# A DYNAMIC ACCOUNT OF THE A-NOT-B ERROR IN CAPUCHIN MONKEYS (*CEBUS APELLA*)

by

CARRIE ROBIN ROSENGART

(Under the Direction of Dorothy M. Fragaszy)

## ABSTRACT

Piaget (1954) found that between 8 to 10 months of age children retrieved an object from a hiding location (A), and were able to do this on repeated trials. However, if the object were switched to a new hiding lo25cation (B) the child would perseverate and search the original A hiding location. This error was more likely to be observed as the delay between hiding and the opportunity for searching increases. Memory mechanisms are not sufficient to explain all findings (i.e., children make errors even when objects are placed under translucent cups). The purpose of this research was to explore the circumstances that lead capuchin monkeys (*Cebus apella*) to make the A-not-B error. According to the dynamic systems perspective the A-not-B error is due to the visual, attentional and motor process involved in searching for the object as well as the short-term memory for where the object was last seen and long-term memory about past searches rather than a lack of object permanence (knowledge that objects continue to exist when they are out of sight). This model was tested in two experiments with eight pair-housed monkeys. In both experiments, the delay between hiding a food reward and opportunity for retrieval was manipulated. Experiment 1 used discrete hiding locations and obvious spatial cues, and Experiment 2 used continuous hiding locations and few spatial cues. Each monkey was tested with four different delay conditions (0, 10, 30 and 120 seconds) for both A and B trials. Regardless of the amount of spatial cues, the monkeys were more accurate on A trials as compared to B trials. The two experiments were also comparable in the way increased delay periods caused decreases in search accuracy. On B trials in Experiment 2 the searches were biased towards the A location. It appears that motor activity associated with searching at the A location contributes to the A-not-B error. This study supports the dynamic systems account for the A-not-B error, indicating the perseverative searching is a more general phenomenon than had previously been suggested.

INDEX WORDS: Memory, Spatial cognition, Primate, Capuchin Monkey, Object Permanence

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B.S., Tufts University, 1995

M.S. The University of Georgia, 2001

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2005

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August 2005

# ACKNOWLEDGEMENTS

I would like to thank Dorothy Fragaszy, Irwin Bernstein and Jonathon Crystal for their support, encouragement and advice. I am grateful to all of the people who have assisted me in data collection and analysis including Alicia Hudson, Bettina von Ammon, Tephillah Jeyaraj, Qing Liu, Jessica Crast, Tamika Blount, Jacqueline Montoya and Jennifer Clementz. I could not have reached this point in my academic career without Erica Kennedy’s and Tracy Lambert’s guidance and counsel. Last, but definitely not least, I would like to thank my parents, Stanley and Terry Rosengart, and my sister Erica Rosengart for being there for me. Through the exciting and challenging parts of my research you have always been my strongest supporters.

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# CHAPTER 1

# INTRODUCTION

The A-not-B error was first noticed by Piaget (1954) as one of the stages in the development of object permanence. According to Piaget (1954), one of the key advances in an infant's cognitive abilities is the understanding that objects continue to exist when they are out of sight. Between 8 to 10 months of age, children were found to search for and retrieve a hidden object from a location (A), and were able to do this on repeated trials. However, if the object were hidden at a new location (B) the child would continue to perseverate and search the original A location. Piaget (1954) labeled this pattern of perseverative reaching to A as "the A-not-B error," and explained the A-not-B error as reflecting the infant's egocentric view of the world. He thought that the child reached for the A location based on an inability to separate the actions of the object (moved by the experimenter) and his or her own actions towards the object. According to Piaget, the child is not aware that the object continues to exist when not seen. He proposed that children believe that reaching to point A brings the object back into existence. Later in development, infants reach effectively to location B in the same circumstances. Piaget claimed this behavior indicated the child had a concept of "object permanence," and understood that objects continue to exist when they are not in view.

Since Piaget's observations, a number of studies have investigated the factors that influence whether or not a child will demonstrate the A-not-B error (see Marcovitch and Zelazo, 1999 for a review and meta analysis). The task has been expanded to include multiple search locations, rather than just two (e.g., Bjork & Cummings, 1984; Diamond, Cruttenden &

Neiderman, 1994), changes in the distance between locations (e.g., Horobin & Acredolo, 1986), and changes in the locations themselves so that the locations are more distinctive (e.g. Harris, 1974). Additionally, a delay period was introduced of up to 15 seconds between hiding the objects and the opportunity for retrieval (Diamond & Goldman-Rakic, 1989) as compared to Piaget's original immediate search. Each change in the task dynamics altered the age at which children demonstrated the error and the prevalence of the error's occurrence. According to Marcovitch and Zelazo's meta-analysis of 107 experiments, the age of the child, the length of delay between search and retrieval, the number of locations and the number of exposures to the original "A" location were all predictive of whether or not a child would perseverate. Object permanence and the A-not-B error have also been investigated in non-human primates. Most studies of adult non-human primates have found that they do not make the A-not-B error (e.g. Natale et al., 1986, Diamond & Goldman-Rakic, 1989, deBlois et al., 1998 and deBlois et al. 1999).

According to Marcovitch and Zelazo's meta-analysis (1999), the A-not-B error has been tested with delay periods ranging from 0-15 seconds with the likelihood of error increasing with delay regardless of the child's age. The delay period necessary to elicit the A-not-B error increased at an average of 2 seconds/month (Diamond, 1985) until delays of over 10 seconds were needed before 12-month-old children made the error reliably.

Squirrel monkeys were able to complete visible displacement tasks without showing the A-not-B error, but were unable to master invisible displacement tasks (deBlois et al., 1998). Rhesus monkeys and 12-month-old human infants show a similar result (Diamond and Goldman-Rakie, 1989). They can both successfully find a hidden object at a new "B" location without making a perseverative error even when there is a 10-second delay period. However, when the monkeys’ dorsolateral prefrontal cortex had been lesioned, their behavior matched that of 7.5-9 month humans (they made the A-not-B error with 10 second delay periods), indicating that this portion of the brain is tapped in this task. Most studies with non-human primates were conducted without a delay period between hiding the objects and retrieval, whereas this variable has been systematically manipulated in studies with human infants.

Perhaps because a number of variables influence whether or not children make the A-not-B error, multiple theories have been proposed to account for the findings. Since the error is more likely to be observed as the delay between hiding and the opportunity for searching increases, memory mechanisms have been used to explain why the A-not-B error occurs (Diamond, Cruttenden & Neiderman, 1994). According to this theory, errors occur on B trials due to competition between the working memory for the B location and previous learning about the A location. Since the child has been rewarded for reaching to the A location in the past, the child should be inclined to reach again to the previously satisfactory location. However, this theory is not adequate to explain all the findings. For example, children continue to make the A-not-B error, though to a lesser degree, even when there is no memory demand at all (e.g., the object to be retrieved is placed under a transparent cup allowing the child to see the object after it has been “hidden” (Butterworth, 1977).

The A-not-B error has also been interpreted from a dynamic systems perspective. According to dynamic systems theory, behavior at a particular time and place reflects the combined contributions of many factors such as biological preparedness, previous experiences, demands of the task, etc. A dynamic systems account of the A-not-B error includes the visual and attentional processes involved in assessing the nature of the hiding locations, the motor process involved in reaching for the object, the short-term or working memory for where the object was last seen and long-term memory about past searches (Spencer, Smith & Thelen, 2001). A key point of this theory is that the error is not directly linked to the age or maturational status of the individual. The A-not-B error can be viewed as a specific type of spatial memory failure (where an individual returns to a habitual search rather than a situation appropriate search) rather than a specific developmental stage. According to this theory, even adults, who without doubt understand that objects persist when not in view, should occasionally make an A-not-B error if the search is sufficiently challenging.

In order to test the dynamic systems account, two-year-old children, who typically do not make the A-not-B error, were tested to see if under the appropriate conditions (such as increased delay periods, reduction in cues to the hiding location, and addition to the number of hiding/search locations) they would show perseverative reaching (Spencer et al, 2001). Rather than using the traditional two-well or multiple well set up to hide an object, Spencer et al. hid, toys in a sandbox. This served to reduce spatial cues because the sandbox is large and uniform, and it increased the number of hiding/search locations because any spot in the box could be searched or have had an object hidden in the sand. This design, unlike previous designs, allows one to determine if the child searches at the correct location and it also allows one to probe more deeply into what kind of error the child is making. There are fewer cues in a smooth sandbox, so the child must now recall where the toy was hidden, rather than simply recognize where the object was last seen. Since there are continuous search locations available, the child is not forced to make a choice between a set number of cued locations. The searches can be assessed in this procedure in accord with the position of the first contact with the sand relative to the A and B locations. In this way, the relative strength of the impulse to reach towards A can be assessed. In the past, the A-not-B error was measured based on a dichotomous correct/incorrect judgment for each search. With Spencer et al.'s methodology, a measure of accuracy could be obtained based on the distance of the B trial search from the hiding location and whether that search was towards the A location. A stronger impulse to search at the A location would be reflected in decreased accuracy, with the searches coming nearer to the A location.

Spencer et al. (2001) found that indeed, two-year-old children do still make perseverative reaches towards the initial A location on B trials when searching for toys hidden in a sandbox. The B trial performances were both less accurate (searches were further away from the exact hiding location) and more important, the errors were biased towards the original A location. Spencer et al. proposed that repeated visual attention to the A location and searches at that spot may serve to prime the direction of the motor search. If reaching is primed, then there will be a habitual impulse to search at the primed location. On A trials, priming will assist the individual in making a correct response as they are already prepared to behave in a consistent manner. This would be reflected in A trials having shorter response latency, especially when they are correct searches. On the other hand, on B trials, if an individual is primed to search at the A location, this would either prompt searching perseveratively at the A location or the reaching to A must be inhibited. Since it takes cognitive effort, and therefore time, to inhibit a behavior, the response latency should be longer on correct B trials.

The purpose of this research was to explore the circumstances that lead capuchins to make the A-not-B error from a dynamic perspective. According to this perspective, responses are the results of the combined effects of many factors. For this research, the factors of interest were the length of the delay period and the complexity of the hiding locations. This was tested in two experiments. In both cases the delay between hiding a food reward and opportunity for retrieval was manipulated. Experiment 1 was an experiment with discrete hiding locations and clear spatial cues, and Experiment 2 was an experiment with continuous hiding locations and less obvious spatial cues.

Two primary hypotheses were evaluated. The first hypothesis (Hypothesis 1, see Table 1 and Table 2) is that the monkeys will make the A-not-B error and that this error will be more likely to occur as the delay period increases. This is expected to occur because there are multiple opportunities for the monkeys to learn about the positive outcome associated with searching at the A location on the A trials and only a brief glimpse of the food reward at the B location. With longer delays memory about what occurred at both the A and B location should fade, but the A memory should be stronger and degrade relatively less than the weaker B memory. For Experiment 1, if memory deficits are responsible for the A-not-B error, I predict that on both A and B trials, there should be fewer correct searches as the delay period increases. On the other hand, if motor priming is responsible for the A-not-B error, I predict that A trial performance will not be impacted by increased delay periods, but there will be fewer correct searches on the B trials as the delay period increases. For Experiment 2, if memory deficits are responsible for the A-not-B error, I predict that on both A and B trials, searches should be symmetrically further away from the goal as the delay period increases. A and B trials should have the same average accuracy. If motor priming is responsible for the A-not-B error, I predict that A trial accuracy will not change according to delay periods, but B trials will be less accurate on average than A trials and will be increasingly biased in the direction of A as the delay period increases.

