Perseverative Reaching in Infancy: The Roles of Hidden Toys and Motor History in the AB task

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Two experiments tested the roles of hidden toys and motor history in the AB task with 10-month-old infants. In Experiment 1 \((N = 24)\), infants were tested in lid and toy versions of the task, each comprised of A and B trials. No toys were ever hidden in the lid condition. On all A trials, an experimenter directed infants’ attention to one of two lids (the A lid) and allowed infants to reach following a 5-s delay. On B trials in the lid condition, the experimenter directed infants’ attention to the other, B lid. On B trials in the toy condition, the experimenter directed infants’ attention to a toy that was then hidden underneath the B lid. Following a 5-s delay, infants reached perseveratively to A—producing the AB error—in the lid condition (replicating Smith, McLin, Titzer, & Thelen, 1995), but not in the toy condition. In Experiment 2 \((N = 24)\), infants were tested in similar lid and toy versions of the task, except that on all A trials the experimenter directed attention to a toy that was then hidden underneath the A lid. Infants produced AB errors across lid and toy conditions. Contrary to Smith et al.’s (1995) claims, these findings indicate that infants distinguish hidden toys from lids alone in the AB task. The presence of hidden toys on A trials and on B trials, not simply infants’ motor history, influences production of the AB error.

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What do infants know about hidden objects, and when do they know it? After decades of empirical work on these questions, researchers give widely disparate answers. This disparity is based largely on disagreements about how to interpret infant behavior. Although many innovative techniques have been designed to test what infants know about hidden objects, these techniques often appear to be outnumbered by challenges to what the techniques actually measure. For example, the visual habituation technique has provided a wealth of data taken as evidence for an object concept in very young infants (Baillargeon, 1993; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Wynn, 1992; Xu & Carey, 1996). However, multiple alternative interpretations of the data do not rely on an object concept (e.g., Bogartz, 1995; Fischer & Bidell, 1991; Munakata, in press; Munakata, McClelland, Johnson, & Siegler, in press; Thelen & Smith, 1994). These challenges to the visual habituation paradigm allow for a range of perspectives on infant knowledge of hidden objects.

The task of specifying what a given technique measures is thus of central importance. The current paper addresses a recent challenge to the AB task as a measure of object knowledge in infants, and provides empirical support for the relevance of hidden objects to performance in this task.

In the AB task, devised by Piaget (1954), infants watch an experimenter hide an object in one location \((A)\). Typically, infants are allowed to retrieve the hidden object after a short delay, and this procedure is repeated some number of times. Infants then watch the experimenter hide the object in a new location \((B)\). When they are allowed to reach after a short delay, infants often show the AB error, reaching perseveratively back to A rather than to the new hiding location at B. Wellman, Cross, and Bartsch (1986) conducted a meta-analysis indicating four factors that influence the production of AB errors: participants’ ages and the length of delays (e.g., Diamond, 1985), number of hiding locations (e.g., Cummings & Bjork, 1983a; 1983b), and distinctiveness of hiding locations (e.g., Bremner, 1978). The striking and robust AB finding and the influences upon it have been the basis for many theories of object permanence (e.g., Butterworth, 1977; Cummings & Bjork, 1983b; Diamond, 1985; Gratch, Appel, Evans,
Several studies demonstrated that infants show the AB error even when a toy is visible at B (Bremner & Knowles, 1984; Butterworth, 1977; Harris, 1974) and appeared to challenge the assumption that hidden toys are required for the AB error. However, Butterworth (1977) found that AB errors were more persistent when the toy was hidden than when it was visible. In addition, Sophian and Yengo (1985) ran an AB experiment with visible toys using a third, control location, and found that infants were as likely to err to the control location as to the A location. In contrast, with hidden toys, infants searched perseveratively at the A location rather than at the control location, leading Sophian and Yengo (1985) to argue that occasional errors with visible objects differ from the systematically perseverative AB errors observed with hidden toys. Thus, although infants can err with visible toys, the use of a hidden toy still seems relevant to the AB error.

