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A$\bar{B}$ With Multiple Wells: 1. Why Are Multiple Wells Sometimes Easier Than Two Wells? 2. Memory or Memory + Inhibition?

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Seventy-two infants of 9½–10 months were tested with a 7-well apparatus and a 5-s delay. Other researchers had found worse performance with 2 wells than with more wells, leading some to question the role of memory in A$\bar{B}$ performance. We hypothesized that a difference in procedure might have caused the performance difference: In 2-well studies, both wells are covered simultaneously. In multiple well studies, only the correct well is uncovered and re-covered, which might help one maintain attention on the correct well. This was tested in Part 1 with 3 conditions: (a) all wells covered simultaneously with slits, (b) toy hidden by lowering it through a slit (last action at correct well), and (c) uncovering correct well only, hiding toy, re-covering that well (again, last action at correct well). Predictions were (a) worse performance in Condition 1 than in Conditions 2 or 3 or 2-well A$\bar{B}$ studies and (b) comparable performance in Conditions 2 and 3, equal or better than in 2-well A$\bar{B}$ studies. Predictions were confirmed. The use of 7 wells enabled the testing, in Part 2, of whether errors are due to forgetting or to forgetting plus a failure to inhibit a rewarded response. If the problem is memory, errors should be normally distributed about the correct well. If the problem is memory + inhibition, more errors should occur in the direction of the previously correct well. These hypotheses were tested using 2 wells between A and B and 2 wells on the other side of B. Errors occurred disproportionately in the direction of the previously correct well, suggesting that A$\bar{B}$ requires both memory and inhibition.

In the standard A$\bar{B}$ task, an infant watches as a toy is hidden in one of two possible locations, a brief delay is imposed, and then the infant is allowed to reach. Infants of 7½ to 12 months typically reach correctly at the first place the toy is hidden, but they reach incorrectly when the toy is hidden at a new location (the *A$\bar{B}$ error*). Once the infant is correct at the new location, if the toy is again hidden at the original location, the infant will now err by reaching back to the location most recently correct. The A$\bar{B}$ error is characterized by the infant's errors when the hiding location changes despite excellent performance on the first trial and on trials in which the toy is again hidden where the infant last found it.

Part 1 of this article addresses the counterintuitive finding that infants have often been found to perform better on the A$\bar{B}$ task when multiple hiding locations are used than when only two hiding locations are used (e.g., Cummings & Bjork, 1983a, 1983b; see also review by Wellman, Cross, & Bartsch, 1987). For example, using a 3-s delay with infants of 9 months, studies using two wells have found the percentage of infants reaching correctly on the first reversal trial (the first B trial) to be 32% (Bremner, 1978), 54% (Butterworth, 1977), and 25% (Gratch, Appel, Evans, LeCompte, & Wright, 1974). However, by using the same 3-s delay with infants of the same age (9 months), studies using five wells (with A and B at the endpoints) have found the percentage correct on the first B trial to be 60% (Cummings & Bjork, 1983a) and 50% (Cummings and Bjork, 1983b). A study using six wells (with A at Well 2 and B at Well 5, same delay, and same-age infants) found the percentage correct on the first B trial to be 65% (Cummings & Bjork, 1983b). In their meta-analysis of 30 A$\bar{B}$ studies, Wellman, Cross, and Bartsch (1987) concluded that "increasing the number of locations increases correct performance . . . and increases it to above-chance levels" (p. 38).

We hypothesized that this curious difference in performance, which has led some to question the role of memory in performance of the A$\bar{B}$ task, might be an artifact of a difference in procedure: When two wells are used, both wells are typically uncovered and then re-covered simultaneously. However, when multiple wells are used, because we have only two hands, the procedure has been to uncover only the correct well, hide the toy, and then re-cover that well alone. Investigators using more than two wells intended to keep everything the same as in the two-well studies, except for the number of hiding locations. However, they had to make a concession to reality. Although it is possible to take a cloth in each hand and cover two wells simultaneously, it is not possible to similarly cover three, five, or six wells simultaneously. Therefore, investigators using multiple wells changed the procedure: They left the covers on all the incorrect wells, removed the cover from the correct well, hid the toy, and then replaced the cover over the correct well.

When the last thing that happens occurs at the correct well, it might be easier for subjects to keep their attention focused there than when the last thing that happens occurs simultaneously at all the choice locations. Indeed, Harris (1973, Experiment 3) has shown, using two hiding wells, that if the experimenter cov-

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ers the correct well last, infants perform significantly better on the first B trial (the reversal trial) than they do if both wells are covered simultaneously (compared with results from other studies) or if the incorrect well is covered last (compared with Harris's own results). We reasoned, therefore, that better performance had been found in infants when multiple wells were used because of the difference in the procedure for covering the wells in multiple-well studies versus two-well studies. We predicted that, if all of the wells were covered simultaneously, infants' performance with multiple wells would *not* be better than their performance with only two wells. We tested this using three conditions of hiding with a multiple-well apparatus.

Part 2 of the article presents a test of two hypotheses that have been offered to account for the cause of errors on the $A\bar{B}$ task. Several investigators (e.g., Cummings & Bjork, 1983a, 1983b; Goldman-Rakic, 1987) have hypothesized that inadequate memory alone can account for the errors infants make on the $A\bar{B}$ task. It is certainly true that the $A\bar{B}$ error generally occurs only when a delay is imposed. When no delay is used (e.g., Gratch et al., 1974) or when the delay is reduced (e.g., Diamond, 1985), errors typically disappear. With age, infants are able to succeed at increasingly long delays (e.g., Diamond, 1985; Fox, Kagan, & Weiskopf, 1979; Gratch et al., 1974). Findings such as these strongly implicate memory (or maintaining attention over a brief delay of 1–10 s) in successful performance of the $A\bar{B}$ task.

There are some findings, however, for which a memory interpretation alone has difficulty accounting. For example, some errors (albeit fewer) occur even when transparent covers are used (i.e., even when the toy is visible; e.g., Bremner & Knowles, 1984; Butterworth, 1977; Nielson, 1982). Errors are not randomly distributed over trials (they occur primarily when the side of hiding changes and on the next one or two trials at the new hiding location; e.g., Diamond, 1985; Wellman et al., 1987), although the delays, and presumably the memory requirements, are the same on each trial considered in isolation. In visual habituation paradigms, infants appear to indicate that they remember where the hidden object is located, although when they have to reach they reach incorrectly (e.g., Baillargeon, 1986; Baillargeon & DeVos, 1991; Baillargeon, DeVos, & Graber, 1989; Baillargeon, Spelke, & Wasserman, 1985). Infants occasionally look to the correct well (as if they remember where the toy is hidden) even as they reach toward the previously correct well, or more often, they uncover the previously correct well but do *not* search there, and immediately attempt to correct their error (e.g., Diamond, 1990b, 1991). Findings such as these have led Diamond (1985, 1990a, 1990b, 1991) to hypothesize that successful performance on the $A\bar{B}$ task requires both memory and inhibition of the tendency to repeat a rewarded response (i.e., inhibition of the pull to reach back to where the toy was previously found [Well A]).

If errors on the $A\bar{B}$ task are due simply to forgetting, then incorrect reaches should be clustered around the correct location (B), evenly distributed to both sides of B (see Figure 1, top panel). ("According to the present memory explanation . . . search attempts should form a spatial gradient around the currently correct location," Cummings & Bjork, 1983b, p. 73.) If, on the other hand, errors are due to the combination of weak memory plus a pull to reach back to where the infant was successful (and rewarded) in the past, then incorrect reaches should occur primarily in the direction of the previously correct well (A), rather than symmetrically about B (see Figure 1, bottom panel). To test these hypotheses required multiple hiding locations in addition to A and B, wells located on the far side of B, and wells located in between A and B. To do this, we built a multiple-well apparatus with seven wells. Half of the infants were tested with Wells 2 and 5 from the left as the A and B locations, and half were tested with Wells 2 and 5 from the right. Butterworth (1975) has demonstrated that infants show a strong tendency to reach along the midline in the $A\bar{B}$ task (Butterworth, 1975, Experiment 1) and also that arranging the wells in a semicircle "effectively eliminated any bias to the midline" (Butterworth, 1975, Experiment 2, p. 869). Because of that work, we arranged our hiding wells in a semicircle with the center well farthest from the child in the front-back plane to offset the tendency of infants to reach along the midline.