The second hypothesis (Hypothesis 2, see Table 1 and Table 2) is that the monkeys' search accuracy will be related to the joint effects of trial type (A or B) and the latency of their search, which is measured as the time elapsed between the movement of the apparatus to within the subjects reach and the first contact with either the cup or sand for Experiments 1 and 2 respectively. For both experiments, if memory deficits are responsible for the A-not-B error, I predict on both A and B trials the correct searches should have shorter search latencies than incorrect searches. However, if motor priming is responsible for the A-not-B error, I predict that A trial performance will be better when there is shorter search latency, whereas B trial performance will be impaired when there is a shorter search latency.

Table 1. Outline of hypothesized results for Experiment 1.

*Search Accuracy*: Dependent variable – Which cup is selected by the monkey on the first search attempt?

*Hypothesis 1a:* If memory deficits are responsible for the A-not-B error, then on both A and B trials, there will be fewer correct searches as the delay period increases

*Hypothesis 1b:* If motor priming is responsible for the A-not-B error, then A trial performance will not be impacted by increasing delay periods, but there will be fewer correct searches on the B trials as the delay period increases.

*Search Latency*: Criterion variable – How much time elapsed between the opportunity for the monkey to search and the first time a cup is lifted?

*Hypothesis 2a*: If memory deficits are responsible for the A-not-B error, then both A and B trials the correct searches will have shorter search latencies than for incorrect searches.

*Hypothesis 2b*: If motor priming is responsible for the A-not-B error, then A trial performance will be better when there is shorter search latency, whereas B trial performance will be impaired when there is a shorter search latency.

Table 2. Outline of hypothesized results for Experiment 2.

*Search Accuracy*: Dependent variable – Where is the first contact with the sand?

> *Hypothesis 1a:* If memory deficits are responsible for the A-not-B error, then that on both A and B trials, searches will be symmetrically further away from the goal as the delay period increases. A and B trials will have the same average accuracy.
>
> *Hypothesis 1b:* If motor priming is responsible for the A-not-B error, then A trial accuracy will not change according to delay periods, but B trials will be less accurate on average than A trials and will be increasingly biased in the direction of A as the delay period increases.

*Search Latency*: Criterion variable – How much time elapsed between the opportunity for the monkey to search and the first contact with the sand?

> *Hypothesis 2a*: If memory deficits are responsible for the A-not-B error, then both A and B trials the correct searches will have shorter search latencies than incorrect searches.
>
> *Hypothesis 2b*: If motor priming is responsible for the A-not-B error, then A trial performance will be better when there is a shorter search latency, whereas B trial performance will be impaired when there is a shorter search latency.

# CHAPTER 2

## EXPERIMENT 1: DISCRETE SEARCH LOCATIONS

This study aimed to determine if capuchin monkeys demonstrated the A not B error when tested with a traditional, dichotic A not B task. If the monkeys continued to reach for the original hiding location (under cup A) after the food reward had been placed in a new location (under cup B), this indicated that capuchin monkeys did not remember where the object had been placed. This study also investigated the role of changes in the delay between hiding a food reward under a cup and the opportunity to retrieve the food reward on where the monkey searched. It was hypothesized that the monkeys' performance would be impaired by a longer delay and that the effects of the delay would be the same on A and B trials (Hypothesis 1a).

Both memory abilities and motor priming could have influenced performance on this task. In order to differentiate how each contributed to the retrieval of a hidden food reward, the latency to the first search attempt was analyzed. If memory (Hypothesis 2a) was an important factor that influences the monkey's search accuracy, then within each delay condition, trials with a shorter latency to search for the reward should have been more accurate than the longer latency trials. On the other hand, if the errors were due to motor priming (Hypothesis 2b), then the “A” location would have been selected more often on short latency than long latency trials. In order for the monkey to have reached for the “B” location, it must have overcome the initial tendency to reach for “A.” If this were the case, then short latency, impulsive actions, should have led to more errors than slower latencies.

# Method

## *Participants and Housing*

The participants in this experiment were eight, young adult, male capuchin monkeys (*Cebus apella*). The monkeys were housed in pairs in indoor cages at the University of Georgia. All monkeys were housed in the same room with visual access to all of the other home cages. The home cages were 181 x 137 x 71 cm, and could be partitioned into four equal sized quadrants using removable dividers. In addition, the panel at the back wall of each quadrant could be moved in order to facilitate the monkey's transfer between the quadrants. The monkeys were fed Lab Diet monkey chow and various types of fruit twice a day and were given ad libitum access to water.

## *Apparatus*

All testing was conducted in the lower right quadrant of the monkey's home cage. Each monkey was presented with a 60 x 12.5 x 12.5 cm box of sterile sand. This box was on a stand 45 cm above the ground outside of the home cage. In order to facilitate object placement and scoring, the walls of the box were marked at 2.5cm intervals with a black permanent marker, corresponding to the bars of the monkey's home cage that were 2.5cm apart from each other. Raisins were hidden at one of two locations in the box (±10 cm from the center of the box on the left and the right) All hiding places were 2.5cm from the front of the box, a distance that the monkeys could reach by extending their arms through the bars of their home cage (see Figure 1). The raisin was covered by one of the identical 7.5cm x 6.25cm cups that were placed at both locations. All trials were videotaped with a Sony 360x Digital Zoom camcorder.

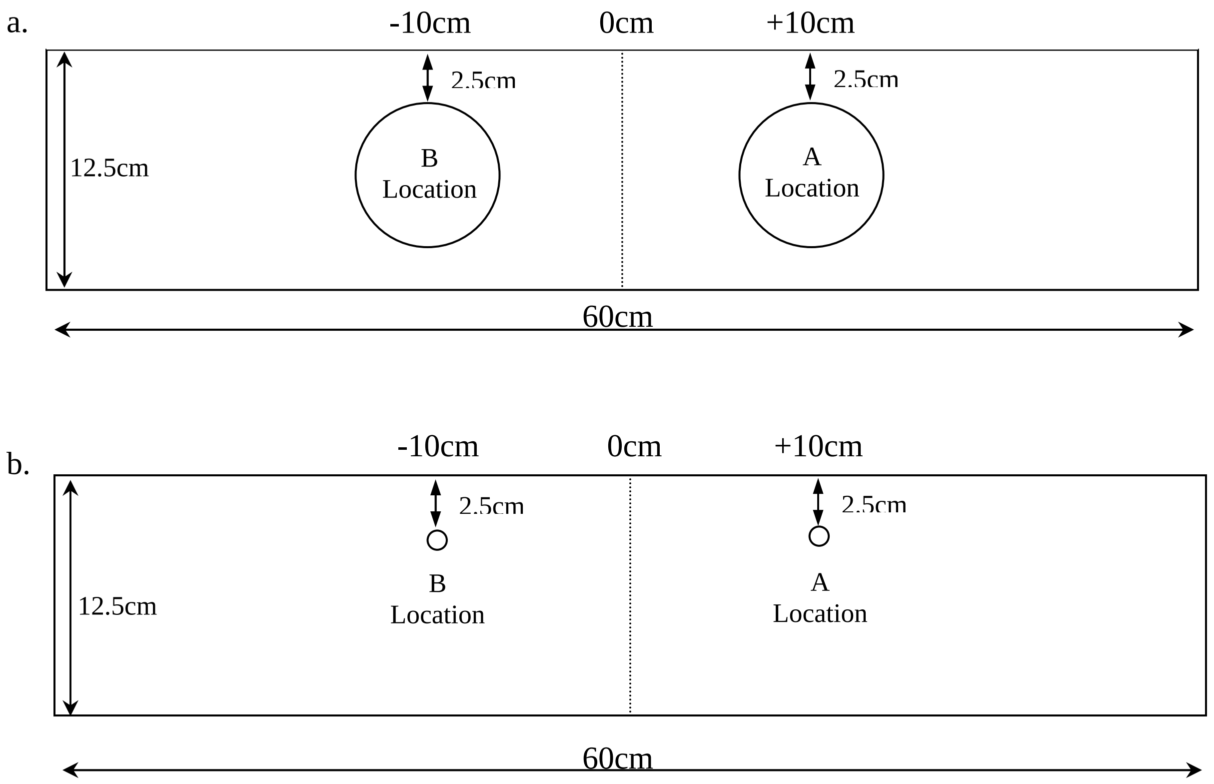


Figure 1. A scale representation of the sandbox and hiding locations. The midpoint of the box is marked 0cm. In this example, the B location is 10 cm to the left of the center of the box and the A location is 10 cm to the right of the center of the box. The apparatus in Experiment 1 is depicted in (a) where the large circles represent cups. The apparatus in Experiment 2 is depicted in (b) where the small circles represent raisins hidden under the sand.

### *Testing*

Each testing session consisted of five trials. For the three initial trials the food reward was hidden at a single randomly selected location (±10 cm from center). This initial location was referred to as the A location for this testing session. In the remaining two trials the reward was placed at the location that was not used for the first three trials. Regardless of the trial, two identical cups were lifted and placed over each of the potential hiding locations after the reward had been placed.

The delay period between hiding the raisin and when the monkey was allowed to retrieve the raisin was manipulated. Each monkey was tested with five different delay conditions: 1) a 0 second delay on the A trials and a 0 second delay on the B trials, 2) a 10 second delay on the A trials and 10 second delay on the B trials, 3) a 10 second delay on the A trials and 30 second delay on the B trials, 4) a 30 second delay on the A trials and 10 second delay on the B trials, and 5) a 120 second delay on the A trials and 120 second delay on the B trials. These delay lengths were chosen to exemplify performance with and without delay. The 10-second delay period was selected because it was adequate to elicit the A-not-B error in 12-month-old infants (Diamond, 1985). The 30-second delay was chosen because it was greater than the range typically tested in infants. The 120-second delay was chosen because it was outside of the range usually covered by short-term memory (Schwartz & Evans, 2001). The delay conditions were monitored with a stopwatch and the sandbox was pushed flush against the home cage and within the monkeys' reach after the appropriate amount of time elapsed. The monkeys could see the sandbox for the entire delay period. Additionally, the delay conditions 3 (10sec A delay, 30sec B delay) and 4 (30sec A delay, 10sec B delay) were useful to differentiate the relative roles of memory load on the A and B trials. Commonly (e.g., Spencer et al, 2001) a longer delay period is used for B than

A trials in order to increase the prevalence of the A-not-B error. In the current study, however, the aim was to probe the consequences of delay for trials at both the A and the B locations rather than merely to produce errors at B.

Each monkey was tested 8 times for each of five different delay conditions, producing 24 A trials and 16 B trials per delay condition, and yielding 120 A trials and 80 B trials total. The delay period, as well as the hiding location, was randomly chosen for each monkey for each session. Only one session was conducted per monkey per day.

