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BEHAVIOR CHANGES BETWEEN 6 TO 12 MONTHS OF AGE: WHAT CAN THEY TELL US ABOUT HOW THE MIND OF THE INFANT IS CHANGING?

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Behavior Changes between Six to Twelve
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about How the Mind of the Infant Is
Changing?

presented by Adele Diamond

candidate for the degree of Doctor of Philosophy and hereby certify that it is worthy of acceptance.

Signature Jerome Kagan

Typed name Jerome Kagan

Signature James Stellar

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Date Jan 10 1983

Behavior Changes Between 6 to 12 Months of Age:

What can they tell us about how the Mind of the Infant is Changing?

A thesis presented

by

Adele Diamond

to

The Department of Psychology and Social Relations

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

in the subject of

Personality and Developmental Psychology

Harvard University

Cambridge, Massachusetts

January, 1983

I would like to dedicate this thesis to three people:

-- Mildred Golden Diamond, who is the most wonderful person I know

-- Jerome Kagan and Leon Bramson, for believing in me, even when I did not always believe in myself.

"No answer... is an entire or a permanent answer."

William Dickey,
Address at Phi Beta Kappa Initiation,
San Francisco State University, 1981

ABSTRACT

This study examined the hypothesis that some behavioral changes occurring between 6-12 months depend upon frontal cortex maturation. Two experiments linked to frontal cortex function by work with brain-damaged adults and animals were administered to 25 infants whose performance was assessed every 2 weeks. Another 84 children were tested only once.

In Experiment 1 (Piaget's A$\bar{B}$ Object Permanence Task) the infant watched E hide a toy at one of two identical wells. After a brief delay, the infant was allowed to reach. Experimental manipulations explored the effects of identical covers versus covers of different color, a color landmark signaling the toy's location, the effect of solely visual prior experience, delays of lengths varying from 0-12 seconds, the effect of level of motivation, and whether infants err by reaching to the same physical place or same relative position. Infants' errors followed a lawful pattern. Errors disappeared with a shorter delay or when a landmark consistently marked the toy's location. By one year, infants succeeded with longer delays and no landmark.

In Experiment 2 (Object Retrieval), the infant's task was to retrieve a toy from an open box. Experimental manipulations included the use of transparent and opaque boxes, box opening at front, top, left and right side, placing toy contiguous with front wall of box, the effect of training trials, and the effect of E supplied clues. Infants of 6-8 months failed when the box was positioned so they saw the toy through a closed side. They reached on a straight line of sight. Variables which determine line of sight (e.g., height of box or distance of box from child) exercised strict control over the infants' reaching behavior. By one year, infants succeeded under all conditions.

Results similar to those obtained in Experiments 1 and 2 are characteristic of monkeys with frontal cortex lesions. Implications of these results for the development of memory, the ability to inhibit prepotent tendencies, and the ability to relate one thing to another are discussed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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During the months of testing, Fernando Vidal and Jody Sabia manned the video camera while simultaneously recording the ongoing behavior on coding forms. They had dozens of tasks to do at once, and they performed them all well, and cheerfully. Babies are often on different schedules than students. Many a morning we came in at 8:00 a.m. for a testing session. Saturdays and Sundays were often the only days working mothers could bring their children to the laboratory. Jody and Fernando came in early in the morning and on weekends without complaint. I am very grateful to them.

Each hour of testing generated several hours of work coding the video tape record of that session. This is painstaking, skilled work. I would like to thank Carey Halsey and Dana Welch for putting in countless hours on the tapes of Object Retrieval sessions. This was a particularly difficult task and they did an excellent job. I am also grateful to Marsha Mak and Kay Estes for coding the tapes of Object

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INTRODUCTION

The brief interval from 6 to 12 months of age is a time of profound advances in the cognitive abilities of the human infant. These cognitive changes are so uniform across variations in children's experience and appear so abruptly that many experts agree the changes reflect not simply the role of learning, but fundamental biological changes as well (e.g., Emde et al., 1976; Kagan, 1976; Fox et al., 1979).