However, Smith et al. (1995) recently showed that 8- and 10-month-old infants made the AB error without hidden toys, when simply reaching to visible lids over empty containers. In their studies, an experimenter directed infants’ attention to one of two identical lids over empty containers and allowed infants to reach following a short delay. Nothing was ever placed inside the containers, and nothing was ever hidden (for details, see Procedure for Experiment 1, lid condition, in the current paper). On A trials, infants tended to reach to the lid to which the experimenter had directed their attention. On B trials, in which the experimenter directed attention to the other lid, infants tended to perseverate in reaching to A. That is, infants made the AB error with completely visible objects. As Smith et al. (1995) argued, these provocative results pose a challenge to existing accounts of the AB error, because most are based upon infants’ knowledge about or memory for hidden toys.

On the basis of their studies, Smith et al. (1995) also made the stronger claim that “The theoretical question to be answered then is not one about hidden objects but one about reaching...[T]he A-not-B error is not about hidden objects and not about infants’ representations of hidden objects.” This claim is based on the following logic:

1. Infants show the AB error with hidden toys.
2. Infants show the AB error without hidden toys.
3. Therefore, hidden toys are not relevant to the AB error.

Smith et al. (1995) proposed that infants reach perseveratively to A simply because they have looked and reached there repeatedly. Repeated looking by itself must suffice because infants make the AB error after merely seeing a toy hidden at A without having the opportunity to reach (Butterworth, 1974; Diamond, 1983; Evans, 1973).

Although Smith et al.’s (1995) data may appear to support the claim that hidden toys have no relevance to the AB error, their studies do not test this claim directly. Instead, their findings indicate that infants make the AB error given repeated exposure to a stimulus in one location and recent exposure to the same stimulus in a different location, whether the stimulus is a lid alone or a lid with a toy hidden underneath. In this paper, I refer to repeated exposures built up over time on prior trials as “history,” and to the most recent exposure as “recency.” Smith et al. (1995) have demonstrated that infants make the AB error when history and recency for lids with and without a toy hidden underneath compete; however, infants may nonetheless represent lids with and without a toy hidden in different ways. Consider the analogy of a game of tug-of-war, with 4 participants. Two participants have “extra strength,” two do not. Following the logic above:

1. If participants with extra strength tie, and
2. Participants without extra strength tie,
3. One can conclude that strength is not relevant to tug-of-war.

The flaw in the logic becomes clear in the analogy, as does the appropriate, direct test of the conclusion. In the case of tug-of-war, the relevance of strength can be tested directly when a participant with extra strength is compared to a participant without. This test would show that extra strength affects performance, although there is a common outcome when equivalent participants compete. Similarly, the relevance of the hidden toy for the AB task can be tested
directly when a visible lid with a toy hidden underneath is compared to a visible lid alone. A visible lid with a toy underneath may have more "strength" to guide behavior than a visible lid alone, even though there is a common outcome when the history of a lid at one location—with or without a toy underneath—competes against the recency of the same stimulus at different location. Experiment 1 tests this possibility in the B trials of an AB task: after infants reach to a visible lid at A, they receive B trials with either a hidden toy (toy condition) or a visible lid (lid condition). If hidden toys are irrelevant and the AB error is about task dynamics alone, infants should show similar AB errors in toy and lid conditions. In contrast, if hidden toys influence infant behavior in this task, AB errors should be reduced in the toy condition.

EXPERIMENT 1

Method

Participants

Twenty-four full-term, healthy 10-month-olds (17 boys, 7 girls; M = 10 months, 7 days, SE = 1 day) participated in the experiment. Participants were recruited primarily through advertisements in Pittsburgh's Child, a local parenting magazine. Parents received $5 and an infant scientist degree for their infants' participation. Participants came predominantly from Caucasian families. Two participants were excluded from the analyses (one failed to reach during the entire first block of the experiment, and one was interrupted by a sibling).