At the beginning of each trial the monkey was isolated in the lower right quadrant of the home cage. After gaining the monkey's attention (the monkey looked at the sandbox), a raisin was hidden in the randomly assigned A location, while the sandbox was out of the monkey's reach. After the appropriate delay period, the monkey was allowed to attempt to retrieve the raisin, by the experimenter moving the sandbox flush with the home cage. The sandbox remained in the monkey's visual field until the retrieval attempt, but it was only moved close enough for contact once the appropriate amount of time had elapsed. The monkey was allowed 30 seconds to retrieve the raisin before the sandbox was again moved out of reach. The procedure was repeated for the second and third A trials. Then, the two B trials were administered, using the same procedure and placing the raisin at the other location.

### *Scoring and Analysis*

The first cup that the monkey lifted (relevant to Hypothesis 1), and the latency to lift it (relevant to Hypothesis 2) were recorded. A two-way, within subjects factorial ANOVA was used to determine if errors occurred disproportionately on B trials (trial types A and B) and/or at longer delays (delay conditions 0, 10, 30 and 120 sec), and if there were any interaction between these two variables. Additionally, binomial tests were used on each cell on the 2x4 matrix to compare the monkeys' performances to chance levels in that condition (50% for each cup). The A-not-B error would be evident in below chance performance on B trials. Statistically, Hypothesis 2 was evaluated with a three-way within-subjects factorial ANOVA to determine how the latency to begin searching was related to the accuracy of the choice (correct or incorrect), the hiding location (trial type A or B) and the delay condition (0, 10, 30 and 120 sec).

## Results

The monkeys were more likely ($F_{(1,7)} = 8.92$, $p = .02$) to select the correct cup on A trials ($M = .66$, $SEM = .02$) as compared to B trials ($M = .55$, $SEM = .02$; see Figure 2). Their searches were also less accurate ($F_{(3,21)} = 5.34$, $p = .01$) as the delay period increased ($M = .73$, $SEM = .03$; $M = .61$, $SEM = .04$; $M = .57$, $SEM = .04$; $M = .54$, $SEM = .02$ for delay periods 0, 10, 30 and 120 seconds respectively). Based on a post hoc analysis with a Bonferroni correction, the monkeys were more accurate after 0 second delays as compared to 10 and 120 second delays. Typically, the monkeys looked away from the correct cup in the period between when the raisin was hidden and when they initiated their searches. The only times that they did not look away were on some of the 0 second delay trials (n = 115 out of 320 trials). This added cue did not aid search accuracy ($t_{(7)} = 1.89$, $p = .10$). There was no interaction between trial type and delay ($F_{(3,21)} = .40$, $p = .75$) on the accuracy of the monkeys' searches.

Based on binomial probabilities, the monkeys were searching with above chance accuracy on A trials when the delay was 0 seconds (150 out of 192 trials, $p < .01$), 10 seconds (272 out of 384 trials, $p < .01$), 30 seconds (119 out of 192 trials, $p < .01$) and 120 seconds (108 out of 192 trials, $p = .03$). Based on binomial probabilities, the monkeys were searching with

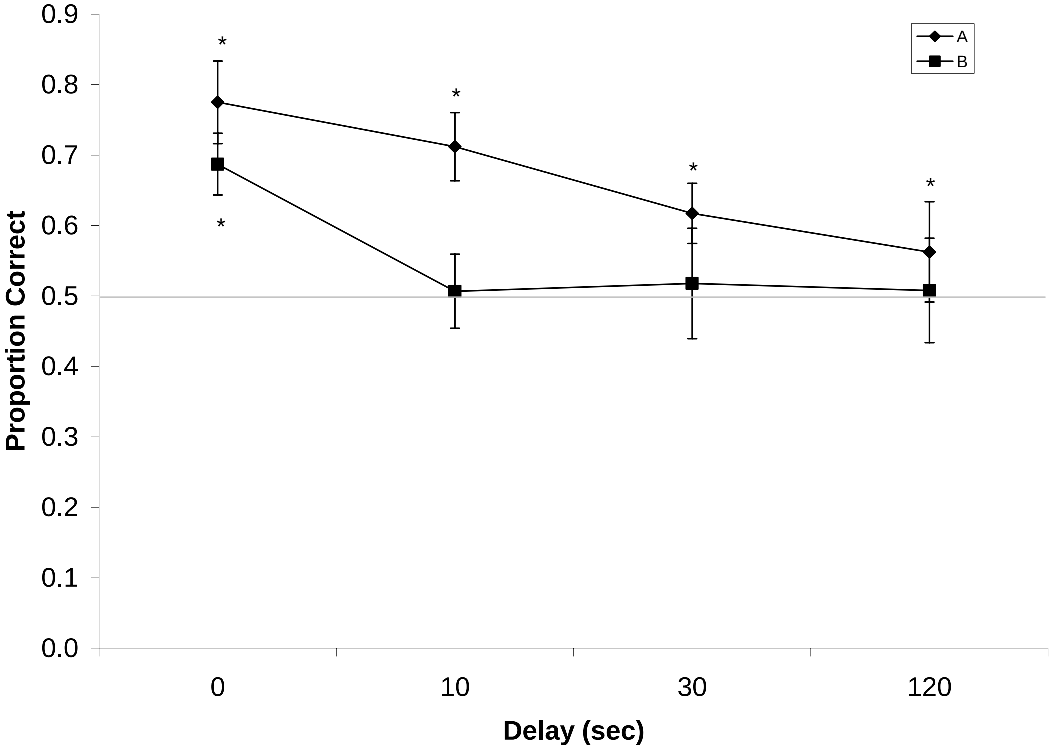


Figure 2. The average proportion of trials, in Experiment 1, where the monkeys correctly located the hidden raisin on their first search attempt. The grey line indicates chance performance. * indicates performance above chance levels based on binomial analysis.

above chance accuracy on B trials only when the delay was 0 seconds (88 out of 128 trials, $p$ <.01). For 10 second (130 out of 256, $p$= .37), 30 second (66 out of 128 trials, $p$= .33) and 120 second (65 out of 128 trials, $p$= .40) delays, the monkeys' searches fell to within the range that would be predicted by chance.

Figure 3 presents search latency data. Search latency did not differ ($F_{(1,7)}$ = .36, $p$ = .57) on A ($M$ = 1.60sec, $SEM$ = .18) as compared to B trials ($M$ = 1.51sec, $SEM$ = .16). Nor did latency vary ($F_{(3,21)}$ = .05, $p$ = .98) with changes in the delay period. The average latencies were comparable for 0 second ($M$ = 1.61sec, $SEM$ = .27), 10 second ($M$ = 1.54sec, $SEM$ = .18), 30 second ($M$ = 1.54sec, $SEM$ = .20) and 120 second ($M$ = 1.51sec, $SEM$ = .22) delay periods. Similarly, the monkeys' search latencies were the same ($F_{(1,7)}$ = 1.07, $p$ = .34) when they were correct ($M$ = 1.64sec, $SEM$ = .22) or incorrect ($M$ = 1.47sec, $SEM$ = .22) in their first search. None of the 2-way interactions were significant, but there was a significant 3-way interaction ($F_{(3,21)}$ = 3.20, $p$ = .04). For A trials, as the delay increased, if the monkeys were incorrect, they were also likely to have shorter search latencies. The opposite was true on B trials. On B trials, as the delay increased and the monkeys were incorrect, they were likely to have longer search latencies. On the other hand, for both A and B trials, as the delay increased and the monkeys were correct, there were no changes in their search latencies.

## Discussion

The results from Experiment 1 show that there were fewer correct searches as the delay period increased for both A and B trials. There were also fewer correct searches on B as compared to A trials. This provides support for both Hypotheses 1a and Hypothesis 1b. Memory deficits would lead to increased search errors as the delay period increased. In adult humans, spatial memory begins to decay at retention intervals as short at 50ms (Werner &

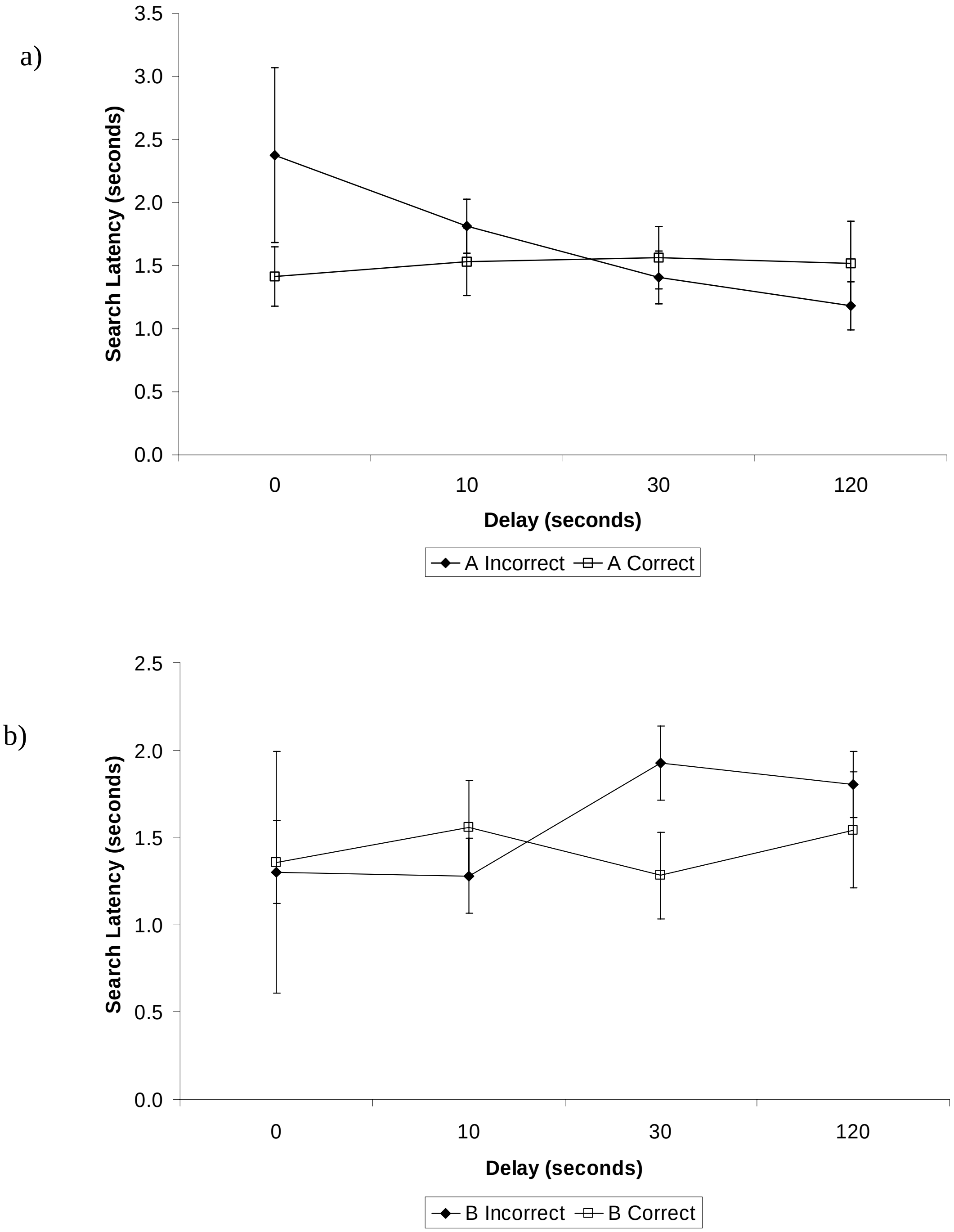


Figure 3. The average amount of time taken, in Experiment 1, to initiate searches. a) latency on A trials; b) latency on B trials.

