions of the task share the cognitive skills of working memory, inhibition, and attention. (The main difference between the two versions is the response system.) The cortical circuitry associated with these three cognitive skills involves the frontal cortex (Johnson, 1995; Nelson & Dukette, 1998). Thus, both looking and reaching versions of the task involve similar, but not necessarily identical, brain circuitry. The response output, of course, would involve the FEF for the looking task and the motor cortex for the reaching task.

While the working memory requirements and brain circuitry may be very similar for the two versions of the task, the attention and inhibition associated with eye movements would require different circuitry relative to that associated with gross motor movements. Attention and inhibition of eye movements appears to require the superior colliculus and substantia nigra, as well as the FEF and the parietal cortex (Johnson, 1995; Posner & Raichle, 1994). Inhibition of gross motor movements is associated with the DLPC (Diamond, 1990a) and the motor cortex. If different response systems are utilized in the versions of the task, then the inhibition of these different response systems would be essential for successful A-not-B performance.

Secondly, at 8 months of age, there appears to be a wide range of individual differences in performance on the object permanence scale used in this and other studies (Bell & Fox, 1992, 1997; Diamond, 1985). A wide range of individual differences in frontal lobe development and functioning (measured via EEG recordings and behavioral outcomes) has been reported in both the cognitive development literature (e.g., Bell & Fox, 1992, 1997) and the temperament literature (e.g., Calkins, Fox, & Marshall, 1996; Fox, 1994). Because the frontal cortex appears to be involved in object permanence performance (Diamond, 1990a, 1990b), the wide range of behaviors should not be surprising.

It also should not be surprising to find that scores on the looking and reaching scales were comparable, but not identical. There appear to be different areas of the frontal lobe associated with performance on the two versions of the A-not-B task. The DLPC has been shown to be involved in the reaching version (e.g., Diamond, 1990b) and the FEF areas appear to be involved in the looking version of the task (e.g., Funahashi, Bruce et al., 1993). Although frontal lobe maturation is the argument for comparable performance on looking and reaching, it may be that individual infants experience different patterns of FEF and DLPC maturation. Hence, performance on tasks that utilize these two brain areas is comparable but not identical. From an individual differences perspective, the infants who scored more than two scale levels apart on the looking and reaching versions of the task (n = 39, 27% of the combined sample), particularly those who scored higher on the reaching version relative to the looking version, are intriguing. Electrophysiological data could be used to examine these different groups of infants. Measures of EEG power and coherence during task performance may provide insight into these diverse patterns of task performance.

What is intriguing is to speculate concerning object permanence performance prior to 8 months of age. Many infants will not reach for a hidden object before 7 months of age (Diamond, 1985). The coordination of the gross motor movement with the working memory, inhibitory, and attentional skills appears too difficult for the young infant's repertoire. If, however, the cognitive skills are comparable across response modalities, and the major difference is maturation of circuitry associated with the actual response itself, it should be possible to watch the simultaneous development of performance on both the looking and reaching versions of the task. The hypothesis would be that looking performance would be superior to reaching performance prior to about 7 or 8 months of age, but that after this age performance on the two tasks would be comparable. We are testing that hypothesis now (Bell, 1999).

While the looking version of the A-not-B task gives valuable information concerning the nature of the object concept during infancy, two questions are raised concerning the conversion of this classic marker of infant cognitive development from a reaching task to a looking task. First, are perceptual demands added to the visual version that are not present in the reaching version of the task? This is a very salient question, especially in light of recent criticisms concerning the violation-of-expectations paradigm for assessing infant knowledge (e.g., Bogartz et al., 1997). It remains the case, however, that the cognitive skills of working memory, attention, and inhibition appear to be essential for success on both versions of the task. Any additional visual perceptual demands of the looking task may be offset by the tactile perceptual demands of the parent's restraint of the infant's arms and hands during the reaching task.

Second, can a task that is so grounded in sensorimotor functioning have the "motor" component removed, save for eye movements, and still describe sensorimotor development? This is a crucial question for Piagetian concepts of infant cognition. On the other hand, one could also argue that this is a moot point because the focus of this looking task is on the cognitive constructs of memory, attention, and inhibition and thus informs of infant development. For example, Diamond (1995) recently noted that infant performance on looking and reaching versions of a recognition memory task is similar across task modality. That is basically the same finding we have with these two studies on object permanence. Indeed, the long-held notion that looking may be a better indicator of cognitive ability than reaching is beginning to be questioned in the developmental literature (e.g., Smith, Thelen, Titzer, & McLin, 1999).

These important questions notwithstanding, the results of this type of work have the potential to add greatly to our knowledge of infant cognitive development. In conjunction with possible physiological methodologies, the looking version of the object permanence task will allow exploration of the intricacies of cognitive functioning during the first year of life. We are now recording EEG during looking task performance. This task-related measure will be used to examine frontal electrical activity during cognitive processing and, thus, has the potential to give us valuable information regarding the early development of complex cognitive functions.

Acknowledgments: Experiment 1 was conducted while the first author was a Visiting Assistant Professor of Psychology at the University of South Carolina, where data collection was supported by a Research and Productive Service Award from the University. Portions of the data in Experiment 1 were used by the second author in her Senior Honors

Thesis, submitted to the South Carolina Honors College at the University of South Carolina. Experiment 2 was conducted at the first author's current institution, where data collection was supported by a Small Grant Award from the College of Arts and Sciences at Virginia Tech. The authors thank Jonathan Roberts, Sabrina Pope Shealy, and numerous undergraduate research assistants at both institutions for help with data collection and coding.

NOTE

1. In actuality, Hofstadter and Reznick (1996) utilized the Delayed Response (DR) task in their study. The A-not-B and the DR tasks differ only in the schedule for determining where the object is to be hidden. In the DR task, the object is hidden randomly according to a predetermined pattern. In A-not-B, the object is hidden based on the infant's behavior in the previous search trial. Both tasks allow for examination of infant performance on *reversal trials*, those crucial for determining the "A-not-B error." It is the DR task that initially was linked to DLPC function (see Diamond, 1990b, for comparisons of A-not-B and DR).

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26 January 1999; Accepted 28 July 1999 ■