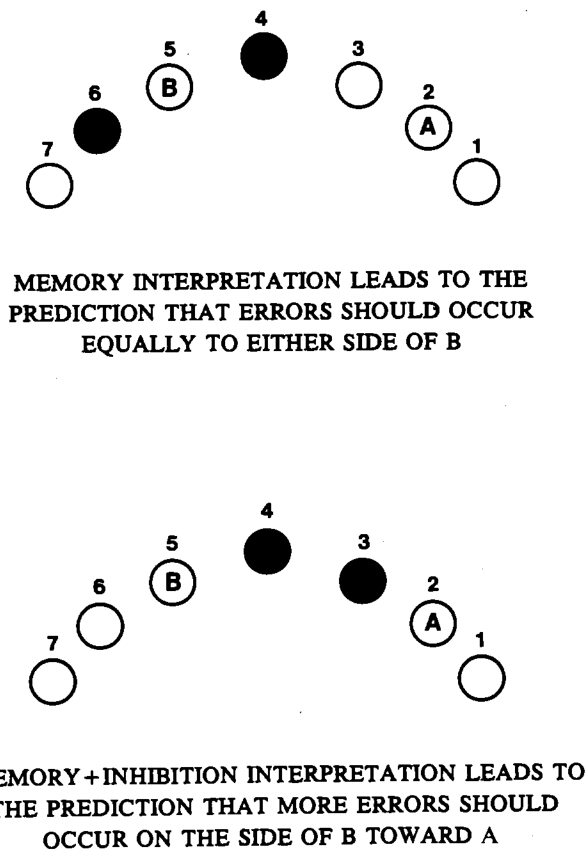

Figure 1. An illustration of the different predictions derived from the two interpretations of the sources of error on the $A\bar{B}$ task. The memory interpretation leads to the prediction that most errors should occur at Wells 4 and 6. The memory + inhibition interpretation leads to the prediction that most errors should occur at Wells 3 and 4.

Method

Subjects

Seventy-two infants (36 boys and 36 girls) were tested at the age of 9½–10 months (*M* age = 9.9 months [42 weeks 6 days], age range = 40 weeks 1 day to 45 weeks 3 days). All infants were healthy and full term, most were from middle-class families, and all were from intact homes.

Table 1
Characteristics of the Subjects in Each Condition and Their Families

Demographic variable	Slits: Simultaneous	Slits: Attention to correct	Covers: Attention to correct
M age	42 weeks 5 days	43 weeks 0 days	42 weeks 4 days
Age range	40 weeks 5 days–45 weeks 3 days	41 weeks day 1–45 weeks 2 days	40 weeks 1 day–45 weeks 0 days
Social class[a]	45.4	46.2	46.7
M no. of siblings	0.88	1.26	0.65
% subjects with no siblings	42	38	54
% of mothers			
Not working	79	67	54
Working part time	13	21	25
Working full time	8	8	21

Note. $n = 24$ in each condition.
[a] Rating on the Hollingshead (1975) scale: 77 = highest socioeconomic status (SES), 11 = lowest SES.

They were located through city and county birth records and were tested in the laboratory.

There were 24 infants per condition (see description of the three experimental conditions discussed later). Half of the subjects in each condition were boys and half were girls. Within each Sex × Condition cell, half of the subjects began testing at Well 2 from the right and half at Well 2 from the left. Within each Sex × Condition × Side of Hiding Cell, half of the subjects were tested by L.C. and half by D.N. Thus, sex, condition, side of hiding, and tester were completely counterbalanced. A summary of the background characteristics of the subjects in each condition is provided in Table 1.

Subjects were not used if they were too sleepy, cranky, or uninterested in the task. Three subjects in Condition 1, 3 subjects in Condition 2, and 4 subjects in Condition 3 were eliminated for this reason. In addition, 1 subject each in Conditions 1 and 2 could not be used because they were afraid to reach through the slits, and 2 subjects in Condition 3 could not be used because they were too interested in the felt covers.

Some infants never reached correctly on two trials in a row at the first hiding location and thus never received a reversal trial. (Side of hiding was only changed after a subject was correct on two consecutive trials). Because so many of the traditional analyses of A$\bar{B}$ performance focus on performance on reversal trials and the trials immediately following a reversal, subjects who never received a reversal were replaced for the purposes of the data analyses. Seven infants never received a reversal: 6 infants in Condition 1 (slits: wells covered simultaneously) and 1 infant in Condition 2 (slits: attention drawn to correct well). This distribution of performance over conditions (6-1-0) is significantly different from chance (trinomial distribution, $p < .05$) and markedly different from performance in two-well studies in which such poor performance on the trials at A is almost unheard of. These 7 subjects were similar to the 72 usable subjects in all respects except that they tended to be at the lower end of the age range (*M* age = 41 weeks [0 days], range = 40 weeks [3 days]–41 weeks [3 days]). Their failure to succeed on the trials at A was not due to their being tested for fewer trials; they were tested for the same number of trials as the other infants (*M* for both groups = 19 trials). The differences by condition are even more striking when these 7 subjects are included in the analyses.

Testing Procedure

All seven hiding wells were 7.5 cm in diameter and 6 cm deep and were embedded in the testing table, which stood 74 cm high, 92 cm long, and 42 cm wide. The wells were arranged in a semicircle with the center well (Well 4) 20 cm farther back than the two end wells (Wells 1 and 7; see Figure 1). The distance between the two end wells was 70 cm. Each well was lined with green felt. A collection of toys (keys, squeak toys, rattles, stuffed animals, etc.) were available so that the tester could find something to keep the child's level of interest high.

The infant was seated on the parent's lap facing the testing table and was centered so that all wells were equidistant from the infant (distances in the front-back plane were offset by distances in the left-right plane). The experimenter sat on the other side of the table, opposite parent and child. All sessions were recorded on videotape.

Pretesting. Infants were first tested for their ability to uncover a hidden object. The experimenter placed a toy in which the infant showed clear interest in the center of the table and covered it partially. All infants succeeded in retrieving the toy. This procedure was then repeated with the toy completely covered. If there was any doubt about whether the child was reaching for the toy, the trial was repeated. All infants succeeded here as well.

The first trial at Well A was a "giveaway" trial in that the toy extended partially out of the well and was visible. This was done to help the infant overcome initial reluctance to reach inside the well or through the slit. We introduced this because infants seemed not to understand our "game" without it. They did not search or searched half-heartedly and randomly over repeated trials at A. Just giving this one trial seemed to alert them to what our task was about. All infants succeeded on this "giveaway" trial. Performance here is not included in our analyses.

Testing. A trial began with the experimenter holding up a favored toy and hiding the toy in a well as the infant watched. If there was any doubt about whether the infant had seen where the toy was hidden, the hiding was repeated. A 5-s delay was then imposed during which the experimenter called to the infant and counted aloud to make him or her look up. The parent restrained the infant's arms and torso during the hiding and delay to prevent reaching, leaning, or straining toward the correct well.

A reach to the correct well was rewarded by a play period with the toy. If an infant reached incorrectly, he or she was allowed to try to self-correct by reaching to another well, but the infant was only allowed to play with the toy if correct on the initial reach. If the infant did not find the toy on the second reach, the experimenter showed the infant where the toy had been but did not allow the infant to play with it. The intertrial interval was 10 s.

Testing began at Well 2 (the A hiding location). Once a subject was correct on two trials in a row, the toy was hidden in Well 5. Well 5 (the B hiding location) was two wells from the endpoint and two wells from Well A. Once an infant was correct two times in a row at B, the toy was once again hidden at A. We tried to administer four reversals to all subjects, but some infants made so many errors that it would have required unreasonably many trials for them to receive all four reversals.