Diedrichsen, 2002). As in the current experiment, Werner and Diedrichsen found that their participants were less accurate in how they reproduced a spatial memory as the retention interval increased. As time elapsed, a memory trace would fade, leading to poorer performance. In the A trials, the monkeys always performed at above chance levels, indicating that even after 2 minutes, the monkeys still retained some memory for where the raisin was hidden.

Memory decay alone cannot account for the findings in Experiment 1. Hypothesis 1b predicted that the monkeys would have fewer correct searches on B trials as compared to A trials. The fact that the B trials have decreased search accuracy, as compared to the A trials, indicates that there may be a motor priming effect that contributed to search failures beyond the deficits caused by delay alone. It appears that the effect of priming on search is a constant. There is no interaction between different delay periods and the performance on A and B trials.

Neither Hypothesis 2a nor 2b were supported by the data. Search latency was unrelated to search accuracy or the kind of trial (A or B). Although accuracy data provided evidence of priming, priming does not appear to lead to more rapid search latencies. This is in contrast to Blough's (2000) findings that valid cues (a cue that could be used by pigeons to correctly predict what they would be required to locate in a visual search) led pigeons to have quicker reaction times when searching for targets (a specific letter) in a visual array (other letters). Blough also found that ambiguous cues (a cue that did not allow the pigeons to predict correctly what they would be required to locate in a visual search) led to relatively longer reaction times. In the current study, the monkeys' experiences on previous trials could have served as cues. On A trial, the prior visual and motor experiences could be considered valid cues because they would allow the monkeys to predict correctly which cup was covering the raisin. Conversely, on B trials, the monkeys' experiences on A trials provided cues that were worse than ambiguous. If A trial cues were used on B trials they would result in an incorrect search. Since the monkeys' search latencies were the same on A and B trials it does not appear that the validity of the cues altered reaction time in this task in the same manner as in Blough's visual search task. In Blough's task, the pigeon had to find the correct target, but there was no memory requirement. All targets were visible at all times. The delay period in the current study required the monkeys to remember where to search. Although it was hypothesized that the monkeys would have different search latencies on A and B trials this hypothesis was not supported.

There was a three-way interaction between delay, search accuracy, and trial (A or B) on search latency. Regardless of these three factors, search latency remained the same when the monkeys made correct searches. It was only when monkeys made incorrect searches that search latencies varied. On A trials, priming, if it occurs, should help performance, whereas it should impair performance on B trials. On A trials the monkey responded more slowly when they were incorrect if there was a short delay and more quickly if they were incorrect when there were longer delays. For B trials, when the monkeys were incorrect, the opposite occurred. They responded more slowly when they were incorrect and there was a short delay and more quickly when they were incorrect and there was a long delay. Perhaps after longer delay periods the effect of the prime stimulus on reaction time begins to wear off.

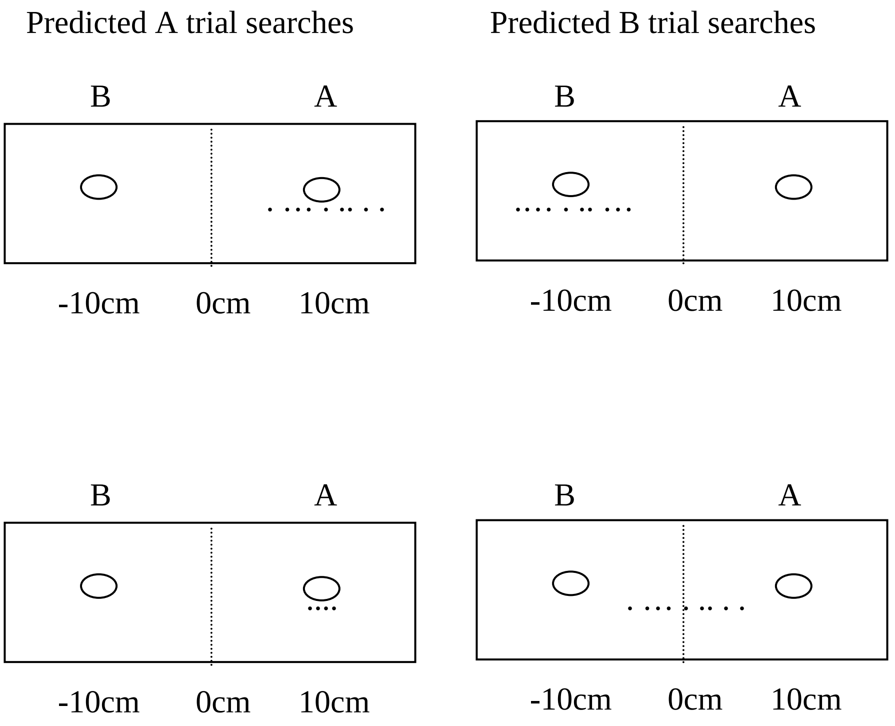
These results expand the concepts of memory and priming as they relate to spatial search tasks. This experiment showed that when adult capuchin monkeys are tested with discrete hiding locations they do show the A-not-B error. This error exists beyond what would be predicted by memory deficits alone. The tendency to search at the A location may be due to the monkeys' heightened sensory and motor contact with the original A hiding location. The question remains, are the monkeys searching at the A location because they expect to find the raisin at that particular spot or are they simply selecting the cup that they view as the best option available? Where would the monkeys search if they were able to search at intermediate points, rather than being forced to make a dichotomous decision?

# CHAPTER 3

## EXPERIMENT 2: CONTINUOUS SEARCH LOCATIONS

This experiment expanded on the first experiment by exploring the A not B error in a more dynamic environment. Now rather than only having two possible hiding locations, the rewards were buried in a sandbox with continuous search locations. There were no cups or other markers indicating where the food had been hidden. This methodology tested if the A not B error was absolute or relative. By looking at the actual search location, it could be determined if the monkeys expected the hidden reward at the original point or if their responses shifted towards the location where they had previously received a reward for searching.

As in Experiment 1, it was hypothesized that the monkeys would show a decrease in accuracy on B trials as compared to A trials. Specifically, it was hypothesized (Hypothesis 1b) that errors in B trials would be biased towards A, rather than actually at the A location. Furthermore, I predicted that the monkeys would be less accurate when there was a longer delay between hiding and search access. Search accuracy was determined based on the distance of the first search attempt from the actual hiding location (see Figure 4). Additionally, by comparing the relative latencies of trials resulting in errors and successes, the relative roles of memory abilities and impulsivity could be differentiated. If latencies of all trials were the same regardless of accuracy, then this would indicate memory failure was responsible for error (Hypothesis 2a). However, if the “A” trials had shorter latencies for correct reaches and the “B” trials had shorter latencies for the incorrect reaches then this would indicate that motor priming was at least partially responsible for perseverative reaching to the habitual “A” location (Hypothesis 2b).



Hypothesis 1a) If memory failure is entirely responsible for errors, searches will be evenly distributed around the A and B location on the respective trials.

Hypothesis 1b) If memory failure and motor priming contribute to the errors, searches will be centered and focused on A on A trials, but will be variable and biased towards the A location on B trials.

Figure 4. Hypothesized behavior on A and B trials if the monkeys showed the A-not-B error in Experiment 2. Ovals represent the locations in the sand where food was hidden. Dots represent searches.

# Method

## *Participants and Housing*

The participants in this experiment were seven, young adult, male capuchin monkeys (*Cebus apella*). The monkeys from the previous experiment were used, but one monkey had to be dropped based on pilot testing of the apparatus that indicated that he would not comply with the task. He attempted to destroy the sandbox rather than search for the food reward. Housing and care conditions were the same as in the previous experiment.

## *Apparatus*

The apparatus was the same as in the previous experiment, except now the food item was buried directly in the sand without the use of covering cups.

## *Baseline*

Prior to Experiment 1 and before any raisins were hidden each monkey was given a single exposure for 10 minutes or 25 searches (whichever came first) in the sandbox in order to determine location preference for contact with the sand.

## *Testing*

The procedure was the same as in Experiment 1, except for two differences. First, instead of hiding the food reward under a cup, it was hidden directly in the sand at ±10cm from the center of the sandbox (see Figure 1). The food item was placed less than 2.5cm from the front edge of the sandbox and buried just below the surface of the sand. The second difference was that at the start of each testing session each monkey was given three training trials. This followed the Spencer et al. (2001) procedure. These training trials were needed to familiarize the monkey with the task of digging in the sand. All training trials were conducted at that session’s A location with a 0-second delay. Training trial 1 entailed placing the food directly on top of the sand, completely visible. Training trial 2 consisted of the reward being partially buried in the sand, but still visible. In training trial 3, the food reward was completely buried, but an indentation was left where the reward was pushed under the sand allowing for visual identification of the hiding location. As compared to Experiment 1, the monkeys experienced 3 extra reaches towards the A location. Three A and two B trials followed the training trials, as described for Experiment 1, except now the raisin was buried under the sand rather than being placed under a cup. After the raisin was buried, the sand was smoothed from left to right and again from right to left to remove all indentations from the sandbox.

As in the previous experiment, the delay period between hiding the raisin and when the monkey was allowed to retrieve the raisin was manipulated. The food was hidden in the sandbox while it was out of the monkey's reach, and the sandbox was moved flush to the home cage after the delay period. Each monkey was tested with five different delay conditions: 1) a 0 second delay on the A trials and a 0 second delay on the B trials, 2) a 10 second delay on the A trials and 10 second delay on the B trials, 3) a 10 second delay on the A trials and 30 second delay on the B trials, 4) a 30 second delay on the A trials and 10 second delay on the B trials, and 5) a 120 second delay on the A trials and 120 second delay on the B trials. These were the same delays as in Experiment 1.

Each monkey was tested 8 times at each of five different delay conditions, producing 24 training trials, 24 A trials and 16 B trials per delay condition, yielding 120 A trials and 80 B trials total. The delay period and the A location were randomly determined for each monkey for each session. Only one session was conducted per monkey per day, consisting of 3 training trials, 3 A trials and 2 B trials.

### *Probe trials*

In order to assess the monkeys' persistence of search in a specific location, two probe trials were conducted for each monkey with each delay condition in which there was no food to be found. After three training trials and three A trials, the monkey was again shown the food being hidden at the A location. The food was surreptitiously removed and the sand was again smoothed. The monkey was then allowed to search the sandbox for 30 seconds. The monkey was allowed to search multiple times within a single trial. All search locations were recorded.