Apparatus

The experimental apparatus was a black box (28.5 cm x 22.25 cm x 6.25 cm) with two wells (9 cm in diameter, 4 cm high, centers 14 cm apart) that could be covered by lids (10 cm in diameter, with a 3 cm high spherical knob attached on top). The knob and the tops of the lids were painted black; the undersides of the lids were made of brown cork. Wooden tracks constrained the path of the black box across the experimental table, so that the experimenter presented the box to infants in the same way on each trial. A set of colorful plastic keys served as the toy in the toy condition. A tape recording of a metronome played into an earphone so that the experimenter could count seconds to determine delay and trial times.

Procedure

The experiment was videotaped for later analysis. Each infant was tested individually in the laboratory, while seated on the parent's lap. Each infant was tested with one block of toy trials and one block of lid trials, with order of blocks counterbalanced across participants. The initial location of the A well was counterbalanced across participants, and the location of the A well was changed between blocks. Between blocks, infants took a 5-min break in a separate room.

Each block comprised 4–6 pretrials, two A trials, and at least two B trials. The pre-trials were run to familiarize infants with the apparatus and the experimental procedure and to encourage infants to reach to the A side of the apparatus. The lid on only the A well was present during pretrials. On each pretrial, the experimenter called the infant's name, waved the lid at the A location until the infant fixated the lid, and replaced the lid over its well. If the infant failed to fixate the lid in its resting position, this procedure was repeated. The experimenter then pushed the box across the table to within the infant's reach and held the box in this position until the infant removed the lid or 10 s passed. If 10 s passed without the infant removing the lid, the experimenter (and the parent, if necessary) tapped the lid until the infant removed it. The experimenter then pulled the box back to its starting location. Pre-trials were repeated until the infant removed the lid within 10 s without reaching into the B well on 4 consecutive trials, or six trials passed. This 4–6 pretrial criterion was chosen based on Smith et al.'s (1995) procedure (four pretrials) and pilot testing that indicated that some infants took several trials before reaching to A.

Lids on both wells were present during all A and B trials. On the two A trials, the experimenter called the infant's name, waved the lid at the A location until the infant fixated the lid, and replaced the lid over its well. If the infant failed to fixate the lid in its resting position, this procedure was repeated. The experimenter then waited 5 s. Visual fixation of the hiding wells was not broken during the delay period, and straining toward the correct well was not prevented during the delay period (cf. Diamond, 1985). The experimenter then pushed the box across the table to within the infant's reach and held the box in this position until the infant removed the lid on the A well or 10 s passed. If 10 s passed without the infant removing the A lid, the experimenter (and the parent, if necessary) tapped the A lid until the infant removed it. The experimenter then pulled the box back to its starting location.

On B trials in the lid condition, the experimenter presented the lid at the B location in the same way that the lid at the A location had been presented on A trials. On B trials in the toy condition, the experimenter called the infant's name, waved a toy over the B location until the infant fixated the toy, and placed the toy in the B well. If the infant failed to fixate the toy just before it was lowered into its resting position, this procedure was repeated. The experimenter then covered the well with its lid. In both the lid and toy conditions, the experimenter waited 5 s after covering the well, pushed the box across the table to within the infant's reach, and held the box in this position until the infant removed the lid on the B well or 10 s passed. If 10 s passed without the infant removing the B lid, the experimenter (and the parent, if necessary) tapped the B lid until the infant removed it. Infants were allowed to play with the toy after removing the B lid at any point during B trials in the toy condition.

Two obligatory B trials were presented in each block. If the infant removed the B lid without touching the A lid on either of these trials, testing for the block was terminated. Otherwise, extra B trials were presented until the infant removed the B lid without touching the A lid or a total of 5 B trials had been presented. This procedure for terminating blocks allowed for useful comparisons between conditions,
though it may have led to an underestimation of infants' tendencies to reach perservatively to $A$.