Therefore, we include here any sessions in which, if the full four reversals were not administered, the subject received at least 15 trials and at least one reversal. A subject who performed perfectly would complete four reversals in 10 trials.

Experimental Conditions

Condition 1 (slits: all wells covered simultaneously). For the outset of each trial in this condition, all of the wells were uncovered by pulling a tray, which sat between the tabletop and the wells, back toward the experimenter. The toy was then placed in one well, and the tray was pushed forward, simultaneously covering all wells. All of this was done as the child watched. With the tray in place, each well was covered by a cloth with a slit cut into it. Infants could retrieve the toy by reaching through the slit (see Figure 2, top row).

A 2-cm space between the tabletop and the wells allowed for the tray to slide in and out, covering and uncovering the wells. The tray had seven holes cut into it, each covered with denim with two perpendicular slits cut into the denim. With the tray in place, each well was covered by denim. It was not possible to see into any well covered in this way, but one could reach into a well by reaching through the slit in the denim.

Condition 2 (slits: attention drawn to the correct well). Here, the tray was in place throughout testing. The toy was hidden by lowering it through a slit into the well. Note that in this condition the last action before the delay (lowering the toy) occurred at the correct well (see Figure 2, middle row). Condition 2 was included to allow us to rule out the possibility that, if poor performance was found in Condition 1, it might be because of infants' reluctance to reach through the slits into a well. In Condition 2 slits were also used, yet we predicted good performance because the last action (in this case, the only action) focused attention on the correct well.

Condition 3 (covers: attention drawn to correct well). For Condition 3 the tray was removed. This condition replicates the standard procedure with multiple wells: Cloth covers were used and only the correct well was uncovered and then re-covered on each trial (see Figure 2, bottom row). Here again, the last action before the delay (covering the well) occurred at the correct well. A set of seven green felt covers (10.5 cm square) was used.

One third of the subjects in each Sex × Side of Hiding × Tester cell were tested with the wells covered simultaneously, one third with the toy lowered through a slit into the correct well, and one third with only the correct well uncovered and then re-covered.

Part 1: Why Multiple Wells Are Sometimes Easier Than Two Wells

Predictions

We used the three conditions of hiding to test our hypothesis that the manner in which the wells were covered might have made multiple wells easier for infants than the two-well task. We predicted, first, that performance in Condition 1 (all wells covered simultaneously with slits) would be significantly worse than in Conditions 2 and 3, even though both Conditions 1 and 2 used the tray with slits to cover the wells. This prediction is based on the hypothesis that covering all the wells simultaneously (as is done with two wells) may interfere with the infant's sustained attention to the correct hiding location. On the other hand, we hypothesized that when the last action before the delay is at the correct well alone, it should be easier for infants to keep their attention focused on the correct well.

Second, we predicted that performance would be comparable in the two conditions in which the last action before the delay occurred at the correct well (i.e., Condition 2 [hiding the toy by putting it through the slit over the correct well] and Condition 3 [uncovering and re-covering only the correct well with a cloth cover]), even though in one condition slits were used and in the other condition cloth covers were used.

Third, we predicted that performance in the latter two conditions would be at least as good as, if not better than, performance in two-well studies of A$\bar{B}$, whereas performance in Condition 1 would be worse than that in two-well studies.

Results

No significant differences were found by tester. No significant differences were found by whether testing started on the right or the left, with a single exception: number of trials until second reversal. Infants were correct on two consecutive trials sooner after the first reversal when the hiding started on the right and reversed to the left (M = 4.9 trials until two correct in a row) than when the hiding started on the left and reversed to the right (M = 7.3 trials until two correct in a row), $t(70) = 2.09$, $p = .02$. There was no difference by initial side of hiding in any other dependent variable, including number of trials until two correct in a row at the initial hiding place or in number of trials until two correct after the first, second, third, or fourth reversal. There were no significant sex differences, except on two dependent variables: Girls performed better than boys on Trial 1: girls = 100% correct and boys = 86% correct; $t(70) = 2.37$, $p = .02$. Boys needed fewer trials than girls to reach correctly twice in a row at the initial hiding place: girls, M = 5.4 trials; boys, M = 3.8 trials; $t(70) = 2.09$, $p < .04$. There were no significant interactions between condition and tester, initial side of hiding, or subject's gender. For all results reported here, we have collapsed across tester, initial side of hiding, and gender.

All predictions were confirmed.

Prediction 1. Performance in Condition 1 (slits: wells covered simultaneously) was significantly worse than performance in either Condition 2 or 3 across a wide range of dependent measures (see Table 2). When the wells were covered simultaneously, infants performed significantly worse on the first reversal trial, made more consecutive errors after the first reversal, and required more trials before they were correct twice in a row after the first reversal. These are the dependent variables most commonly reported in studies of A$\bar{B}$. A comparison of performance over all the trials yielded similar results. Infants tested with the wells covered simultaneously (Condition 1) were correct on significantly fewer trials overall, fewer reversal trials, fewer repeat following correct trials, and fewer repeat following error trials than were infants in Conditions 2 or 3. A reversal trial is a trial on which the toy is hidden in a different location from the preceding trial. (In the present study, hiding reversed back and forth between Wells 2 and 5.) A *repeat following correct* trial is defined as any trial following a correct reach where the toy is hidden in the same well as on the previous trial. A *repeat following error* trial is defined as any trial following an incorrect reach where the toy is hidden in the same well as on the previous trial. (Reversals were administered only after correct reaches.)

It is not possible to equalize the number of trials and the number of reversals across subjects if the subject must be correct twice in a row before a reversal can be administered. Although subjects in Condition 1 (slits: wells covered simultaneously) received on average one more trial than did subjects in the other two conditions (M number of trials = 20, 19, and 19 for Conditions 1, 2, and 3, respectively), they were able to re-