This is the time when infants enter Sensorimotor Stages 4 and 5 described by Piaget (1952; 1954). The crowning achievement of these stages is the emergence of intentionality (goal-directed behavior) and, hence, of intelligent behavior. Instead of primarily reacting to this stimulus or that, infants begin actively to direct their own behavior. In means-end behavior (where one action, e.g., removing or circumventing an obstacle, is done in order to obtain a goal) one can see evidence that the infant had a goal in mind at the outset of the action sequence; he no longer simply responds with an automatic reach to whatever catches his eye. One action is put into relation with another action in the service of a plan. Moreover, the orientation toward the goal is maintained long enough for the plan to be executed. Infants in Stages 1-3 are easily distracted, easily diverted from a course of action once begun.

Sensorimotor Stages 4 and 5 are also marked by the first evidence of a future orientation, not only in means-end behavior, but in the appearance of expectations or anticipations of what other people are about to do or what might happen next.

Behavior in Sensorimotor Stages 1-3 is essentially conservative. The "circular reactions" which mark this early period consist of repetition of an action over and over again. Behavior becomes less rigid and more flexible in Stages 4 and 5 as infants become better able to adjust to the demands of new situations. Stage 5, in particular, is marked by the active pursuit of the new and different. Now behavior is purposely varied. Those who study the development of emotional attachments during infancy have also been struck by the emergence of active exploration around 9-12 months (e.g., Ainsworth, 1967; Bowlby, 1969). The whole orientation of the infant toward the world around him becomes more active. Younger children react to the overtures made by their caregivers (attachment figures); children of 9-12 months actively reach out to others to sustain and renew contacts. Younger infants passively anticipate the re-emergence of an object from behind a screen; infants of Sensorimotor Stages 4 and 5 initiate active steps in order to regain the object.

In addition to Sensorimotor Stages 4 and 5 and Stage 3 Attachment, the last few months of the first year are marked by the emergence of the "fears" of infancy (separation anxiety, stranger distress, and avoidance of the visual cliff). Before this period, evidence of wariness is not generally found. Younger infants will calmly allow themselves to be placed atop a seeming abyss and will notice with seeming indifference the departure of their mother.

When an adult has suffered injury to the brain, specific behavioral deficits appear depending upon the site and extent of the damage. Damage to one area of the brain, the frontal lobe, disrupts all of the behaviors which show their first major advance during the second half of the first year of life. The overlap between the set of behaviors and abilities which developmental psychologists have linked to the period from 6-12 months and the set of behaviors and abilities which clinical neurologists have linked to the frontal lobe is virtually complete; injury to no other area of the brain influences behavior in quite these ways,

The hallmark of patients with frontal lobe pathology is a lack of planfulness, a breakdown of goal-directed behavior. No sooner is something begun than it is abandoned. Their behavior is stimulus-bound, dominated by the needs and stimuli of the moment, seeming to lack any perspective with respect to past or future. They react to the world, but rarely take the initiative. Their actions are repetitive and they show a marked lack of curiosity and exploration.

They are also noted for their lack of anxiety, worry, or fear. Friends and family often express concern that these patients do not appreciate the gravity of a situation; however, when the patients "are asked why they don't worry, they not infrequently shrug their shoulders" (Denny-Brown, 1951:67).

If injury to the frontal lobe can disrupt these behaviors, perhaps the emergence of these abilities toward the close of the first year is linked to a maturation in the frontal lobe.