Coding

Trials were coded for the location of the first lid removed. Coders did not score the reaches induced after 10 s by the experimenter. A removal of a lid was scored if an infant uncovered a well completely, uncovered a well at least halfway by grasping the lid, or tilted the lid in its well so that the lid was at least vertical. If an infant removed both lids at the same time, a removal was scored for both location $A$ and $B$. A coder blind to the purpose and hypotheses of the study coded the tapes for half of the participants. Inter-rater reliability was .96, with coders agreeing on 266 out of 278 judgments.

Results

The hidden toy influenced the number of $AB$ errors in the two obligatory $B$ trials and the number of extra $B$ trials required. There were no effects of the ordering of lid and toy conditions or of the initial location of the $A$ well, so the data are collapsed across these factors for analysis.

$AB$ Error

Figure 1 shows percentages of $A$ and $B$ lid removals for $A$ and $B$ trials under lid and toy conditions. Infants occasionally failed to remove a lid or removed both lids simultaneously, so $A$ and $B$ lid removals for a single trial type sum to approximately 100%. The $AB$ error results are reported below in terms of removals of the $A$ lid on $A$ trials and the $B$ lid on $B$ trials; equivalent patterns hold when the data are analyzed in terms of removals of the other lid.

Infants removed the $A$ lid on 65% ($SE = 5\%$) of the $A$ trials, more often than expected by chance, $t(23) = 2.96, p < .01$. Removals of the $A$ lid on $A$ trials did not differ between lid ($M = 63\%, SE = 8\%$) and toy conditions ($M = 67\%, SE = 7\%), F(1, 22) = .16, p = .70$, a nonsurprising result because the conditions were identical at this point. Removals of the $B$ lid on $B$ trials did differ between lid ($M = 23\%, SE = 7\%$) and toy conditions ($M = 65\%, SE = 9\%), F(1, 22) = 11.06, p = .003$. Infants produced the $AB$ error with lid trials, removing the $B$ lid on $B$ trials less often than the $A$ lid on $A$ trials, $F(1, 22) = 11.85, p = .002$. This finding replicates Smith et al. (1995). However, infants did not make the $AB$ error with toy trials, removing the $B$ lid on $B$ trials as often as the $A$ lid on $A$ trials, $F(1, 22) = .02, p = .90$.

Extra $B$ Trials

The lid and toy conditions also differed in the number of extra $B$ trials required before infants removed the $B$ lid without touching the $A$ lid. Three extra trials was the maximum allowed.

Figure 1. Mean percentage of $A$ and $B$ lid removals (SE) for $A$ lid trials (lid and toy conditions) and $B$ lid and $B$ toy trials. $A$ trials were identical across lid and toy conditions, with the experimenter waving a lid and placing it over the $A$ well. Following these $A$ lid trials, 10-month-old infants ($N = 24$) showed more $AB$ errors with $B$ lid trials than with $B$ toy trials.
Infants on average required 71% (SE = 9%) of this maximum in the lid condition and 38% (SE = 10%) of this maximum in the toy condition, $F(1, 22) = 5.19, p = .033$. The toy also reduced the number of infants requiring the maximum of three extra trials; 16 of the 24 participants required the maximum in the lid condition, and 8 of the 24 participants required the maximum in the toy condition, McNemar $\chi^2 (1, N = 24) = 4, p < .05$.

Discussion

These results demonstrate that a hidden toy can influence 10-month-old infants’ reaching in the AB task. Following two A trials with a lid alone, B lid trials yielded more AB errors than B toy trials. Contrary to Smith et al.’s (1995) claims, AB errors are not simply a result of prior experience, independent of representations of hidden toys. Infants in Experiment 1 had the same prior experience in the pretrials and A trials of the lid and toy conditions. In addition, the apparatus looked identical on B trials of the lid and toy conditions during the delay period, as it was pushed forward to the infant, and until the infant removed a lid. Yet, infants distinguished an empty B well from a B well with a hidden toy.