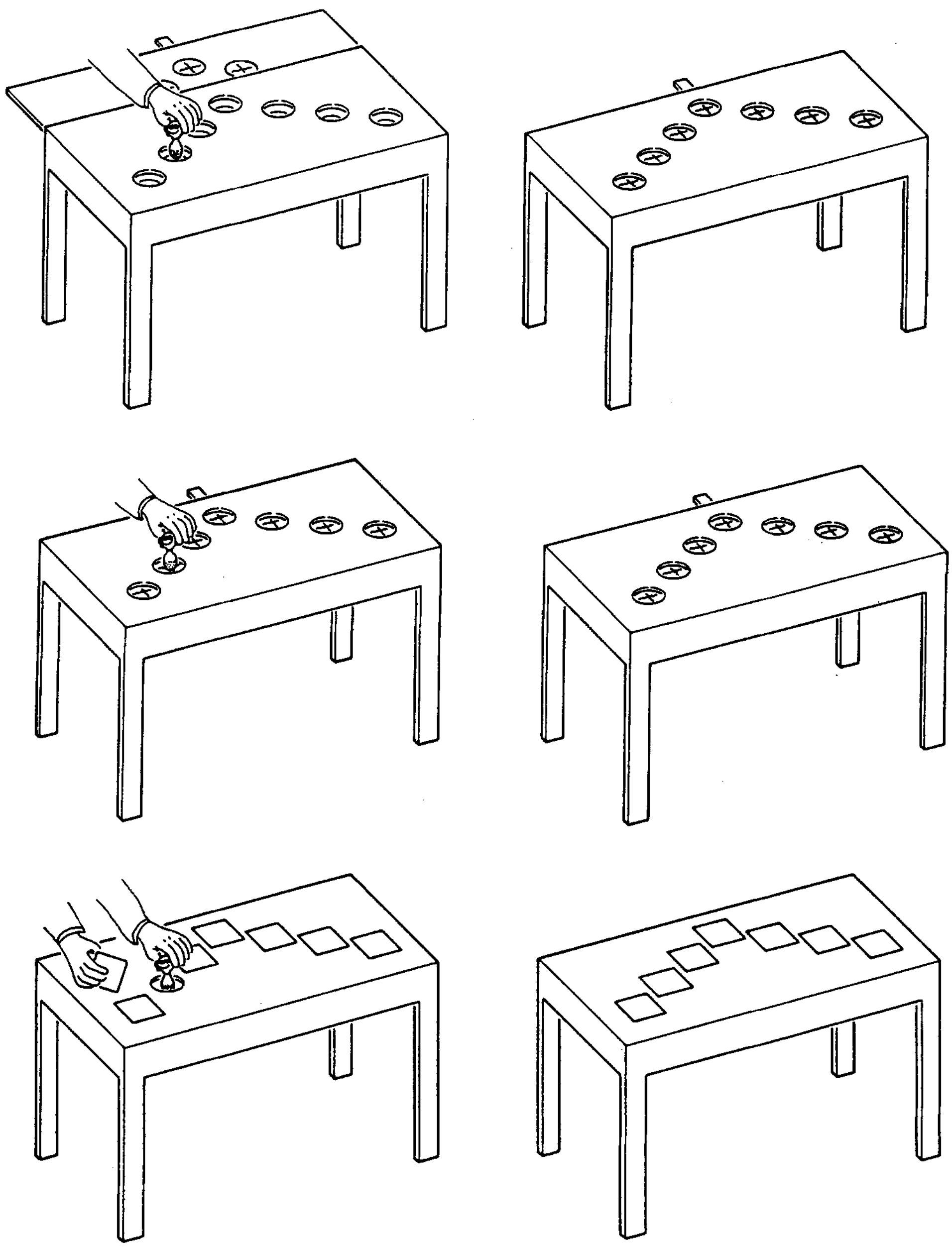

Figure 2. An illustration of the three conditions of testing with the seven-well apparatus. The left column illustrates the hiding of the toy, and the right column illustrates how the wells looked to the subject after the hiding. Top row: *Condition 1.* The experimenter pulls the tray with slits back, lowers the toy into a well, and then pushes the tray forward, simultaneously covering all the wells. Middle row: *Condition 2.* The tray with slits remains in place. The experimenter hides the toy by lowering it through a slit. Bottom row: *Condition 3.* The tray with slits has been removed. The experimenter uncovers the correct well, lowers the toy into it, and the re-covers that well.

ceive only half as many reversals because of failure to reach correctly on two consecutive trials (M number of reversals = 1.7, 3.3, and 3.6 for Conditions 1, 2, and 3, respectively), $F(2, 69) = 18.38$, $p < .0001$: linear contrast between Conditions 1 and 2 = 20.39, $p < .0001$; linear contrast between Conditions 1 and 3 = 33.19, $p < .0001$; and linear contrast between Conditions 2 and 3 = 1.55, *ns*. This is true despite our replacing the 7 subjects who failed to receive even one reversal.

In contrast to performance once a reversal was introduced, performance on Trial 1 did not differ by condition (Trial 1 performance in Conditions 1, 2, and 3 was 92%, 88%, and 96% correct respectively), $F(2, 69) = 0.84$, *ns*, and the number of trials needed before subjects were correct twice in a row at the initial hiding place only showed the most modest differences by condition (see Table 2).

Prediction 2. Performance in Condition 2 was fully comparable with performance in Condition 3 across the full range of dependent measures (see Table 2). Indeed, there was not one

Table 2
Performance in the Three Conditions of A$\bar{B}$ With Multiple Wells

Dependent variable	Condition: (1) Slits: Wells covered simultaneously	(2) Slits: Attention drawn to correct well	(3) Covers: Attention drawn to correct well	ANOVA $F(2, 69)$	Orthogonal contrasts: (1) vs. (2)	(1) vs. (3)	(2) vs. (3)
% correct on:							
First reversal trial	17	54	50	3.42*	5.75*	5.14**	0.30
All trials	32	55	58	18.43****	24.92****	39.42****	1.45
All reversal trials	17	47	50	7.00***	14.75***	17.59***	0.11
All repeat following correct trials	34	59	60	11.89****	13.52***	17.21****	0.22
All repeat following error trials	25	50	60	14.41****	18.95****	35.26****	2.36
M no. of consecutive errors after first reversal	4.9	2.7	1.5	3.94*	4.95*	14.56***	1.81
M no. of reaches until two correct in a row							
At first well	6.3	4.9	3.8	1.11	1.39	3.54†	0.46
After first reversal	9.0	5.1	4.6	4.66**	5.71*	6.43**	0.92

Note. ANOVA = analysis of variance.
* $p < .05$. ** $p < .01$. *** $p < .001$. **** $p < .0001$. † $p = .06$.

significant difference in performance between these two conditions on any dependent measure.

Prediction 3. Performance in Conditions 2 and 3 was at least as good as that typically found in two-well studies of A$\bar{B}$. However, when all the wells were covered simultaneously (Condition 1), infants' performance fell below that typically found when only two wells are used.

First, we compared the performance of the 24 subjects per condition using the seven-well apparatus reported here with Diamond's (1985) results with 25 subjects at the same age (9½–10 months) and same delay using a two-well apparatus. With two-wells, Diamond found that the mean percentage correct on the first reversal trial was 31% and that the mean performance across reversal trials was 34% correct (see Table 3). Performance on the first reversal trial and across all reversal trials in Condition 1 was half that found in the two-well study, although the differences were not significant, $z = 0.54$ and 0.66, respectively, both nonsignificant. Performance on the first reversal trial and across all reversal trials in Conditions 2 and 3, however, was significantly better than that found with two wells: for the first reversal trial, $z = 2.50$ and 2.32, for Conditions 2 and 3, respectively, versus Diamond (1985), $p < .05$ for both; across all reversal trials, $z = 2.85$ and 2.70, respectively, $p < .01$ for both. Diamond found that the average performance across all repeat following correct trials was 79% correct when two wells were used. This is significantly better than that found in Condition 1 in the present study, $z = 7.98$, $p < .01$, and significantly worse than performance on repeat following correct trials in Conditions 2 and 3 of the present study, $z = 3.75$ and 3.97, respectively, $p < .01$ for both. Finally, Diamond found that the mean percentage correct on repeat following error trials when two wells were used was 34%. Performance on repeat following error trials in Condition 1 of the present study is significantly worse than that, $z = 2.5$, $p = .01$, and performance in Conditions 2 and 3 is better than that, although the difference is only significant for Condition 3: Condition 2, $z = 1.13$, *ns*; and Condition 3, $z = 3.6$, $p < .01$.

Next, we compare performance on the first reversal trial in our study with that reported in other two-well studies conducted with infants of the same age with roughly the same length of delay by Bremner (1978: 32%), Butterworth (1977: 54%), and Gratch et al. (1974: 25%). Fewer infants in Condition 1 of the present study succeeded on the first reversal trial than in any of these studies (only 17% of the infants in Condition 1 succeeded). More infants succeeded in Conditions 2 and 3 (54% and 50%, respectively) than Bremner or Gratch found in their studies, although this is comparable to the performance reported by Butterworth. Thus, comparisons with the data from Diamond (1985) and with the means reported in the three other two-well studies with comparable populations and delays all yield similar conclusions. (a) Performance with seven wells when the wells are covered simultaneously appears to be worse than performance with two wells when the wells are covered simultaneously. (b) Performance with seven wells when attention is drawn to the correct well is at least as good, if not better, than performance with two wells when the wells are covered simultaneously. These conclusions would have been on still firmer ground if the present study had included a two-well condition.