## *Scoring and Analysis*

### *Test trials*

The location of each monkey's first contact with the sand was recorded for each trial based on the 2.5 cm interval markings on the side of the sandbox, in order to evaluate Hypothesis 1. If the monkey was not successful on the first attempt, all contact with the sand for the next 30 seconds, or until the food reward was retrieved, was recorded. The monkeys had different A and B locations for various testing sessions in order to prevent the monkeys from learning a search pattern between testing sessions and minimize the effects of side biases. The search accuracy was analyzed as the absolute value of the distance from the hiding location on each search attempt. Across all of the monkeys, a two-way ANOVA was used to determine if the monkeys performed better overall on A or B trials, if the delay period influenced performance and if there was any interaction between these two variables. Additionally, chi square analyses were used to determine if the searches were equally likely to occur symmetrically around the hiding location. Based on the restrictions imposed by the bars in the monkeys' cages and the width of their hands, there were only 24 different search locations. The cage bars restricted the monkeys' movements, preventing a truly continuous search access. If the monkeys searched the sandbox randomly, they would only be expected to search in the spot where the food had been hidden on approximately

4% of trials. The binomial equation was used to determine if the search pattern was different from chance for both A and B trials. In order to evaluate Hypothesis 2, a three-way, within-subjects factorial ANOVA was used to determine how the latency to begin searching was related to accuracy of the choice (correct or incorrect), the hiding location (trial type A or B) and the delay condition (0, 10, 30 and 120 sec). The accuracy of the choice was classified as correct or incorrect using a median split on the distance of the first search from the target. This split was performed for each monkey for each delay condition and trial type.

### *Probe trials*

The search distribution in probe trials using the model shown in Figure 1b was evaluated according to the markings on the sandbox to determine if the B location was searched disproportionately (either more or less) in comparison to the rest of the sandbox. If the monkeys searched disproportionately at areas A and B where they had previously found a reward, it was taken as evidence of between trial generalization for where the food reward had previously been hidden. Additionally, the distribution of searches on probe trials were compared to the baseline data with a 2 (baseline and probe) x 5 (5 sandbox regions, see Figure 5) chi-square test of independence.

### *Comparison of Experiment 1 and Experiment 2*

Proportion correct and latency variables were compared across Experiment 1 and Experiment 2 with two-tailed, within subject factorial ANOVAs in order to compare impact of recall and recognition tasks on the A-not-B error following confirmation that the data fit the assumptions of this test. Homogeneity of variance and normality of the data were confirmed. A correct response on the trials where the monkey had to lift the cup could easily be assessed

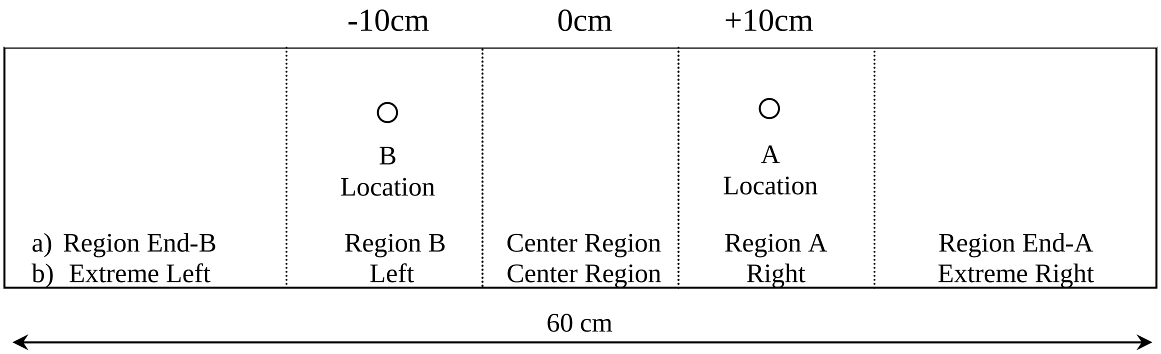


Figure 5. Regions of the sandbox for use in the a) probe trial and b) baseline trial analysis in Experiment 2.

based on the cup that was selected. On the recall (sandbox) trials, a “correct” search was one that was exactly at the hiding spot. In order to equate the data from Experiments 1 and 2, each score was converted to the difference from chance. In Experiment 1, chance would predict that each monkey would correctly lift the cups when searching for the raisin on .50 of the trials. In Experiment 2, chance would predict that each monkey would correctly search in the sand for the raisin .04 of the trials.

## Results

### *Test trials*

The monkeys were more likely ($F_{(1,6)} = 40.03$, $p < .01$) to search in the correct location on A trials (*M* = .30, *SEM* = .04) as compared to B trials (*M* = .15, *SEM* = .02; see Figure 6). Their searches were also less likely to be at the exact target ($F_{(3,18)} = 10.00$, $p < .01$) as the delay period increased (*M* = .31, *SEM* = .04; *M* = .24, *SEM* = .02; *M* = .21, *SEM* =.04; *M* = .16, *SEM* = .03 for delay periods 0, 10, 30 and 120 seconds respectively). Based on a post hoc analysis with a Bonferroni correction, the monkeys’ first searches were more likely to be at the correct location after 0 and 10 second delays as compared to 120-second delays. On some of the 0 second delay trials (n = 45 out of 280 trials) the monkeys kept their eyes on the location where the raisin was hidden from the time the raisin was hidden to the time when they were allowed to search. There was not a significant difference in the number of first searches at the target based on the monkeys’ attention to the stimuli ($t_{(7)} = 1.82$, p = .12). There was no interaction between trial type and delay ($F_{(3,18)} = .71$, $p = .56$) on the likelihood that the first search was exactly at the target location.

According to binomial probabilities, the monkeys were searching with above chance accuracy on A trials when the delay was 0 seconds (65 out of 168 trials, $p < .01$), 10 seconds (108

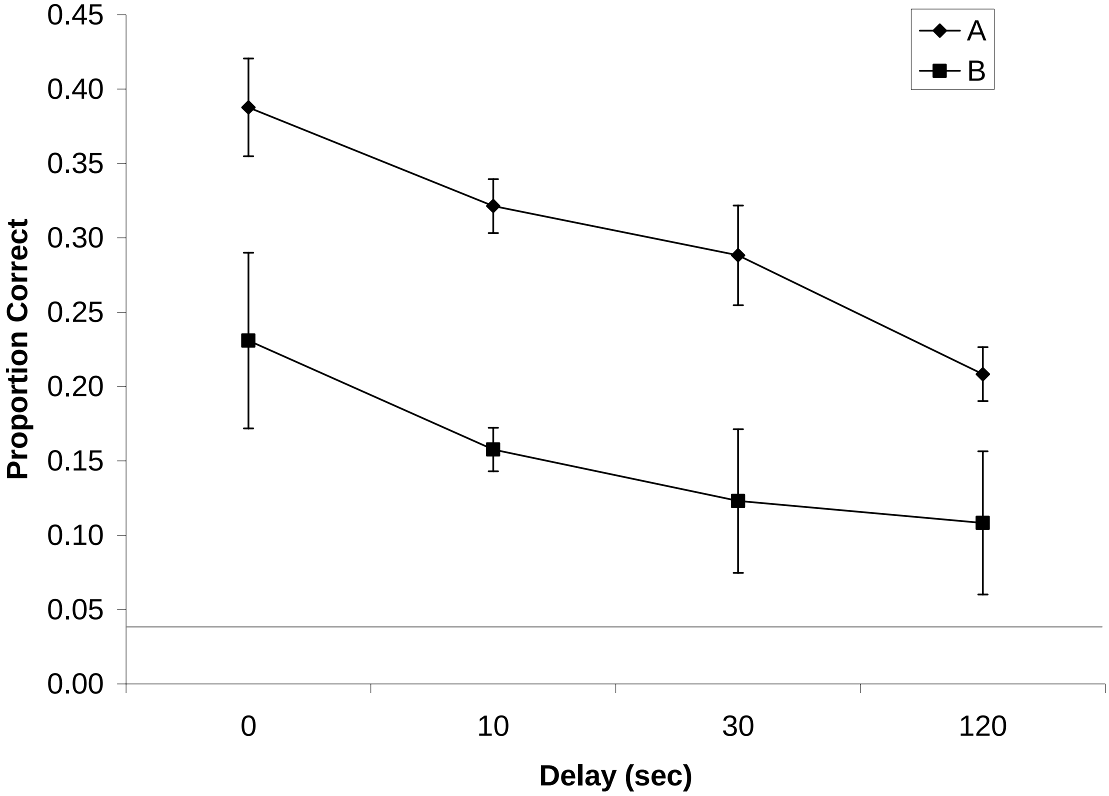


Figure 6. The average proportion of trials, in Experiment 2, where the monkeys correctly located the hidden raisin on their first search attempt. The grey line indicates chance performance. All conditions were above chance levels based on binomial analysis.

out of 336 trials, $p <.01$), 30 seconds (48 out of 168 trials, $p <.01$) and 120 seconds (35 out of 168 trials, $p <.01$). The monkeys searched with above chance accuracy on B trials for all delay lengths: 0 second (25 out of 112 trials, $p < .01$), 10 second (35 out of 224 trials, $p < .01$), 30 second (14 out of 112 trials, $p < .01$) and 120-second (12 out of 112 trials, $p < .01$) delays.

The monkeys searched more closely ($F_{(1,6)} = 38.40$, $p < .01$) to the hidden raisin on A trials ($M = 4.87$cm, $SEM = 0.34$cm) as compared to B trials ($M = 8.63$cm, $SEM = 0.87$cm; see Figure 7). Searches were closer ($F_{(3,18)} = 11.60$, $p < .01$) to the target when there was a shorter delay period ($M = 4.62$cm, $SEM=0.52$cm; $M = 6.84$cm, $SEM=0.58$cm; $M = 7.25$cm, $SEM=0.94$cm; $M = 8.215$cm, $SEM=0.70$cm for 0, 10, 30 and 120 second delays respectively). Based on a post hoc analysis with a Bonferroni correction, the monkeys were more accurate when there was a 0-second delay as compared to a 120-second delay. There was also an interaction ($F_{(3,18)} = 3.23$, $p < .05$) where the monkeys' accuracy degraded more rapidly with increased delays on B trials as compared to A trials.

The monkeys did not search symmetrically around either the A or B location in any of the delay conditions (Table 3). The monkeys showed a center bias for both A and B trials (Figure 8), but they had a stronger tendency to search towards the center of the sandbox on B trials in all delay conditions ($\chi^2(1) = 20.90$, 21.81, 11.03 and 13.17 for delay periods 0, 10, 30 and 120 seconds). The average search location on A trials was at 6.45 cm, or 3.55 cm away from the correct target and towards the center of the sandbox. The average search location on B trials was at -0.56 cm, or 9.44 cm away from the correct target and towards the center of the sandbox.