Infants may have been more sensitive to the recent stimulus of the toy because it was more interesting and more desirable than a lid. This account is consistent with Diamond’s (1983) findings that infants make fewer AB errors if they show high levels of interest in the toy hidden at B, and they require longer delays to make the AB error when the object hidden at B is highly desirable (e.g., when food is hidden instead of a toy). Infants appear better able to encode more interesting and desirable stimuli so that they can respond to them following occlusion and in the face of competing stimuli and distinguish them when hidden underneath a lid from a lid alone.

However, Experiment 1 is open to alternative “reinforcement” and “novelty” interpretations. These will be discussed briefly here, and then addressed more systematically with Experiment 2.

According to the reinforcement account, infants did not make an AB error in the lid condition, they merely reached back sensibly to a reinforced location. That is, infants may have been sensitive to the recently presented lid at B, but they could reach to either A or B to come up with the identical result—a lid. And, they had been reinforced to remove the A lid during the pre-trials and A trials, so removing the A lid on B trials was not an error at all. It is important to note that this reinforcement account is consistent with the main claim from Experiment 1, that infants distinguish hidden toys and visible lids. That is, whether infants reached to A simply because they had reached there before, or because they had been reinforced to reach there, they made the AB error more often with a visible lid at B than with a hidden toy at B. Contrary to the claims of Smith et al. (1995), AB behavior is not about task dynamics alone; the hidden toy does matter.

However, there are two reasons to believe that infants’ AB errors were not based on reinforcement. First, infants were not provided with any reinforcement for removing the A lid. The experimenter simply pulled the box back to its starting location. In the rare cases when infants reacted to this event, responses were typically negative rather than positive, presumably because the box was moved out of reach. It seems unlikely that this contingent box-withdrawal reinforced infants to reach to A. Second, even if infants received subtle or unobservable reinforcement for removing the A lid on pre-trials and A trials, such reinforcement would not necessarily lead 10-month-old infants to prefer the reinforced location. Willatts (1979) found that 4-month-olds reached more for an object in a reinforced location than in a novel location, but this effect disappeared by 5 months, when infants reached equally to an object in reinforced and novel locations. Vecera, Rothbart, and Posner (1991) found that 6-month-olds presented with two identical toys reached equally often to the toy in a reinforced location as to the toy in a novel location, whereas 18-month-olds preferred the toy in the novel location. If the infants in Experiment 1 were reaching on the basis of reinforcement alone, one might interpolate from these findings to expect that infants would respond at chance on B trials or prefer the nonreinforced location (B). Instead, infants reached perseveratively to A.

According to the novelty account, infants removed the B lid on B trials more often in the toy condition than in the lid condition simply because the B trials in the toy condition were
more novel. All prior trials were presented with a lid alone, so the B trials in the toy condition were the first of their kind (compared to just another lid trial in the lid condition). This novelty may have led to more removals of the B lid in the toy condition.

Experiment 2 tested the reinforcement and novelty accounts and completed the coverage of all combinations of A and B lid and toy trials. Infants were tested with pretrials and A trials with a hidden toy, followed by B trials with a hidden toy (the standard AB experiment) or a visible lid. Infants were able to play with the toy after removing the A lid on each pretrial. The reinforcement account thus predicts that Experiment-2 infants should remove the A lid on the A trials more often than Experiment-1 infants, who received no such toy-reinforcement. In addition, the B trials in the lid condition of Experiment 2 were now the first of their kind, because all prior trials were presented with a toy. The novelty account thus predicts that infants should remove the B lid on B trials more often in the lid condition than in the toy condition.

**EXPERIMENT 2**

**METHOD**

**Participants**

Twenty-four full-term, healthy 10-month-olds (14 boys, 10 girls; M = 10 months, 10 days, SE = 1 day) participated in the experiment. Participants were recruited primarily through advertisements in Pittsburgh’s Child, a local parenting magazine. Parents received $5 and an infant scientist degree for their infants’ participation. Participants came predominantly from Caucasian families. One participant was excluded from the analyses for becoming fussy at the start of the experiment so that no data could be collected.

**Apparatus**

The apparatus was identical to that in Experiment 1.