Discussion

Previous reports that infants perform better with multiple wells than with only two wells can apparently be accounted for, in large measure, by the order in which the hiding places were covered: Uncovering and re-covering only the correct well with multiple wells made the task easier for infants than the simultaneous covering that is used with two wells. When all the wells were covered simultaneously in the multiple-well condition, performance in the multiple-well condition was no longer superior to performance in the two-well condition. We replicated previous findings that infants perform quite well when multiple wells are used and the last action before the delay draws attention to the well where the toy was hidden (Conditions 2 and

Table 3
Comparison of Performance in This Study With Performance in Other Studies of $A\bar{B}$

Study	% correct: First reversal trial	All reversal trials	All repeat following correct trials	All repeat following error trials
Present study				
Condition 1: 7 wells, simultaneously covered	17	17	34	25
Condition 2: 7 wells, covers remained in place, toy lowered through slit	54	47	59	50
Condition 3: 7 wells, only correct well uncovered then re-covered	50	50	60	60
Diamond (1985): 2 wells, simultaneously covered	31	34	79	34
Bremner (1978): 2 wells, simultaneously covered	32	—	—	—
Butterworth (1977): 2 wells, simultaneously covered	54	—	—	—
Gratch, Appel, Evans, LeCompte, & Wright (1974): 2 wells, simultaneously covered	25	—	—	—
Cummings & Bjork (1983a): 5 wells, only correct well uncovered then re-covered	50	—	—	—
Cummings & Bjork (1983b): 5 wells, only correct well uncovered then re-covered	60	—	—	—
Cummings & Bjork (1983b): 6 wells, only correct well uncovered then re-covered	65	—	—	—

Note. The other two-well and multiple-well studies included here are those that used approximately the same length of delay, with infants of approximately the same age, as the present seven-well study. Dashes indicate no data.

3). We found, as predicted, that performance was significantly worse when the wells were covered simultaneously (Condition 1) than performance in Condition 2 or 3. This was true for all dependent measures. There was no significant difference in performance by whether the toy was hidden by pushing it through a slit (Condition 2) or by covering the well with a cloth (Condition 3). The poor performance in Condition 1 cannot be accounted for by infants' reluctance to reach through a slit to retrieve the toy because they performed well in Condition 2, which also required reaching through a slit. The difference in performance in Condition 1 as compared with Conditions 2 and 3 would have been even more pronounced had we included the subjects who performed so poorly that they received no reversal (86% of these subjects were in Condition 1).

We assume, although we have not proven, that infants performed better in Conditions 2 and 3 because there was less distraction. If this is so, one would expect even stronger differences by condition if we had not called to all infants during the delay to visually distract them.

Part 2: A Test of the Memory Versus Memory + Inhibition Hypotheses

Predictions

The memory and the memory + inhibition hypotheses yield different predictions about where infants should reach when they make an error. Cummings and Bjork (1983a, 1983b) have made specific predictions based on their memory hypothesis that errors should cluster around the correct location, forming a spatial gradient with fewer reaches to wells farther from B. According to this hypothesis, distance from B is the only relevant variable; distance from A is irrelevant:

> Errors are seen as indicating encodings of spatial location information that are accurate enough to direct search to the vicinity of the correct location, but are not accurate enough to produce correct search . . . [Proactive] interference during B hiding trials owing to response competition . . . resulting from A location hiding trials has probably not been a significant source of error during B hiding trials. (Cummings & Bjork, 1983b, pp. 73–74)

In our seven-well apparatus, with B at Well 5, this means that errors should occur predominantly at Wells 4 and 6 (the wells immediately adjacent to B on *either* side; see Figure 1).

The memory + inhibition interpretation leads to the prediction that errors should occur disproportionately on the side of B toward A. That is, infants should be pulled to reach back to A, and errors should reflect some compromise between this tendency and the recollection of where the toy was just hidden. According to this interpretation, then, there are two relevant independent variables: (a) attention to where the hiding occurred on the current trial and (b) the outcome of infants' responses on previous trials. In our seven-well apparatus, with B at Well 5 and A at Well 2, this means that errors should occur predominantly at Wells 4 and 3 (the wells between B and A; see Figure 1). Note that there are two wells between A and B and two wells on the side of B away from A.

On the next reversal, when the toy is once again hidden at Well 2, the memory interpretation leads to the prediction that errors will occur predominantly at Wells 1 and 3, whereas the memory + inhibition interpretation leads to the prediction that errors will occur predominantly at Wells 3 and 4. Table 4 summarizes the set of contrasting predictions generated from these two interpretations of the causes of error on the $A\bar{B}$ task.

Results

The dependent variables of interest for this part of the article are as follows: Where do infants reach when they reach incor-

Table 4
Outline of the Predictions Derived From the Memory Versus Memory + Inhibition Interpretations

Predictions derived from the memory interpretation	Predictions derived from the memory + inhibition interpretation
1. The number of reaches to each of the two wells bordering the correct well should be roughly equal. That is, the number of reaches to the following wells should be roughly equal: Wells 4 and 6 when the hiding is at B (Reversals 1 and 3) Wells 1 and 3 when the hiding is at A (Reversals 2 and 4)	1. The number of reaches to the well bordering the correct well on the side toward the previously correct well should exceed the number of reaches to the well bordering the correct well on the side away from the previously correct well. That is, there should be more reaches to Well 4 on Reversals 1 and 3 than to Well 6 and more reaches to Well 3 on Reversals 2 and 4 than to Well 1.
2. The number of reaches to the wells one removed from B on either side (Wells 3 and 7) should be roughly equal.[a]	2. The number of reaches to the well one removed from B toward A (Well 3) should exceed the number of reaches to the well one removed from B away from A (Well 7).[a]
3. Most errors should occur at the two wells bordering the correct well (Wells 4 and 6 when the hiding is at B [Reversals 1 and 3]; Wells 1 and 3 when the hiding is at A [Reversals 2 and 4]).	3. Most errors should occur at the two wells between the correct well and the previously correct well (Wells 3 and 4).
On Reversals 1 and 3, more errors should occur at Well 6 than at Well 3 (twice as many errors, because Well 3 is twice as far away from the correct well).	On Reversals 1 and 3, more errors should not occur at Well 6 than at Well 3.
On Reversals 2 and 4, more errors should occur at Well 1 than at Well 4 (twice as many errors, because Well 4 is twice as far away from the correct well).	On Reversals 2 and 4, more errors should not occur at Well 1 than at Well 4.

[a] These predictions can only be tested on the trials at B. On reversal trials back to A, the only well on the side away from the previously correct well is the well adjacent to A (Well 1).

rectly? Where do infants reach when given the chance to correct themselves?

A 3 (condition) × 2 (gender) × 2 (tester) × 2 (initial side of hiding) analysis of variance for each of the dependent variables pertaining to Predictions 1, 2, and 3 revealed that none of these variables, nor any interaction between or among them, had a significant effect on where errors occurred. Therefore, in the analyses reported here, the results are pooled across condition, gender, tester, and initial side of hiding.

Where do infants reach when they reach incorrectly? When the toy is first hidden at A, there is no competition between the infant's memory of where he or she saw the toy hidden and the infant's earlier experience of being rewarded for finding the toy in any other well. Therefore, the memory and memory + inhibition interpretations do not lead to different predictions. Both predict errors will be clustered around the correct well. Indeed, we found that most infants (92%) succeeded on the first trial (see Table 5). When all of the initial trials at A were averaged, 72% of the reaches were correct, and 66% of the incorrect reaches occurred at one of the two wells adjacent to A, even though there were seven wells from which to choose. The actual percentage of reaches to each well over all of the initial trials at A were as follows: 9% to Well 1 (the well on the far side of A), 71% to A, 11% to Well 3 (the well on midline side of A), 4% to Well 4, 2% to Well 5, 1% to Well 6, and 1% to Well 7. (Infants were tested at A until they were correct twice in a row. Therefore, infants who reached incorrectly received more trials at A. To count each infant's performance equally, we first calculated the percentage of reaches to each well individually for each infant, then we averaged these percentages over all infants.)