To investigate the hypothesis that a maturation in the frontal lobe underlies behavior changes between 6-12 months, two experimental tasks (the $A\bar{B}$ Stage 4 Object Permanence Task and Object Retrieval) were administered to a longitudinal and a cross-sectional sample of infants. Both of these tasks are similar to ones firmly linked to frontal lobe function by work with animals and with human adults, i.e. animals and human adults with lesions to the frontal lobe fail tests very similar to A$\bar{B}$ and Object Retrieval. We hypothesized that infants below 9-12 months would fail these tests, while older infants would not, and that the pattern of errors shown by the younger infants on these tasks would also mirror the pattern shown by frontally operated subjects. Similar gross behavior (e.g., simple success and failure rates) may be obtained for different reasons and mean different things. However, if varying the task parameters affects the behavior of infants in the same ways it affects the behavior of frontally damaged monkeys or human adults, then these tasks probably tap similar abilities in these different populations.

The investigation of A$\bar{B}$ and Object Retrieval cannot prove that maturation in the frontal lobe underlies behavioral changes during the second half of the first year. Such proof would require a non-intrusive method for studying finely localized neural activity and no such technique yet exists. However, if our predictions for the performance of infants on A$\bar{B}$ and Object Retrieval are confirmed, this will be important evidence in favor of the frontal lobe maturation hypothesis. Moreover, it will be the first demonstration of a link between a cortical region and a test sensitive to developmental change in the cognitive ability of the human infant. It will have important implications for our understanding of cognitive development, of the functions of the frontal lobe, and of the relationship between cognitive development and the brain.

Section 1 presents the results obtained with infants on A$\bar{B}$. Section 2 presents the results obtained with these same infants on Object Retrieval. Section 3 relates these findings to those obtained with frontally damaged animals and human adults and describes what is known of the postnatal maturation of the frontal lobe.

OVERVIEW OF THE EXPERIMENTAL DESIGN AND SUBJECT POPULATION

A longitudinal sample of 25 full-term infants received testing on 2 tasks, A$\bar{B}$ and Object Retrieval. Each child was tested individually every two weeks on both experiments throughout the second half of the first year of life. To control for the effect of repeated testings another 84 children were tested only once.

All infants were located through the Boston birth records, which are open to the public. Parents were called and asked to participate. Two criteria were used to determine if an infant was at the proper age to begin longitudinal testing: 1) the infant must be able to reach for and grasp a free standing object (Object Retrieval required the child to reach around an obstacle for a toy and presupposed the ability to retrieve the toy without an obstacle present), and 2) the child must not yet be able to find a totally hidden object (the A$\bar{B}$ error is first seen when the child can uncover a fully covered toy and we wanted to observe the developmental course of this error from its very outset). The youngest infant included in the longitudinal sample began testing at 22 months and the infant to begin biweekly testing at the oldest age did so at 32 weeks. (The age of an infant in months is calculated by estimating that there are 4.33 weeks per month. Thus a 22 week old is in his 5th month and a 32 week old is 7-1/2 months.) The average number of experimental sessions per child in the longitudinal sample was 12, the range being 10-15.

Infants in the control sample who received only one testing were also located through the Boston birth records. They were chosen for inclusion in the study on the basis of age and sex: 6 male and 6 female full-term infants were tested at 6, 7, 8, 9, 10, and 11 months of age, and 3 male and 3 female full-term infants were tested at 5 and 12 months. No infant with major health problems, past or present, was included in either the longitudinal or cross-sectional sample.

The response rate from the phone requests for participation in the study was 85%. Of the original 28 infants (14 male, 14 female) who were selected to participate in longitudinal testing, only 3 infants dropped out (all male). We were pleasantly surprised by the low attrition rate. Two families left the study after two experimental sessions and one after three sessions. Their reasons for discontinuing testing were: 1) the death of a grandparent, 2) the mother began a new job, and 3) the father took a new job which required the family to relocate.

In general, the results presented here are based on the longitudinal sample alone -- only when the findings with the cross-sectional sample showed a significant departure from that seen with the infants tested repeatly are these findings also presented. It is much harder to interpret the behavior of an infant tested only once; much time is wasted in simply determining the proper level of testing for the child; a much more sensitive analysis of behavior is possible when the children are followed regularly over a substantial period of time.