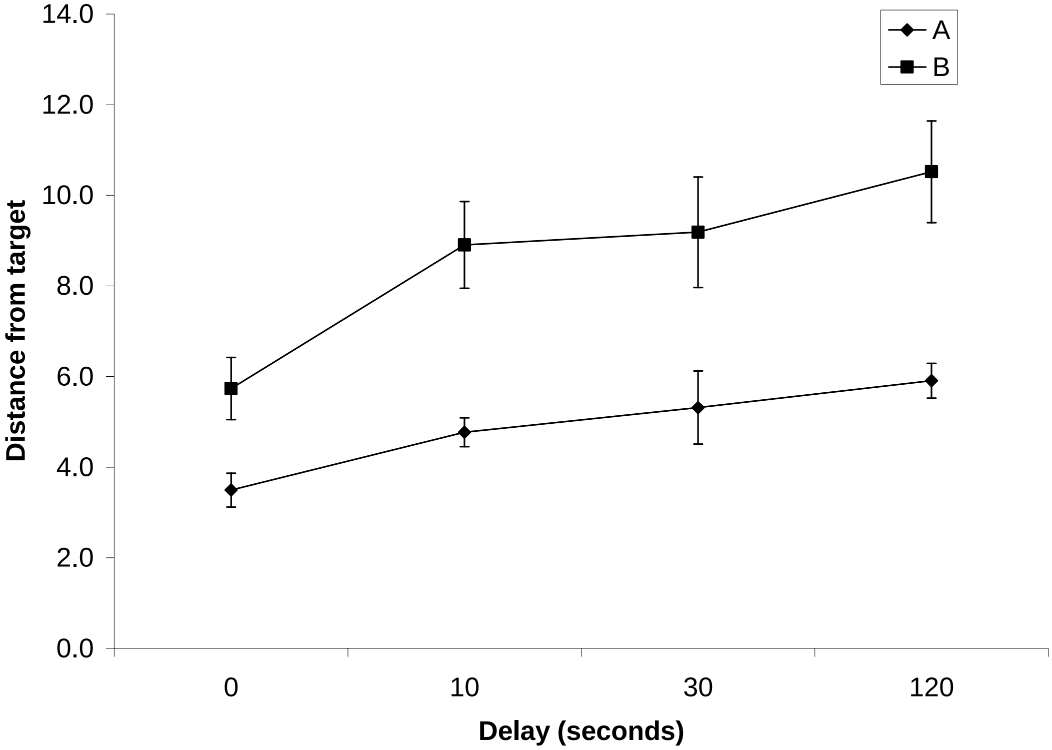


Figure 7. The average distance from the raisin of the monkeys’ first search in the sandbox in Experiment 2.

*Table 3*

The number of searches that were towards the middle or the outside of the sandbox, relative to the hiding location of a raisin in Experiment 2.

| | | Search Location | | | | |
|---|---|---|---|---|---|---|
| Delay (sec) | Trial | Middle | Outside | Total | $\chi^2$ (df=1) | p |
| 0 | A | 70 | 32 | 102 | 14.17 | <.01 |
| | B | 80 | 4 | 84 | 68.76 | <.01 |
| 10 | A | 82 | 47 | 129 | 79.59 | <.01 |
| | B | 178 | 9 | 187 | 152.73 | <.01 |
| 30 | A | 100 | 20 | 120 | 53.33 | <.01 |
| | B | 98 | 3 | 101 | 89.36 | <.01 |
| 120 | A | 109 | 22 | 131 | 57.78 | <.01 |
| | B | 97 | 2 | 99 | 91.16 | <.01 |

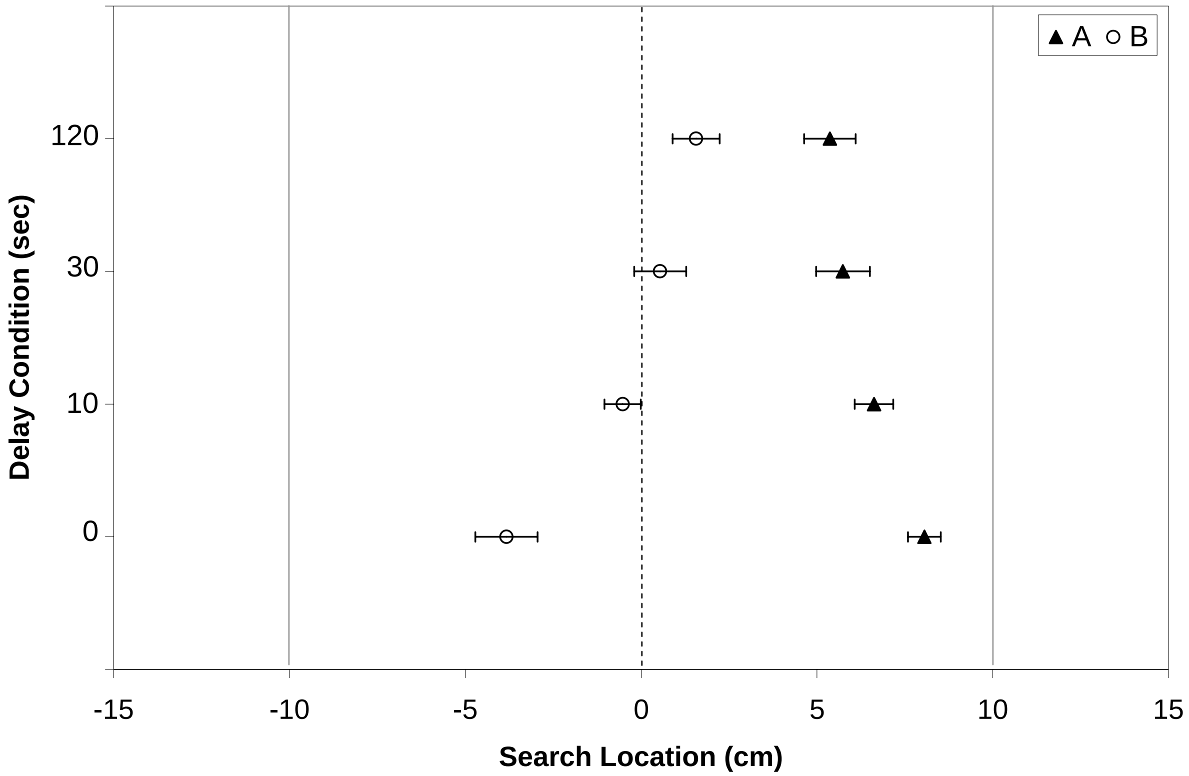


Figure 8. The average search location on A and B trials in Experiment 2. The grey lines reflect the correct search locations. The dashed line indicates the center of the sandbox. The line at 10cm is the correct search location for A trials and the line at -10 cm is the correct search location for B trials. A trials are graphed on the right and B trials are graphed on the left.

Search latency was not predictable based on trial type ($F_{(1,6)} = 1.47$, $p = .27$), length of the delay period ($F_{(3,18)} = 1.07$, $p = .39$), or the accuracy of the first search ($F_{(1,6)} = .09$, $p < .77$). No interaction appeared between search accuracy, search latency, and trial type ($F_{(1,6)} = .75$, $p = .52$).

*Probe trials*

The monkeys were more likely than would be predicted by chance to search at the A location in the probe series for each delay period. Since the area associated with “Region A” (Figure 5) encompasses 16% of the sandbox, it would be predicted that 16% of the searches would fall in this area if the monkeys were searching randomly. The “Region B” area is the same size and also reflects 16% of predicted searches. For each of the delay periods ($\chi^2_{(4)} = 255.15$, 170.22, 191.22 and 200.52, all $p < .01$ for 0, 10, 30 and 120 second delays, respectively) the monkeys did not search randomly (Figure 9). Additionally, the monkeys were more likely than chance to search Region A while they searched Region B at chance levels. The baseline search distribution was also different from all subsequent probe trials. ($\chi^2_{(4)} = 169.58$, 129.11, 137.17 and 133.73, all $p < .01$ for 0, 10, 30 and 120 second delays, respectively). In comparison to the baseline data, the probe searches were more likely to be in Region A and less likely to be in either of the Region-Ends.

*Comparison of Experiment 1 and Experiment 2*

In both experiments the monkeys showed the same pattern of more accurate searches ($F_{(1,6)} = 20.92$, $p < .01$) on A trials ($M = 22\%$, $SEM = 2.8\%$) as compared to B trials ($M = 9\%$, $SEM = 1.7\%$) when equated in terms of how far the monkeys’ performances were from chance levels (Figure 9). Both experiments also had similar patterns of increased accuracy ($F_{(3,18)} = 9.70$, $p <.01$) on trials with shorter delay periods (0 seconds: $M = 25\%$, $SEM = 3.4\%$; $M = 16\%$, $SEM =$

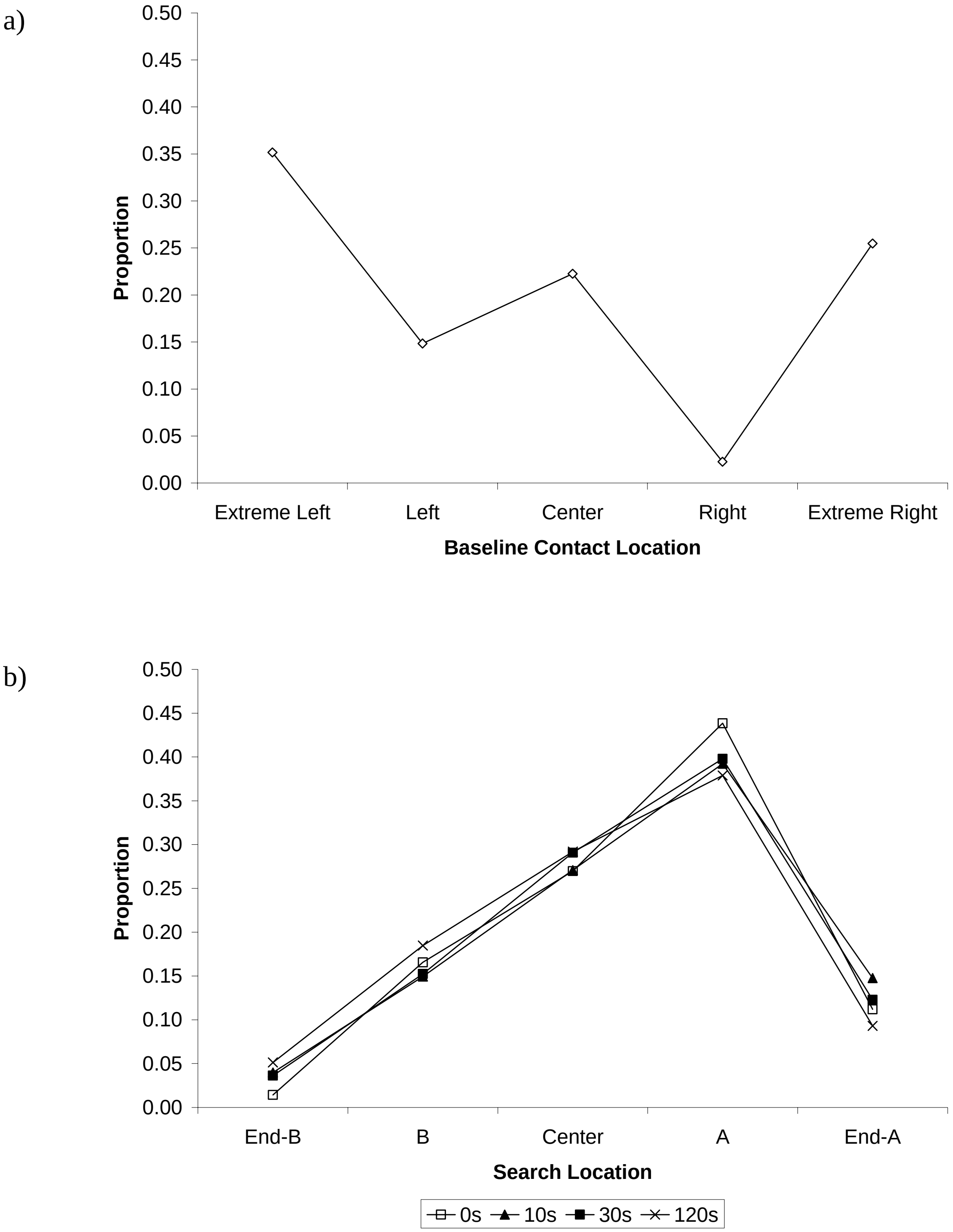


Figure 9. The location of a) baseline and b) probe searches relative to the different areas of the sandbox in Experiment 2. In panel b, the A and B locations do not correspond to the left and right sides of the sandbox as in the baseline data. For the probe trials the A and B locations were counterbalanced.