The relevant trials for testing between the two sets of predictions begin when the toy is first hidden at B, for here is the first time that (a) the infant has seen the toy hidden at more than one place and (b) the infant has had previous experience of successfully finding the toy elsewhere. The memory interpretation leads to the prediction that approximately equal numbers of errors should occur at the wells adjacent to B on either side and at the wells one removed from B on either side. As shown in Tables 5 and 6, however, these error rates were not equal; infants were much more likely to reach on the side of B toward A. This is consistent with the prediction generated from the memory + inhibition interpretation, that is, that errors would occur disproportionately in the direction of A. Over all the trials in the session, and on the trial most commonly used to study the A$\bar{B}$ error (the first reversal trial), more than twice as many infants reached to the well adjacent to B, or to the well one removed from B, on the side of B toward A than reached to the corresponding wells on the other side of B (see Table 6). This was significantly different from the memory interpretation's predicted 50-50 distribution (p values for binomial distribution and for z scores are provided in Table 3).

An even more stringent test of the memory + inhibition hypothesis is to compare performance not against 50%, but against the actual distribution of reaches observed during the

Table 5
Number of Children in Each Condition Reaching to Each Well on Selected Trials

Trial	Condition								
	Trials at A								
	2 away	1 away, Well 1	Correct, Well 2	1 toward, Well 3	2 toward, Well 4	Well to be used on 1st reversal, Well 5	4 toward, Well 6	5 toward, Well 7	No reach
First trial	—	0	66	2	1	1	1	0	1
Second trial	—	11	39	10	3	1	2	2	4
Third trial[a]	—	4	22	6	3	1	1	1	0
Total	—	15	127	18	7	3	4	3	5
	First reversal								
	2 away, Well 7	1 away, Well 6	Correct, Well B	1 toward, Well 4	2 toward, Well 3	Previously correct, Well A	4 toward, Well 1	5 toward	No reach
First trial at B	4	6	27	14	10	4	2	—	5
Second trial at B	5	5	40	13	5	0	2	—	2
Third trial at B[a]	4	3	22	11	5	3	0	—	2
Total	13	14	89	38	20	7	4	0	9
	Second reversal								
	2 away	1 away, Well 1	Correct, Well 2	1 toward, Well 3	2 toward, Well 4	Previously correct, Well 5	4 toward, Well 6	5 toward, Well 7	No reach
First trial back at A[b]	—	5	32	5	13	6	1	0	0
Second trial back at A[b]	—	5	36	7	7	3	1	1	2
Third trial back at A[a]	—	4	16	6	6	2	1	2	3
Total	—	14	84	18	26	11	3	3	5

Note. All $ns = 72$, unless otherwise specified. Results are collapsed across the three conditions of testing because there was no evidence that condition had any effect whatsoever on where infants reached when they erred. Dashes indicate no data.
[a] Infants who are correct on both of the first two trials at a location do not receive a third trial at that location. [b] $n = 62$. Nine infants in the simultaneous condition found the task so difficult that they never made it to the second reversal. One subject in the slits: attention-to-correct-well condition never reached correctly on two trials in a row after the first reversal, even though that child was tested for 24 trials. Hence, that child was never tested on a second reversal.

initial hiding at A. We arranged our wells in a semicircle to minimize the tendency of infants to reach toward the midline, and, indeed, the work of Butterworth (1975) has shown this to be a sufficient precaution. However, if we did not adequately offset midline reaching, then more reaches might be observed toward A, not because A happened to be in that direction, but because the midline happened to be in that direction. The initial trials at A provide a pure measure of the tendency to reach toward the midline because infants had no experience before these trials of retrieving the reward at another well; hence a disproportionate tendency to reach toward the inside wells on these trials would have to be because of a tendency to reach toward the midline. There was only one well on the far side of A, so the appropriate comparison is the number of reaches to that well versus the number of reaches to the well adjacent to A on the other side (the inside). The distribution of reaches to these two wells over the initial trials at A was 45.5% to the outside well adjacent to A and 54.5% to the inside well adjacent to A. Once side of hiding was reversed, the distribution of reaches was significantly more skewed toward the previously correct well (32% to the outside adjacent well vs. 68% to the inside adjacent well) than even this more stringent empirical baseline (see Table 6, lines 1 and 2). The significant tendency to reach in the direction of the previously correct well does not appear to be caused by a tendency to reach toward the midline. On the first reversal trial, the distribution was still more skewed (30% vs. 70%).

It might be noted that when there is no previously correct well (i.e., on the initial trials to A) the number of reaches to the adjacent wells on either side of the correct well is roughly equal. That is, the observed distribution of 45% versus 54% on the initial trials to A is not significantly different from 50%. This is consistent with both hypotheses under consideration: When there is no pull to reach back to where they were previously rewarded, infants' performance should conform to a normal forgetting curve.

Perhaps the strongest test of the memory interpretation versus the memory + inhibition interpretation is the comparison of the number of reaches to the well adjacent to Well B, but on the side of B away from A (Well 6 in Figure 1), and the number of reaches to the well one removed from B, but between Wells A and B (Well 3 in Figure 1). (Here and below, A and B are used in the generic sense to mean the previously correct well and the presently correct well.) If reaches were normally distributed around the correct well, as the memory interpretation would lead one to predict, then there should be twice as many reaches at each well adjacent to the correct well as at a well one removed

Table 6
Tests of Predictions Outlined in Table 4

Trial	n	%	%	Statistical tests	p
		Tests of Prediction 1[a] Wells adjacent to the correct well			
		Reaches to the well toward the previously correct well	Reaches to the well on the other side of the correct well		
All trials[b]	68	69	31	z (69 vs. 50%) = 3.16	<.001
				z (69% vs. 54.5%)[c] = 2.42	<.01
First trial of the first reversal (first B trial)	20[d]	70	30	Binomial (50%)	= .03
				Binomial (54.5%)[c]	= .08
All trials of the first reversal[e]	39	67	33	z (67% vs. 50%) = 2.08	<.02
				z (67% vs. 54.5%)[c] = 1.53	= .06
First trial of the second reversal (first trial back at A)	10	50	50	Binomial (50%)	*ns*
All trials of the second reversal	33	77	23	z (77% vs. 50%) = 2.96	<.001
				z (77% vs. 54.5%)[c] = 2.45	<.01
		Tests of Prediction 2[a,f] Wells one removed from the correct well			
		Reaches to the well toward the previously correct well	Reaches to the well on the other side of the correct well		
All trials[g]	53	74	26	z (74% vs. 50%) = 3.43	<.0003[h]
First trial of the first reversal (first B trial)	14	71	29	Binomial (50%)	= .05[h]
All trials of the first reversal[e]	29	76	23	z (76% vs. 50%) = 2.79	<.003[h]
		Tests of Prediction 3[9]			
		Reaches to the well one removed from the correct well, but toward the previously correct well	Reaches to the well adjacent to the correct well, but on the other side of the correct well		
All trials[b]	61	66	34	z (66 vs. 50%) = 2.43	<.01
				z (66% vs. 33%)[i] = 5.40	<.0001
				z (66% vs. 33%)[c] = 5.63	<.0001
First trial of the first reversal (first B trial)	16	63	37	Binomial (50%)	= .10
				Binomial (33%)[i]	<.005
				Binomial (32%)[c]	<.005
All trials of the first reversal[e]	35	60	40	z (60 vs. 50%) = 1.19	= .12
				z (60% vs. 33%)[i] = 3.40	<.0003
				z (60% vs. 32%)[c] = 3.55	<.0002
First trial of the second reversal (first trial back at A)	18	72	28	Binomial (50%)	<.03
				Binomial (33%)[i]	<.0002
				Binomial (32%)[c]	<.0002
All trials of the second reversal	24	71	29	z (71% vs. 50%) = 2.04	<.02
				z (71% vs. 33%)[i] = 3.95	<.0001
				z (71% vs. 32%)[c] = 4.07	<.0001