The characteristics of the children in the longitudinal sample and their parents are summarized in Tables 1, 2, and 3. The characteristics of the 3 children who dropped out are outlined in Table 4 a, b, and c. The children tended to come from Jewish or Catholic homes; (one boy and one girl were black). The average age of the fathers was 31 (range =

Table 1

CHARACTERISTICS OF INFANTS STUDIED LONGITUDINALLY

	Sex	Birth Weight Lb.s(Oz.s)	Wt. at 7½ Mo.s	Birth Order	Age When 1st Sat Up On Own (Months)	Age at 1st Testing (Weeks)	Child Care
Jack	M	7(15.5)	18	1 half sib elsewhere	7.5	31	home with mom
Lyndsey	F	6(16.5)	14.5	2nd	5.5	29(2)	home with dad
Tyler	M	7(5.5)	16	1st	5.5	28(2)	home with mom
Jamie	F	7(8.0)	17	1st	6.0	32	home with mom
Emily	F	8(0)	17	1st	5.5	32(2)	home with mom
Rachel	F	8(5.8)	17	2 half sibs elsewhere	6.5	29(1)	home with mom
Brian	M	7(10.5)	19.5	1st	4.5	22(3)	home parents share
Ryan	M	8(2.0)	19	2nd	6.5	29(1)	home with mom
James	M	8(13.0)	18	1st	5.0	23	home with mom
Erin	F	7(10.5)	17.5	1st	4.0	28(3)	home with mom
Sarah	F	8(9.5)	15.5	1st	6.0	28(6)	home with mom playgrp 1 afternoon
Julia	F	7(7.0)	13	2nd	6.5	24(2)	home with mom
Mariama	F	7(5.0)	17.5	1st	6.0	31(6)	home with caretakers
Kate	F	9(4.0)	16	2nd	6.0	29(5)	home with mom playgroup
Rusty	M	7(2.5)	15.5	1st	7.5	31	home w/ mom; babysitter 1 afternoon
Todd	M	7(10.0)	16	1st	4.0	27(2)	home with mom
Nina	F	7(15.0)	16	1st	4.0	27	at babysitter with 1 other child
Isabel	F	7(14.5)	16.5	1st	5.0	28(5)	home with mom
Jennine	F	8(2.5)	19	1st	5.5	23(2)	home with mom
Jane	F	7(14.5)	19	1st	5.0	30	home w/ babysitter parents work at home
Bobby	M	8(12.0)	19	1st	6.0	31(3)	home with mom
Graham	M	8(6.5)	18	1st	5.0	32(1)	home w/ mom; with grandmother 2 days
Blair	M	7(5.0)	18.5	1st	5.0	31	home with mom
Michael	M	6(6.0)	18.5	1st	5.0	27(1)	home with mom
Chrissy	F	8(7.0)	16	1st	5.5	29(1)	home with mom