**Procedure**

The experimental procedure was identical to that in Experiment 1 (with 4–6 pretrials, 2 A trials, and at least 2 B trials), except that the experimenter hid a toy on all pretrials and A trials. When hiding the toy, the experimenter called the infant’s name, waved the toy over the A location until the infant fixated the toy, and placed the toy in the A well. If the infant failed to fixate the toy just before it was lowered into its resting position, this procedure was repeated. The experimenter then covered the well with its lid. As in Experiment 1, the experimenter pushed the box toward the infant immediately on pre-trials, and following a 5-s delay on A trials. The B trials in the lid and toy conditions were run as in Experiment 1. Whenever an infant removed the lid covering the toy, the experimenter handed the toy to the infant at his or her midline. This procedure ensured that infants in Experiments 1 and 2 had similar opportunity to reach to the A location: at most once per pre-trial or trial.

**Coding**

The coding procedure was identical to that in Experiment 1. A coder blind to the purpose and hypotheses of the study coded the tapes for half of the participants. Inter-rater reliability was .98, with coders agreeing on 266 out of 272 judgments.

**Results**

Infants produced similar patterns of AB errors in the two obligatory B trials across lid and toy conditions. Results did not support the alternative accounts based on reinforcement or novelty. There were no interaction effects with the ordering of lid and toy conditions or of the initial location of the A well, so the data are collapsed across these factors for analysis.

**AB Error**

Figure 2 shows percentages of A and B lid removals for A and B trials under lid and toy conditions. Infants removed the A lid on 68% (SE = 6%) of the A trials, more often than expected by chance, t(23) = 3.12, p < .005. Experiment 2 infants did not differ from Experiment 1 infants in removals of the A lid on A trials, F(1, 44) = .20, p = .70.5 Removals of the A lid on A trials did not differ between lid (M = 67%, SE = 8%) and toy (M = 69%, SE = 8%) conditions, F(1, 22) = .03, p = .90, a nonsurprising result because the conditions were identical at this point. Removals of the B lid on B trials also did not differ between lid (M = 38%, SE = 8%) and toy conditions (M = 38%, SE = 10%), F(1, 22) < 1, so the data were collapsed across these conditions. Infants produced the AB error overall, removing the B lid on B trials less frequently than the A lid on A trials, F(1, 22) = 11.19, p = .003. This finding replicates the standard AB error, and also demonstrates that infants produce the same error when B trials consist of a visible lid alone.

The lack of difference between AB errors in lid and toy conditions in Experiment 2 was significantly different from the difference between AB errors in lid and toy conditions in Experi-
Figure 2. Mean percentage of A and B lid removals (SE) for A toy trials (lid and toy conditions) and B lid and B toy trials. A trials were identical across lid and toy conditions, with the experimenter waving a toy and hiding it in the A well. Following these A toy trials, 10-month-old infants (N = 24) showed similar AB errors across B lid and B toy trials.

Discussion

These results demonstrate that infants make similar AB errors after retrieving a toy hidden at A and then watching a toy hidden at B or watching a visible lid waved at B. These data seem to contradict Appel and Gratch's (1984) finding that 9-month-old infants, after searching for a toy at A, searched more often at A on B toy trials than on B knock trials, in which the experimenter rapped sharply in front of the hiding apparatus. Appel and Gratch (1984) took their finding as evidence that the hiding of a toy at B was a factor leading to the AB error. The discrepancy between the two studies may be based on (a) Appel and Gratch's (1984) knock trials reducing searching (five out of the 13 infants failed to search on their first knock trial—of the remaining eight, six searched at A, and two at B, suggesting an AB error—compared to 0 out of 13 in their toy trials and 0 out of 24 in the current study's lid trials); and (b) the experimenter drawing infants' attention to the front of the hiding apparatus in Appel and Gratch (1984) vs. to the lid over a second hiding location in the cur-
rent study. In any case, the current study demonstrates that infants can make similar $AB$ errors following toy and no-toy $B$ trials.