[a] Cummings and Bjork's (1983a, 1983b) memory interpretation predicts that columns 1 and 2 will be equal (i.e., *p* values will not be significant). Diamond (1985, 1990b) memory + inhibition interpretation predicts that the numbers in column 1 will be greater than those in column 2 (i.e., *p* values will be significant). [b] The percentage of times a subject reached to the two wells in question was calculated over all trials beginning with the first trial on which there was a previously correct location (i.e., the first reversal trial), and then a grand mean for all subjects was calculated from these individual means. When $N < 72$, that is because any infant who never reached to either of the two wells in question was excluded. [c] Second line tests performance against the observed percentage correct on the initial trials at A. [d] Of the 20 infants who reached to one of the wells adjacent to the correct well on the first trial at B, 14 infants (70%) reached to the well toward A, and 6 infants (30%) reached to well on the other side of B. [e] The percentage of times an individual subject reached to the two wells in question was calculated over all trials at B before the toy was again hidden at A, and then a grand mean for all subjects was calculated from these individual means. When $N < 72$, that is because any infant who never reached to either of the two wells in question over this set of trials was excluded. [f] When the hiding is at A there is only one well on the side of A away from B; to test Prediction 2 requires two wells on either side of the correct well. Hence, Prediction 2 could not be tested for the trials back at A (i.e., the second reversal). [g] Includes all trials with the hiding at B, but no trials at A. The percentage of times a subject reached to the two wells in question was calculated over all trials at B and then a grand mean for all subjects was calculated from these individual means. N is <72 because any infant who never reached to either of the two wells in question on any trial at B was excluded. [h] There were no comparable trials at A with which to compare performance here. [i] If reaches were normally distributed around the correct well, as the Cummings and Bjork's memory interpretation would predict, half as many reaches should go to the well one removed from the correct well compared with the number of reaches to the well adjacent to the correct well (33% to well one removed, 67% to adjacent well).

from the correct well. We compared the number of reaches to the outside well adjacent to B with the number of reaches to the well one removed from B in the direction of A against this hypothesized 67% versus 33% distribution (see Table 6, tests of Prediction 3). The results are strongly in favor of the memory + inhibition hypothesis; in fact, they are directly opposite to the prediction generated from the memory interpretation (37% vs. 63% for first trial of the first reversal, 28% vs. 72% for the first trial of the second reversal, and 34% vs. 66% over all trials beginning with the first reversal). With reference to Figure 1, infants were approximately two times more likely to reach to the well next to A (between A and B) than to the well next to B away from A.

Again we tested this against the observed distribution of reaches on the initial trials to A. The results of these tests are the same (see Table 6), as the distribution of reaches on the initial trials at A was quite close to the predicted 67% versus 33% distribution (observed distribution over the initial trials to A = 68% vs. 32%). Note once again that when there is no previously correct well, performance conforms quite well to what a memory interpretation alone would predict.

All of the results are equally true whether the toy was hidden at Well A (Reversals 2 and 4) or Well B (Reversals 1 and 3). To check this, for all of the trials at each reversal, we calculated the percentage of reaches to each of the pairs of wells corresponding to Predictions 1, 2, and 3 for each subject. Then we compared the pattern of reaches as revealed by these percentages for Reversal 1 versus Reversal 2 and for Reversals 1 and 3 versus Reversals 2 and 4 using matched pairs t tests. None of the analyses yielded a significant difference.

Few infants reached back precisely to the previously correct well once side of hiding was reversed (only 10% of the reaching errors on the first trial of each reversal were to Well A), and more infants erred by reaching closer to Well B than by reaching closer to Well A (27% of the reaching errors on these trials occurred at the well toward A adjacent to B, whereas 18% occurred at the well toward A adjacent to A). However, the memory + inhibition interpretation does not require that errors occur precisely at A or closer to A, but only that they occur disproportionately in the direction of A. The percentage of reaches to A is highest on the first trial of a reversal, and then diminishes over consecutive trials at this location. This is consistent with the notion that there is competition between previous experience of retrieving the reward at A and newer information. As the infant sees the toy hidden at B repeatedly over trials and receives repeated feedback over trials that reaching to A is now incorrect, one would expect the pull to reach back to A to diminish.

Where do infants reach when given the chance to correct themselves? We allowed infants to reach again (i.e., to self-correct) if their initial reach on any trial was incorrect, although infants were rewarded only when their initial reach was correct. On only 20% of these self-corrections did infants reach to the correct well. Many more of these self-correction reaches were to the side of B toward A rather than to the other side of B (e.g., 15% were to the well adjacent to B on the A side, whereas only 8% were to the well adjacent to B on the outer side). Moreover, unlike what was found for initial reaches on each trial, more self-correction reaches were to the well adjacent to A, one removed from B, than to either well adjacent to B: 22% of the self-correction reaches were to the former location as compared with only 15% of the reaches to the well adjacent to B on the A side and only 8% to the well adjacent to B on the outer side. Indeed, many self-correction reaches occurred at Well A itself (25% of the self-corrections on the first trial of each reversal). The hypothesis of a bell-shaped distribution of reaches around Well B motivated by the memory hypothesis would appear to fare even worse here than it did for the initial reach data. On the first trial of each reversal, the tendency to reach to A or to the well adjacent to A was far stronger in self-correction behavior than in infants' initial reaches, although, as we saw for initial reaches, this tendency decreased over successive trials (see Table 7).

There were fewer self-corrections than there were reaches because not all infants who reached incorrectly reached again to correct themselves, and no infants who initially reached correctly or who initially did not reach at all self-corrected. For this reason, comparisons of the locations of self-correcting that are based on performance on a single trial have very small sample sizes and often did not reach significance (see Table 8). However, all comparisons based on performance over multiple trials were significant at $p < .0001$ (see Table 8). (We did not compare performance after the first reversal with performance on the initial trials at A here because there were so few self-corrections on the initial trials at A.)

Discussion

The pattern of errors over trials on the A$\bar{B}$ task, even when only two wells are used, has previously been demonstrated to be inconsistent with an interpretation based solely on forgetting (Diamond, 1985, 1990b), for errors do not occur equally over all trials, but are clustered on specific kinds of trials, even though the delay is equal on all trials. The pattern of reaches over trials is consistent with the memory + inhibition interpretation, however. Errors occur primarily when the subject was just rewarded at one location and the reward is now hidden at the other location. Here, the memory + inhibition interpretation would lead one to predict a competition between previous reinforcement experience and present information.

Studies with only two wells do not permit one to determine whether the pattern of reaching within a trial is consistent with a memory interpretation or the memory + inhibition interpretation, however, because subjects can only make an incorrect choice by reaching back to the previously correct well. Previous studies with multiple wells have also not provided adequate data to test the pattern of reaching to different wells against the predictions derived from these two different interpretations. Generally, in multiple well studies, A and B have been at the endpoints (e.g., Cummings & Bjork, 1983a, 1983b). Here, subjects can only err by reaching toward A. To test between the two interpretations, however, it must be possible for subjects to also err by reaching away from A. When A and B have not been at the endpoints, one of them has usually been at the midline with the wells arranged in a straight line (e.g., Cummings & Bjork, 1983a, 1983b), so that a great deal of the variance could be accounted for by the tendency of infants to reach toward the midline. One condition in the study by Cummings and Bjork (1983b) did not have A or B at an endpoint or at the midline. Six wells were used; Well 2 served as A and Well 5 served as B. Thus, there was one well on the side of B away from A (Well 6) and two wells between A and B (Wells 3 and 4). On the first

Table 7
Where Each Child Reached When Given the Chance to Self-Correct on the First Three Trials of Reversals 1 and 2