Table 2

DEMOGRAPHIC CHARACTERISTICS OF FATHERS OF INFANTS STUDIED LONGITUDINALLY

	Age at Child's Birth	Occupation	Education	Ethnic Identity	Home Community
Jack	38	Lawyer	JD	Swedish, Eng. & Swiss-Ger. Am.	Needham
Lyndsey	27	Graduate Student	MA	Protestant	Cambridge
Tyler	32	Public Relations	MA	Protestant	Hyde Park
Jamie	29	Equipment Repairman	BA	Italian & Fr. American	Malden
Emily	31	Film Editor	BA	Protestant	Jamaica Plain
Rachel	43	Real Estate Agent	2 yrs. college	Italian-American	Arlington
Brian	27	Air Traffic Controller	BA	Protestant	Cambridge
Ryan	32	Corrective Therapist	BA	English-American	West Roxbury
James	29	Finance Specialist	BA	English & Scottish Am.	Somerville
Erin	25	Credit Manager	2 yrs. college	American	Arlington
Sarah	33	Architectural Designer	BA	Irish & Austrian Am.	Cambridge
Julia	31	Engineer	BS	Caucasian	Acton
Mariama	27	Surgeon; Minister	MD	Black American	Cambridge
Kate	31	Environmental Economist	MA	Jewish	Cambridge
Rusty	30	Surgical Resident	MD	Protestant	Boston
Todd	33	Lawyer	JD	Protestant	Boston
Nina	40	Physicist	PhD	Italian-American	Cambridge
Isabel	36	Medical Illustrator	1 yr. grad sch	Irish & English Am.	Waltham
Jennine	31	Warehouseman	h.s. graduate	Italian-American	Watertown
Jane	32	Self-Employed Businessman	MA	Jewish	Wellesley
Bobby	31	Jr. h.s. Teacher	BA	American	Lexington
Graham	36	Physician	MD	American	Boston
Blair	30	Insurance Broker	BA	Black American	Mattapan
Michael	24	Security Guard	BA	Catholic	Chelsea
Chrissy	25	Electrician	h.s. graduate	Irish-American	Charlestown

Table 3

DEMOGRAPHIC CHARACTERISTICS OF MOTHERS OF INFANTS STUDIED LONGITUDINALLY

	Age at Child's Birth	Occupation	Work History Since Child's Birth	Edu-cation	Ethnic Identity
Jack	35	Psychiatric Social Worker	at home	MSW	Irish & Polish Am.
Lyndsey	25	Administrative Assistant	working	1 yr. college	American
Tyler	32	Recreation; Presch Ed.	at home	BA	Jewish
Jamie	31	none	at home	h.s. graduate	Greek & German Am.
Emily	29	Marketing Research	at home	BA	Protestant
Rachel	29	Speech Pathologist	at home	MA	Jewish
Brian	28	Doctoral Student	in school	BA	Protestant
Ryan	32	Medical Secretary	at home	1 yr. bus sch	English-American
James	32	Secretary	freelance typing	h.s. graduate	Irish, Eng. & Welsh Am.
Erin	25	Hairdresser	works part-time	1 yr. college	American
Sarah	31	Elementary Sch. Teacher	on leave	EdM	American
Julia	31	Textbook Editor	at home	MAT	Caucasian
Mariama	28	Pediatrician	working	MD	Black American
Kate	32	Rehabilitation Counselor	at home	EdM	Jewish
Rusty	29	High School Teacher	on leave	EdM	American
Todd	29	Arts Administrator	on leave	BA	Jewish
Nina	39	Computer Programmer	working	BA	American
Isabel	30	Social Worker	part-time secretary	BA	Finnish-American
Jennine	28	Registered Nurse	at home	RN	Irish-American
Jane	30	Clinical Psychologist	works; office at home	PhD	Jewish
Bobby	25	Elementary Sch. Teacher	at home	BA	American
Graham	32	Nurse Practitioner	works part-time	MA	American
Blair	32	Kindergarten Teacher	at home	EdM	Black American
Michael	22	Hospital Ward Secretary	working	1 yr. jr coll	Catholic
Chrissy	23	Clerk	at home	h.s. graduate	French-American

Table 4A

CHARACTERISTICS OF INFANTS WHO DROPPED OUT OF LONGITUDINAL STUDY

	Sex	Birth Weight Lb.s(Oz.s)	Wt. at 7½ Mo.s	Birth Order	Age When 1st Sat Up (Months)	Age at 1st Testing (Weeks)	Child Care
Dan	M	8(0)	18.5	1st	4.5	28	home w/ mom
Kerin	M	7(4)	17	2nd	4	33	home w/ mom
Sean	M	8(2)	16.5	4th	5	22	home w/ mom