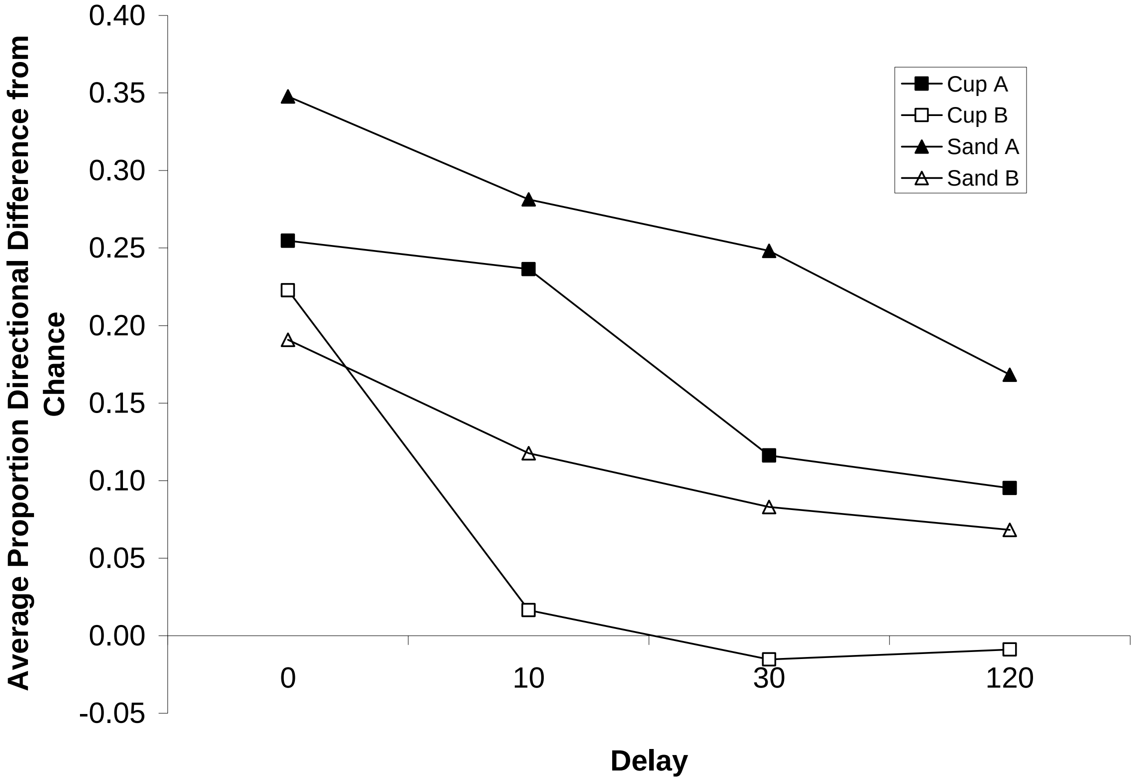


Figure 10. A comparison of the average performance relative to chance in Experiment 1, when the monkeys had to lift a cup to find the raisin, and Experiment 2, when the monkeys had to dig in the sand to find the raisin. A positive value indicates better than chance performance and a negative value indicates below chance performance. N = 7 for this comparison as one of the monkeys included in Experiment 1 did not participate in Experiment 2.

2.5%; *M* = 11%, *SEM* = 2.8%; *M* = 8%, *SEM* = 2.2%). The monkeys' accuracy in the highly cued (*M* = 12%, *SEM* = 1.7%) and low cued search tasks (*M* = 19%, *SEM* = 2.7%) were not the same ($F_{(1,6)}$ = 6.80, *p* = .04).

With regard to search latency, the monkeys initiated their searches at the same rates ($F_{(1,6)}$ = 1.05, *p* = .35) in Experiment 1 (*M* = 1.59 sec, SEM = .21 sec) and Experiment 2 (*M* = 1.45 sec, *SEM* = .20 sec). There were no significant two or three way interactions relating to latency.

## Discussion

Experiment 2 supported both Hypothesis 1a and Hypothesis 1b. Hypothesis 1a suggested that memory deficits contributed to the A-not-B error and the perseverative reaching associated with B trials. The part of Hypothesis 1a that was supported was that both A and B trials showed a degradation in search accuracy as the delay period increased. However, if memory failure alone were leading to decreased search accuracy, then search errors on both A and B trials should have been symmetrically distributed around the correct search location. This was not the case. Searches in both A and B trials searches were biased towards the center of the sandbox. This bias was much more pronounced in B trials. While the center bias for A trials remained the same regardless of the delay period, the B trials became increasingly more biased as the delay increased between when the raisins were hidden and when the monkeys were allowed to begin searching for the food reward increased. The bias on B trials went beyond a simple center bias. They overshot the true center of the sandbox when the delay period was 30 and 120 seconds, to the extent that the searches were actually on the A location side of the sandbox. B trials overall, regardless of the delay period, were consistently less accurate than A trials. Increased errors on B trials and the bias on B trials towards the A location were predicted by Hypothesis 1b. The results were consistent with a motor priming account of the A-not-B error. If priming served to increase the likelihood of an earlier behavior, the monkeys would be more likely to search in a manner consistent with the A trials on the B trials. Longer delay periods provided more opportunities for the memory for where the raisin was hidden on that particular trial to decay. This allowed experiences on past trials to impact the monkeys' searches to a greater extent on trials with longer delays than on trials with shorter delays.

On the B trials, the searches were merely biased towards the A location rather than at the A location itself. This is in contrast to what was seen in Experiment 1 when the dichotomous nature of the two discrete hiding locations forced a search at either the A or the B location. This demonstrates that the A-not-B error cannot be thought of as an all or none phenomenon. Although the monkeys were always less accurate on the B trials, the difference was not large when there was no delay period. It was only when the delay period increased that the performance on B trials decreased substantially. This supports the dynamic systems account of the A-not-B error. According to this theoretical stance, the A-not-B error reflects the visual and attentional processes involved in assessing the nature of the hiding locations, the motor process involved in reaching for the object, the short-term or working memory for where the object was last seen and long-term memory about past searches (Spencer, Smith & Thelen, 2001). Just as the monkeys showed a relatively larger degree of error when there was a longer delay, it is likely that human children and adults would show the A-not-B error in certain circumstances, for instance with few spatial cues and long delay periods. In the future, adult humans could be tested with sand boxes and long delay periods to confirm, as predicted by the dynamic systems account, that they too will show the A-not-B error. This would disentangle the A-not-B error and perseverative reaching from Piaget's concept of object permanence in humans.

The probe trials also provide evidence that the spatial location of the A trials is encoded without a bias in favor of the B location. For all of the delay periods, the monkeys searched the sand in the region near the B location at levels that would be predicted by chance. It did not appear that the monkeys first searched the area around the A location and then the area around the B location. This also indicates that there was no proactive interference between testing sessions.

The second set of hypotheses for Experiment 2 pertained to the relationship between search latency and search accuracy. Neither Hypothesis 2a nor Hypothesis 2b were supported. Search latency was unrelated to search accuracy, regardless of whether the monkey was given an A or B trial. According to Blough (2000) valid priming improves performance and decreases reaction times in pigeons. That means that in this current experiment, either the A trials did not act as a prime or that in the monkeys’ particular search task valid and invalid primes do not work in the same way as they do with pigeons.

Another possibility for the inconsistent relationship between the search latency and search accuracy for either A or B trials is that two different factors could lead to changes in search latency. First, as mentioned above, valid priming could have decreased reaction time because it gave the monkey an additional cue about where the raisin could be found. Similarly, an invalid cue could have increased search latency because the monkey had to perform an extra cognitive step to overcome the misleading information. According to information processing models, each cognitive step requires some amount of time to occur.

An alternate explanation for the similarity in reaction times could be related to the monkey’s confidence in his search response. The monkey may have responded quickly when he was confident in his memory for the search location and more slowly when he was less confident. In an episodic memory task, people’s confidence in their answers was negatively correlated with reaction time (Shaw, McClure and Wilkens, 2001). If both confidence and priming influence reaction time, it could be that in the current study these two factors canceled out each other’s effects.

This experiment showed that when adult capuchin monkeys are tested with continuous hiding locations they do show the A-not-B error. As in Experiment 1, this error exists beyond what would be predicted by memory deficits alone. The monkeys’ bias to reach towards the A location may have been due to the monkeys’ heightened sensory and motor contact with the original A hiding location. These results are in accord with a dynamic systems account of the A-not-B error, which posits that both memory and motor priming, among other factors, affect search patterns.

# CHAPTER 4

# CONCLUSION

When Experiments 1 and 2 were compared to each other directly, they painted a consistent picture. Regardless of the spatial cues, the monkeys were more accurate when they searched on A trials as compared to B trials. The two experiments were also comparable in the way that increased delay periods caused decreases in search accuracy. The discrepancy between A trial and B trial performance was of similar magnitude in the two experiments.

When the two studies were equated in relation to the difference between the monkeys' search accuracies and chance, it appeared that the monkeys were actually better at finding the raisin when there were fewer spatial cues (i.e. Experiment 2). Since the chance performance in Experiment 1 was 50% there might have been ceiling effects that prevented similar success rates relative to chance as in Experiment 2. There also may have been a practice effect in Experiment 2 where the monkeys learned that the raisin was always hidden at either ± 10 cm from the center of the sandbox. The effect of practice could have allowed the monkeys' searches to become more accurate over time. In future studies, the possible A and B locations could be expanded to reduce the possibility of a practice effect, and/or the effect of practice could be assessed directly.

Motor priming is another possible explanation for improved accuracy in relation to chance in Experiment 2. In Experiment 2, the monkeys were given extra training trials at the A location as compared to Experiment 1, in accord with the methods used by Spencer et al. (2001) with a sandbox presentation. The extra training trials have amplified the difference in performance on A and B trials in Experiment 2 as compared to Experiment 1. The extra training trials could have affected the monkeys' search through priming the A location, but they would not have altered trial-specific memory decay. This would explain the increased accuracy on A trials in Experiment 2, but not the observed increased accuracy on B trials in this same experiment.