Trial	Reversal/condition								
	First reversal								
	2 away, Well 7	1 away, Well 6	Correct, Well B	1 toward, Well 4	2 toward, Well 3	Previously correct, Well A	4 toward, Well 1	5 toward	No self-correction
First trial at B (n = 40)	3	5	6	3	6	7	1	—	9
Second trial at B (n = 30)	4	2	6	4	3	3	1	—	7
Third trial at B (n = 18)[a]	1	0	4	2	6	2	1	—	2
Total	8	7	16	9	15	12	3	—	18
	Second reversal								
	2 away	1 away, Well 1	Correct, Well 2	1 toward, Well 3	2 toward, Well 4	Previously correct, Well 5	4 toward, Well 6	5 toward, Well 7	No self-correction
First trial back at A (n = 40)	—	2	5	6	11	10	1	2	3
Second trial back at A (n = 34)	—	4	5	7	12	1	1	0	3
Third trial back at A (n = 16)[a]	—	1	8	4	0	0	0	1	2
Total	—	7	18	17	23	11	2	3	8
Grand total	8	14	34	26	38	23	5	3	26
% of self-corrections to each well	4.5	7.9	19.2	14.7	21.5	13.0	2.8	1.7	14.7
% of incorrect self-corrections[b]	6.8	11.9	—	22.2	32.5	19.7	4.3	2.6	—

Note. Children who reached correctly on their initial reach or who did not reach at all on a given trial are not included in the sample size for that trial in this table. Dashes indicate no data.
[a] Infants correct on both of the first two trials at a location are not tested on a third trial at that location. [b] Excludes correct and no-reach self-corrections.

reversal trial (the first trial at B), no infant reached to the well away from A (Well 6) and all infants who erred reached either to Well 3 or 4. Over the three trials to B that were administered, 1 reach occurred to Well 6 whereas 13 reaches occurred to Well 4 (the corresponding well on the side of B toward A). This would seem to strongly support the memory + inhibition interpretation, except that here, too, the wells were arranged in a straight line. Therefore, this pattern of responses might as easily be due to the tendency to reach toward the midline as to the pull to reach back in the direction of the previously correct well.

The present study compensated for infants' tendency to reach along the midline by arranging the wells in a semicircle with the more centrally located wells farther from the infant in the frontal plane, and the present study provided two wells on the outside of B as well as two wells between A and B. Neither A nor B were at an endpoint or the midline. The results are consistent with all predictions generated from the memory + inhibition interpretation and significantly different from all predictions generated from the memory interpretation.

Infants erred, and tried to correct their errors, by reaching disproportionately to wells on the side of B toward A. Whereas the memory interpretation would lead one to predict that the distance of the wells from B would largely determine the distribution of reaches, with the wells closer to B receiving more reaches and the wells equidistant from B receiving roughly equal number of reaches, our findings were significantly different from these predicted outcomes. Instead, a well's location in relation to A also exerted a powerful influence on infants' behavior.

These results cannot be accounted for by a tendency to reach toward the midline because in the absence of a pull to reach back to the previously correct well (the initial trials to A) infants did not show a significant tendency to reach toward the midline. Indeed, on the initial trials at A, errors were normally distributed about the correct well, suggesting that when there is no reinforced response to inhibit, the memory demands of the task alone determine performance.

General Discussion

Previous findings that infants perform better with three to seven hiding locations (where one would expect the memory requirements to be more severe) than they do when only the traditional two hiding locations are used (e.g., Cummings & Bjork, 1983a, 1983b; Sophian, 1985) raised questions about the role of memory in AB̄ performance. In Part 1, we presented evidence that infants' performance with multiple wells is consistent with the role of memory in the AB̄ task: Infants perform well when tested with multiple wells if the experimenter draws their attention to the correct well immediately before the delay; they do not perform well with multiple wells when they are distracted by the simultaneous covering of all the wells. Other evidence that infants' performance with multiple wells is still consistent with the role of memory in the task comes from the work of Horobin and Acredolo (1986). Infants may also have performed better with multiple wells than with only two wells because of the greater spatial separation (and hence greater discriminability) between Wells A and B in the multiple-well stud-

Table 8
Second Set of Tests of Predictions Outlined in Table 1: Where Infants Reached to Correct Themselves When Their Initial Reach Was Wrong

Trial	*n*	%	%	Statistical tests	*p*
		Tests of Prediction 1[a] Wells adjacent to the correct well			
		Reaches to the well toward the previously correct well	Reaches to the well on the other side of the correct well		
All trials[b]	28	68	32	z (68% vs. 50%) = 1.89	<.03[c]
First trial of the first reversal (first B trial)	8[d]	38	63	Binomial (50%)	*ns*
First trial of the second reversal (first trial back at A)	8	75	25	Binomial (50%)	= .10
		Tests of Prediction 2[a,e] Wells one removed from the correct well			
		Reaches to the well toward the previously correct well	Reaches to the well on the other side of the correct well		
All trials[f]	22	82	18	z (82% vs. 50%) = 2.99	<.001
First trial of the first reversal (first B trial)	9	67	33	Binomial (50%)	= .15
		Tests of Prediction 3			
		Reaches to the well one removed from the correct well, but toward the previously correct well	Reaches to the well adjacent to the correct well, but on the other side of the correct well		
All trials[b]	23	66	34	z (69% vs. 33%)[g] = 3.28	<.0005
First trial of the first reversal (first B trial)	11	55	45	Binomial (33%)[g]	= .06
First trial of the second reversal (first trial back at A)	13	85	15	Binomial (33%)[g]	= .0001

[a] Cummings and Bjork's (1983a, 1983b) memory interpretation predicts that columns 1 and 2 will be equal (i.e., *p* values will not be significant). Diamond's (1985, 1990b) memory + inhibition interpretation predicts that the numbers in column 1 will be greater than those in column 2 (i.e., *p* values will be significant). [b] The percentage of times an individual subject reached to correct himself or herself to the two wells in question was calculated over all trials beginning with the first trial on which there was a previously correct location (i.e., the first reversal trial), and then a grand mean for all subjects was calculated from these individual means. When the *N* is <72 it means that one or more subjects never reached to either of the two relevant wells to correct himself or herself. [c] Performance on the initial trials at A is not used here to provide a second baseline for comparison, as it was in Table 3, because there were so few self-corrections on the initial trials at A. [d] Of the 8 infants who reached to one of the wells adjacent to the correct well to correct themselves on the first trial at B, 3 infants (37.5%) reached to the well toward A, and 5 infants (62.5%) reached to well on the other side of B. [e] When the hiding is at A there is only one well on the side of A away from B; to test Prediction 2 requires two wells on either side of the correct well. Hence, Prediction 2 could not be tested for the trials back at A (i.e., the second reversal). [f] Includes all trials with the hiding at B, but no trials at A, because Prediction 2 cannot be tested for trials at A. [g] See Table 6, footnote i.

ies. Horobin and Acredolo demonstrated that infants perform better with only two wells if those wells are farther apart (comparable to their spatial separation in multiple-well studies) than if the wells are closer together.

The A$\bar{B}$ task requires that infants keep their attention focused on where a toy has been hidden. Procedures that distract infants (e.g., simultaneous covering of all wells) make the task more difficult, whereas procedures that direct attention to the well containing the toy (as in Conditions 2 and 3 earlier) make the task easier. With increasing age, infants are able to maintain their attention on the current location of the toy over longer and longer delays (e.g., Diamond, 1985).

In Part 2, however, we have provided evidence that poor memory alone cannot fully account for the errors infants make on the A$\bar{B}$ task. A disproportionate number of errors are in the direction of the previously correct well. We take this as evidence that although memory or sustained attention is important for success on the A$\bar{B}$ task, it is not the only ability required here. Infants must also resist or inhibit the predisposition to repeat a response that succeeded just minutes earlier. Reinforcement is a very powerful determiner of behavior. On the A$\bar{B}$ task, infants will occasionally reach back to the previously correct well even when their visual attention is firmly directed to the well currently containing the toy (e.g., Diamond, 1991). Infants' reaching errors when multiple wells are provided does not follow a pattern consistent with memory of the latest hiding of the toy being the sole determiner of where infants reach. Instead, where infants reach appears to be determined, in part, by memory of this observation and, in part, by the infant's recent reinforcement history. Thus, we have tried to demonstrate in Part 1 that results on the A$\bar{B}$ task are consistent with memory or sustained attention being one of the abilities required by the task; we have tried to show in Part 2 that this is not the only ability required for success on the task—inhibitory control is needed as well.

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