Table 4B

DEMOGRAPHIC CHARACTERISTICS OF <u>FATHERS</u> OF INFANTS WHO DROPPED OUT OF STUDY

	Age at Child's Birth	Occupation	Education	Ethnic Identity	Home Community
Dan	30	Salesman	2 yrs. college	Caucasian	Dorchester
Kerin	26	Mechanic	2 yrs. college	Caucasian	Medford
Sean	28	Teacher	BA	Irish Am.	Boston

Table 4C

DEMOGRAPHIC CHARACTERISTICS OF <u>MOTHERS</u> OF INFANTS WHO DROPPED OUT OF STUDY

	Age at Child's Birth	Occupation	Work History Since Child's Birth	Edu-cation	Ethnic Identity
Dan	27	Clerk	-----	h.s. graduate	Caucasian
Kerin	24	none	-----	h.s. graduate	Caucasian
Sean	26	Secretary	-----	2 yrs. college	Irish Am.

24-43). The average age of the mothers was 30 (range = 22-39). Level of paternal education ranged from high school diploma to J.D., M.D., and Ph.D.. Paternal occupations ranged from warehouseman, security guard, repairmen and electrician, to surgeon, physicist, finance specialist and lawyer. Mothers exhibited a similar range in their educational attainment, but their average level of education was a little below that of the fathers. The occupations held by the mothers before their children were born ranged from clerk, secretary, and hairdresser to pediatrician, clinical psychologist, psychiatric social worker, and textbook editor. One mother did not report ever working, and six were continuing to work.

The major difference between infants in the longitudinal and cross-sectional samples was in birth order. Most infants in the longitudinal sample had no older siblings. There are probably two reasons why such a disproportionate number of first borns found their way into the longitudinal sample: 1) many first-time parents are more curious about their baby and put more energy and total involvement into parenting than do parents who have been through this at least once before, and 2) the logistics of arranging to test an infant with a brother(s) or sister(s) every two weeks is a major undertaking -- babysitting must be arranged or the siblings must be able to come to the laboratory and yet not disrupt the testing (bear in mind that the siblings of infants are often very young children themselves).

Parents were informed of the general objectives of the study and it was explained that we were primarily interested in developmental changes through which all children progress rather than in differences between children. The parents, however, had their own reasons for participating. Many wanted confirmation that their child was normal; some came for evidence that their child was considerably above normal; some came because by using a standard situation and by allowing two weeks to elapse between testings they could see evidence of significant changes in their babies that were not otherwise revealed; some came for something different to do out of the house; and one mother with an older child joined the longitudinal group because the testing sessions gave her some rare moments where she could be "alone" with the baby (i.e., could devote all of her attention to the baby).

All testing sessions were conducted in the infant study laboratory in William James Hall, Harvard University. Usually the baby was accompanied by the mother, but sometimes it was the father who came (this was especially true for the longitudinal study). Occasionally both parents came or a parent was joined by other family members. On these occasions one adult remained with the child and the others observed the testing through a one-way mirror. One little girl in the longitudinal sample was accompanied on her first 4 visits by both parents, but thereafter she was brought in by the babysitter. Every attempt was made to schedule testing sessions at times most convenient for the parents and when the baby would be most alert and willing to work. Testing sessions were, thus, often scheduled as early as 8 or 8:30 and were rarely scheduled after 2 p.m. Four or five infants were often tested in a day, six days a week, with an occasional visit on Sunday. If an infant became cranky or sleepy during testing, he was given a short break. If the break did not succeed in reviving the infant, the session was terminated and testing resumed on the following day.

Parents were given $3 for each testing session. The sessions lasted an hour and some parents came from as far away as Acton, Reading, and Plymouth, Mass. Thus the money was more a token of our appreciation rather than remuneration. The parents who participated in the longitudinal sample were also given a certificate of graduation from the Harvard Infant Study and they received a report of the major findings.

Sessions were usually scheduled a week or two ahead of time and reminder cards were mailed out a few days before the visit. (The cards are illustrated in Appendix A.) A concerted effort was made to test every baby in the longitudinal sample at intervals of 2 weeks plus or minus 3 days. In general, we were extremely successful in this.