It is important to note that limited windows onto infant behavior in this task can give the impression that a hidden toy does not influence reaching. For instance, as noted above, infants reached similarly to $B$ toy and $B$ lid trials following $A$ toy trials. And, infants reached similarly to $A$ toy and $A$ lid trials. However, the complete picture reveals that a hidden toy does influence infants’ reaching. Experiment 1 showed that after two $A$ trials with a lid alone, infants made more $AB$ errors on $B$ lid trials than $B$ toy trials. Considered together with Experiment 2, these results demonstrate another way in which a hidden toy can influence infants’ reaching in the $AB$ task. Experiment 2 showed that after two $A$ trials with a hidden toy, infants made similar $AB$ errors on $B$ toy trials and $B$ lid trials. Thus, the presence of a hidden toy on $A$ trials influenced infants’ reaching for lids with and without a toy underneath on $B$ trials, despite infants having equivalent motor histories prior to the $B$ trials. Finally, in Experiment 2, infants who received the lid condition first required fewer extra $B$ trials across lid and toy blocks than infants receiving the toy condition first. This unexpected effect is somewhat difficult to interpret, given that both the condition and the well designated as $B$ were changed across blocks. Further work is needed to test the robustness of this finding and its possible causes.

In Experiment 2, infants may have reached similarly to recent trials at $B$ with and without toys because (a) the toy had lost its greater desirability or interest, following repeated exposure; (b) the tendency to reach toward $A$ was more difficult to overcome when it was based on a lid over a hidden toy than when it was based on a lid alone, even though infants reached to $A$ equally often given a lid with a toy underneath and a lid without; and (c) the greater strength of the toy relative to the lid alone to direct infants to $B$ was balanced by its greater strength to remind infants of $A$ trials. In any case, the complete picture from Experiments 1 and 2 clearly indicates that infants distinguish between a lid over a hidden toy and a lid alone—both in repeated exposures at $A$ and in recent exposures at $B$—despite the identical displays and motor histories for these two cases.

The results from Experiment 2 also address alternative interpretations of Experiment 1. First, reinforcement does not seem to play a critical role in infant reaching in these tasks. In contrast with the nonreinforced infants in Experiment 1, infants in Experiment 2 were rewarded with the toy each time they reached to the $A$ lid. This difference across multiple pre-trials had no effect on infant reaching on $A$ trials; infants removed the $A$ lid on $A$ trials equally often regardless of whether they had been reinforced with the toy for doing so. This finding is consistent with Diamond’s (1983) observation that reinforcement for $AB$ errors did not affect infants’ reaching on subsequent trials. In Diamond’s (1983) studies, infants were reinforced with a toy on some trials following incorrect reaches, and on other trials they were not permitted to play with the toy following incorrect reaches. When trials were repeated following incorrect reaches, infants err ed just as often regardless of whether they had been reinforced for their prior errors.

Second, the novelty of trial types did not determine infants’ reaching behavior. In Experiment 1, the $B$ trials in the toy condition were the first of their kind, leaving open the possibility that infants responded more to the $B$ location only because a novel event had occurred there. However, in Experiment 2, the $B$ trials in the lid condition were the first of their kind. If novelty were the determining factor, then infants should have responded more to the $B$ location in this condition. Instead, infants responded equally to the $B$ location in the lid and toy conditions.

GENERAL DISCUSSION

Smith et al. (1995) showed that infants make the $AB$ error when history at $A$ competes with recency at $B$, in both toy and no-toy versions of the $AB$ experiment. The current experiments demonstrate that the hidden toy is still relevant to infant reaching in this task, just as strength is still relevant to a tug-of-war despite ties between strong competitors and between weak competitors. It is obvious why two competitors with equal strength tie in a tug-of-war. It is less obvious why infants make the $AB$ error when history of a given stimulus at $A$ competes against recency of the same stimulus at $B$. Many theories have been proposed (e.g., Diamond, 1985; Munakata, in press; Thelen & Smith, 1994;
Wellman et al., 1986) and some computational models implemented (e.g., Dehaene & Changeux, 1989) to account for this robust finding. However, the current data underscore the need for new or revised models of performance in the AB task. In particular, a complete model of this task must account for the following findings:

1. Ten-month-old infants tend to produce the AB error when history and recency are based on lids alone (Smith et al., 1995, and replication in Experiment 1), but not when recency is based on a lid with a toy hidden underneath and history on a lid alone (Experiment 1).