The prediction that search latency would co-vary with search accuracy as a function of trial type (A or B) was not supported in either experiment. This could be due to the opposing influences of priming and confidence that have previously been shown to have opposite impacts on search latency (Blough, 2000 and Shaw, 2001). When monkeys were correct on B trials, priming would predict longer search latencies, while confidence would predict shorter search latencies. These two influences could work together to produce, on average, similar search latency on all types of trials.

In conclusion, the A-not-B error is related to many factors such as the clarity of cues for where an object is hidden, the length of time that elapses between hiding, the opportunity to search and the experience of searching at a given location. Although Piaget first noticed this error when he was investigating the development of object permanence, the construct of object permanence is not needed to explain this particular type of perseverative reaching. This study supports the dynamic systems account for the A-not-B error, indicating that perseverative searching is a more general phenomenon than one which occurs only briefly at one point in the cognitive development of human children. In the future, it would be interesting to determine if adult humans also show signs of perseverative reaching towards an A location using a much larger sandbox with increased delay periods. It may be possible to disentangle the effects of motor priming and confidence on search latencies by asking adult participants for self reports of their confidence in their memory for where objects are hidden.

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# APPENDIX

## A REVIEW OF THE LETERATURE

The A-not-B error was first noticed by Piaget (1954) as one of the stages in the development of object permanence. As human children progress through stage IV of the sensory motor stage of development, one of the key changes in an infant's cognitive abilities is the understanding that objects continue to exist when they are out of sight. On the path to developing a full concept of how objects behave, children were found to have multiple intermediate levels of object permanence. Between 8 to 10 months of age, children were found to make the A-not-B error. This error consists of a child being able to search successfully for and retrieve an object from a hiding location (A), and being able to do this on repeated trials. However, if the object were switched to a new hiding location (B) the child will continue to perseverate and search the original A hiding location.

According to Piaget (1954), object permanence is mastered during the 6 stages of sensory motor development. During the first two stages, the infant does not search for hidden objects and stares at the point where he or she saw the object disappear. In stage 3, the infant can find a partially hidden object. In stage 4a, the infant can find a completely hidden object, but only if the search is started before the object is completely obscured. By stage 4b infants can locate a completely hidden object, but they will continue to search in the same location even if they see the object being hidden in a new spot. This is the stage when the A-not-B error occurs. The hallmark of stage 5a is that the infant can now find an object even if it is hidden in different locations on multiple trials. The child stops perseverating on the original hiding location. In stage

5b, the child can find objects that are visibly moved to multiple locations within the same trial. By the time the child achieves stage 6a and 6b object permanence he or she can find an object that has been invisibly hidden in various locations on either multiple trials or the same trial respectively. Once an individual can do this, object permanence development is considered complete.

Piaget (1954) explained the A-not-B error as occurring based on the infant's egocentric view of the world. It was thought that the child reached for the A location based on an inability to separate the actions from the object from his or her own actions. Since the child is not aware that the object continues to exist when not seen, reaching to point A can be viewed as bringing the object back into existence. Since Piaget, a number of studies have investigated the factors that influence whether or not a child will demonstrate the A-not-B error (see Marcovitch and Zelazo, 1999 for a review and meta analysis). The task has been expanded to include multiple search locations, rather than just two (e.g., Bjork & Cummings, 1984; Diamond, Cruttenden & Neiderman, 1994), changes in the distance between hiding locations (e.g., Horobin & Acredolo, 1986), and changes in the hiding locations themselves so that the locations are more distinctive (e.g. Harris, 1974). Additionally, the delay was increased (Diamond & Goldman-Rakic, 1989) between the object being hidden and when the child was allowed to retrieve the object as compared to Piaget's original immediate search. Each change in the task dynamics altered the age at which children demonstrated the error and the prevalence of the error's occurrence. According to the meta-analysis (Marcovitch and Zelazo) of 107 experiments, the age of the child, the length of delay between search and retrieval, the number of hiding locations and the number of exposures to the original "A" hiding location were predictive of whether or not a child would perseverate.

Piaget’s concept of object permanence has also been applied to non-human object cognition in many species. Object permanence is a skill that is ecologically relevant for most species. A carnivore hunting for food must recognize that the prey continues to exist even if it runs behind a tree in order to obtain food successfully. Similarly, a frugivore will be more successful at obtaining ripe fruit if it can recall that a non-visible fruit tree still exists. Etienne (1984) suggests that object permanence is required for anticipatory or insightful behavior and is a marker of intelligence in a species. She states that while invertebrates and some vertebrates may utilize a type of operant conditioning that allows them to adjust their behavior to either increase or decrease their further contact with a hidden object, they do not have the ability to adjust their search to predict where an object will be found in a novel situation.

In experimental studies, dogs have been found to search for hidden objects (Fiset, Beaulieu & Landry, 2002). The dogs search accuracy decreased as the delay increased between the disappearance of the hidden object and the opportunity search, but the dogs continued to search even when the retention interval was 240 sec. The dogs did not show proactive interference on this task, which indicates that prior hiding locations did not influence the future search attempts. Although this study did not directly test for the A-not-B error, the dogs did not demonstrate perseverative searching.

In an investigation of the development object permanence in food storing magpies (*Pica pica*), the birds followed a similar progression through stages as humans (Pollok, Prior & Güntürkün, 2000), but these birds never demonstrated the A-not-B error. At the age at which the magpies were able to retrieve a completely hidden object (nine weeks), they were also able to find objects hidden at multiple locations successfully. Nine weeks is also the age of independence for this species. Since this is a food storing species, the ability to locate objects (specifically cached food) in multiple locations is crucial.

Object permanence and the A-not-B error have also been investigated in non-human primates. Gorillas (Natale, Antinucci, & Poti, 1986), chimpanzees (Wood, Moriarty, Gardner & Gardner, 1980) and orangutans (deBlois, Novak, & Bond, 1998) all have been found to have stage 6 object permanence, where they can locate objects even after invisible displacement. Since there is a sequential progression through the stages of Piaget's (1954) object permanence it can then be inferred that the apes do not make the A-not-B error under the standard short-delay, dichotomous choice conditions. Squirrel monkeys were able to complete visible displacement tasks without showing the A-not-B error, but were unable to master invisible displacement tasks (deBlois et al., 1998). Rhesus monkeys and 12-month-old human infants show similar results (Diamond and Goldman-Rakie, 1989). They can both successfully find a hidden object at a new "B" location without making a perseverative error even when there is a 10-second delay period. However, when the monkeys' dorsolateral prefrontal cortex has been lesioned, their behavior matched that of 7.5-9 month humans, indicating that this portion of the brain is involved in organizing reaching following a delay.

Multiple theories have been proposed to account for the number of variables that can influence whether or not the A-not-B error occurs. Since the error is more likely to be observed as the delay between hiding and opportunity for searching increases, memory mechanisms have been used to explain why the A-not-B error occurs (Diamond, Cruttenden & Neiderman, 1994). According to this theory, the reason errors occur on B trials are due to competition between the working memory for the B location and previous learning about the A location. Since the child has been rewarded for reaching to the A location in the past, the child should also be inclined to reach for the previously satisfactory location. If as children get older their memory improves, this could account for infants being able to solve this problem after a certain point in their development. Munakata (1998) points out that infants can correctly gaze at the “B” hiding location prior to being able to reach successfully towards this spot. The argument is that the child has fewer opportunities to reach to the new location than to look at the new spot. This could serve to boost the working memory and allow for earlier non-perseverative reaching. Memory has also been used to explain species differences in object permanence. Only after cueing (which can reduce the memory load for the task) could rhesus monkeys solve the object permanence tasks that the orangutans could do on their own (de Blois, Novak, & Bond, 1999). However, this theory alone is not adequate since children continue to make the A-not-B error, though to a lesser degree, even when the object to be retrieved is hidden under a transparent cup (Butterworth, 1977).

The A-not-B error has also been interpreted from a dynamic systems perspective. According to dynamic systems theory, behaviors develop based on the combined impact of many factors such as biological preparedness, previous experiences, demands of the task, etc. A dynamic systems account of the A-not-B error includes the visual and attentional processes involved in assessing the nature of the hiding locations, the motor process involved in reaching for the object, the short-term or working memory for where the object was last seen and long-term memory about past searches (Spencer, Smith & Thelen, 2001). Since the individual has reached multiple times towards the A location, this spot builds up a heightened level of activation, which may, even over a short delay period, be stronger than the short-term memory activation at the B location. A key point of this theory is that the error is not directly linked to the age of the individual. The A-not-B error can be viewed as a specific type of spatial memory failure rather than a specific developmental stage. According to this theory, adults should occasionally make an A-not-B error given the correct set of circumstances. It is easy to imagine a situation where an adult routinely parks his or her car in a particular parking spot when arriving at work. If one day he or she parks in a different “B” location it would not be unexpected if at the end of the day he or she habitually returns to the original parking location. This example clearly has a much longer delay and wider distance between locations than the A-not-B task typically used with children, but nonetheless shows task similarities.

In order to test the dynamic systems account two-year-olds were tested to see if under the appropriate conditions they would show perseverative reaching (Spencer et al, 2001). Rather than using the traditional two-well or multiple well set up, they tested the children by hiding toys in a sandbox. This is different than other methodologies because it allows not only to determine if the child searches at the correct location, but it also allows for a deeper probe into what kind of error the child is making. Since there are continuous search locations available, the child is not forced to make a choice between a set number of cued locations. The child can make an error on the B trials where the search is pulled towards the A location, resulting in a search attempt between the two hiding locations. In this way the relative strength of the impulse to reach towards A can be assessed. Since there are fewer cues in a smooth sandbox the child must now recall where the toy was hidden, rather than simply recognize where the object was last seen.

Spencer et al. (2001) found that indeed, two-year-old children do still make perseverative reaches towards the initial a location on B trials. This is reflected based on the B trial performance being less accurate and being biased towards the original a location. This bias was not due to the children reaching for the middle of the sandbox. Additionally, when there were a greater number of A trials the more the B trial searches were pulled towards the A location. This indicates that the greater the activation of the A location, the more likely an individual will show an error.

Repeated visual attention to the A location and searches at that spot may serve to prime the motor search response. Infants have previously been shown to be receptive to attentional priming for color and pattern (Wilcox, 2004), so location priming seems likely. If reaching is primed, then there will be a habitual impulse to search at the primed location. On A trials, priming will assist the individual towards a correct response as they are already prepared to behave in a consistent manner. This would be reflected in A trials having shorter response latency, especially when they are correct searches. On the other hand, on B trials if an individual is primed to search at the A location, this would either prompt searching perseveratively at the A location or the prime must be overcome. Since it takes cognitive effort, and therefore time, to engage in a behavior that is counter to the prime, response latency should be longer on correct B trials.

Based on this review of the literature there is a need to further investigate the A-not-B error from a dynamic perspective in non-humans. This error is not simply reflective of the way an individual understands the properties of objects. It is more than an object permanence task. How do task demands, memory for the specific trial, prior experience and motor priming contribute to the A-not-B error?