Infants were seated on the parent's lap for testing on both A$\bar{\text{B}}$ and Object Retrieval. Testing on Object Retrieval was conducted first, and then testing on A$\bar{\text{B}}$. On the four visits when hand preferences were assessed, the Side Preference Test was administered at the very outset of the session. A short break for stretching, nursing, changing diapers, and playing was taken between the two experiments. The testing room was bordered on one side by a one-way mirror behind which was a video camera and an observer who recorded the infant's responses on coding forms. The observer also wrote up a summary of the child's behavior after each session. More detailed behavioral coding was accomplished using the videotape records.

SECTION 1

THE A$\bar{B}$ EXPERIMENT

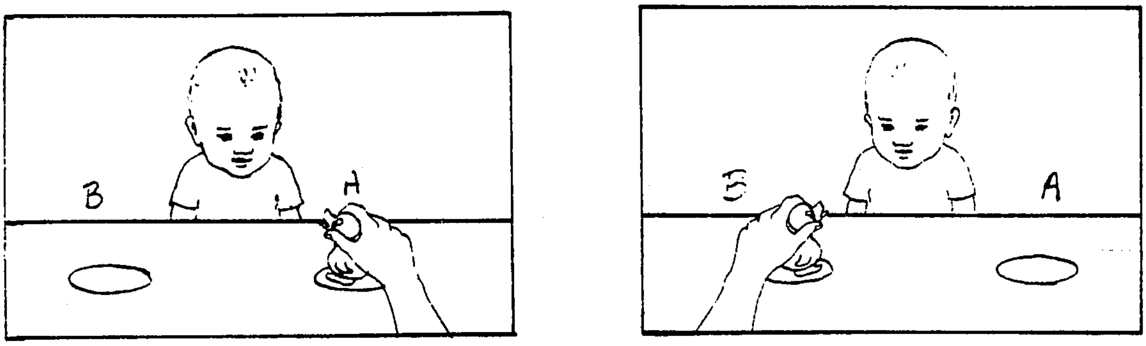
MATERIALS AND METHODS

Ever since Jean Piaget (1952) first described the A$\bar{B}$ (pronounced "A, not B") error, a rich body of experimental evidence has grown up around this phenomenon. The basic paradigm is as follows: The experimenter hides a toy at one of two places while the infant watches. Even a child of only 7 or 8 months can then easily find the toy. But when the experimenter next hides the toy at the other location, the same child reaches for the toy at the <u>first</u> hiding place -- even though the hiding was performed in full view and even though the child dearly wants the toy. Were this trial to be repeated, typically the infant would err again by returning once more to the first location. (Hence the name A$\bar{B}$, for infants who are able to find an object at the first place it is hidden (location A) are unable to find the object at the second place it is hidden (location B). They search at A, not at B.) This is illustrated in Figure 1. It should be noted that typically the infant is required to wait a few seconds before being allowed to reach. This delay interval is kept constant across all trials.

The A$\bar{B}$ apparatus used in this study contained three wells, or three possible places where a toy could be hidden. It stood 27-1/2 inches high, 35 inches long, and 11 inches wide. Embedded in its top were the three wells, each 3-3/4 inches in diameter and 3 inches deep. If the wells had been arranged in a straight line, the center well would have been easily within reach of <u>both</u> of the baby's hands, while each side well would have been easily within reach of only one hand. To equalize