2. Ten-month-old infants tend to produce similar AB errors when history is based on a lid with a toy hidden underneath and recency on a lid alone and when history and recency are based on lids with a toy hidden underneath (standard AB error and Experiment 2).

It is important to note that infants show similar reaching on A lid and A toy trials, but their behavior on B toy trials depends on whether they were presented with A lid or A toy trials. Motor history alone does not predict infant performance. Instead, infants must retain some form of information about the specific stimuli presented repeatedly at A to show sensitivity to this history on subsequent B trials. However, this distinguishing information does not show itself on A trials.

This paradox is reminiscent of that found in other developmental paradigms such as the balance scale task (Inhelder & Piaget, 1958; Siegler, 1981), in which children must indicate which side of a balance scale will go down. Siegler (1976) compared 5- and 8-year-old children that approached this task in the same way, attending to the number of weights on each side of the scale but not their distance from the fulcrum. Following training, the older children were more likely to progress to a more advanced approach. That is, although the 5- and 8-year-olds looked alike in initial performance measures, they showed a differential readiness to learn. McClelland (1989) used a connectionist simulation to account for differential readiness in the balance scale task in the face of similar overt behavior. The simulation learned new rules very gradually so that they were not always evident in overt behavior; however, the gradual learning produced an increasing ability for the simulation to benefit from training.

Similarly, the effects of a hidden toy (vs. a visible lid) in the AB task may build up gradually over trials so that they are not evident in A trials; however, the gradual effects may influence infants’ readiness to switch to B on the B trials. The task remains to specify the form of the information retained about stimuli in history and recency, and the process whereby infants can use this information to distinguish one stimulus from another within history, or within recency, and yet reliably make the AB error when history and recency for equivalent stimuli compete. It is likely that computational models will provide a useful tool for specifying and testing new theories about the mechanisms responsible for these behaviors in the AB task (Munakata, 1996).

Many questions remain about the way in which hidden objects influence reaching. The current experiment is one step in clarifying what the AB task measures. Future research may provide further clarification on the processing mechanisms tapped by the AB task, and the form of infants’ representations of hidden objects that guide their behavior. This type of specification, for this and other object concept paradigms, is likely to be critical in the search for compelling answers to the question of what infants know about hidden objects.

Author’s Note

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Footnotes

1. Tapping of the A lid was required on only 15% of pre-trials and A trials and within only 21 of the 48 testing blocks, and thus did not appear to play a large role in infants’ tendency to remove the A lid on A trials.

2. Based on this finding, Diamond (1983) proposed that different levels of interest may have accounted for the contradictory findings of Schuberth, Werner, and Lipsitt (1978) (AB error reduced if the toy hidden at B was novel) and Evans and Gratch (1972) (equivalent AB errors when old and novel toys hidden at B).

3. It should be noted that across Experiments 1 and 2, the percentage of correct responses on A trials (66%) appears to be lower than that found in other studies (e.g., 80% in Diamond, 1985). This difference may be due to differences in the apparatus used across experiments (e.g., shorter distance between wells in the current experiment; see Horobin & Acredolo, 1986, but see Wellman et al., 1986), or differences in the experimental procedure (e.g., introducing the B lid for the first time on the A trials rather than during the pre-trials in the current experiment). Future work will test these possibilities.

4. This interaction was matched by a nonsignificant trend between Experiment and Condition in removals of the A lid on B trials, $F(1, 44) = 1.87, p = .18$.

REFERENCES


Diamond, A. (1983). Behavior changes between 6-12 months of age: What can they tell us about how the mind of the infant is changing? Dissertation Abstracts International, 44(01B), 337. [University Microfilms No. AAD8311882].