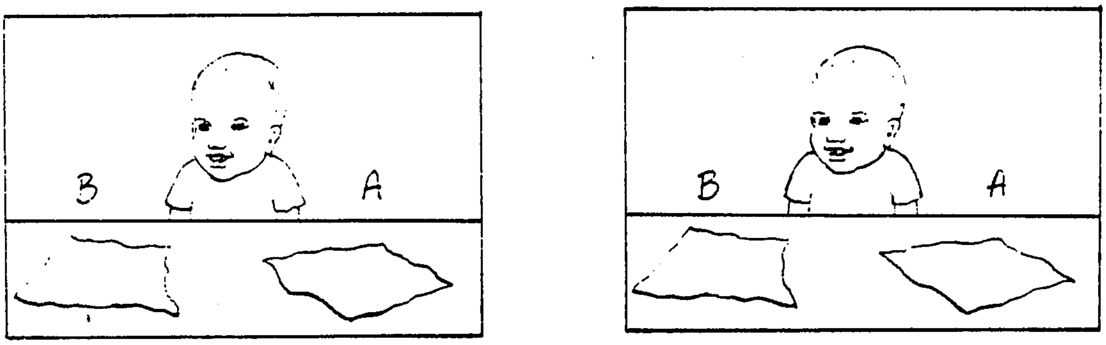
Figure 1

Schematic Representation of the A$\bar{B}$ Error Sequence



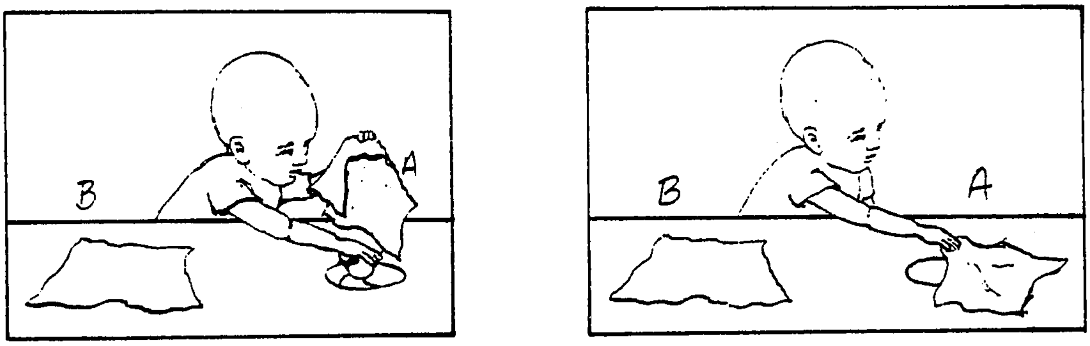
Cue Phase: Infant sees experimenter hide object at A.

Cue Phase: Infant sees experimenter hide object at B.



Delay Period: Infant is made to wait 0-12 seconds before he is allowed to reach.

Delay Period: Infant is made to wait 0-12 seconds before he is allowed to reach.



Response Phase: Infant reaches correctly to A for the object.

Response Phase: Infant errs by reaching to A, not B.

accessibility, the center well was moved back slightly. Thus, the three wells formed an isosceles triangle, with the center well at the apex and the base of the triangle closer to the baby (see Figure 2). The apparatus was brown in color with each of the wells bordered by red tape.[1]

Light blue cotton cloths (9 inches x 10 inches in size) were used to cover the wells. They were chosen because they are easy for infants to pick up and remove. In the "different covers" condition, one of these blue covers occluded one well while a white washcloth (10 inches x 12 inches) occluded the other well. With the covers in place over the wells, there were three inches between covers. Covers over the right and left wells touched the front of the apparatus; the frontmost edge of the center cover reached to within three inches of the front of the apparatus. Only two wells were covered on any trial, but extra covers were always kept in readiness to minimize the time needed to retrieve flung covers after a trial and to keep the intertrial interval as uniform as possible.[2]

An infant was seated on his or her parent's lap facing the apparatus, equidistant from the three wells. This had two important advantages over placing the infant on a seat by himself, and one disadvantage. The advantages were that the infant's feelings of contentment and security were thus maximized and that during the hiding and delay the parent was able to restrain his or her baby, particularly the arms, far more effectively than any infant seat would have. To the extent that straining enables the baby to keep track of where the toy has been hidden, thus circumventing the memory requirements of the task (and we will present data later on to suggest that this is, in fact, the case),

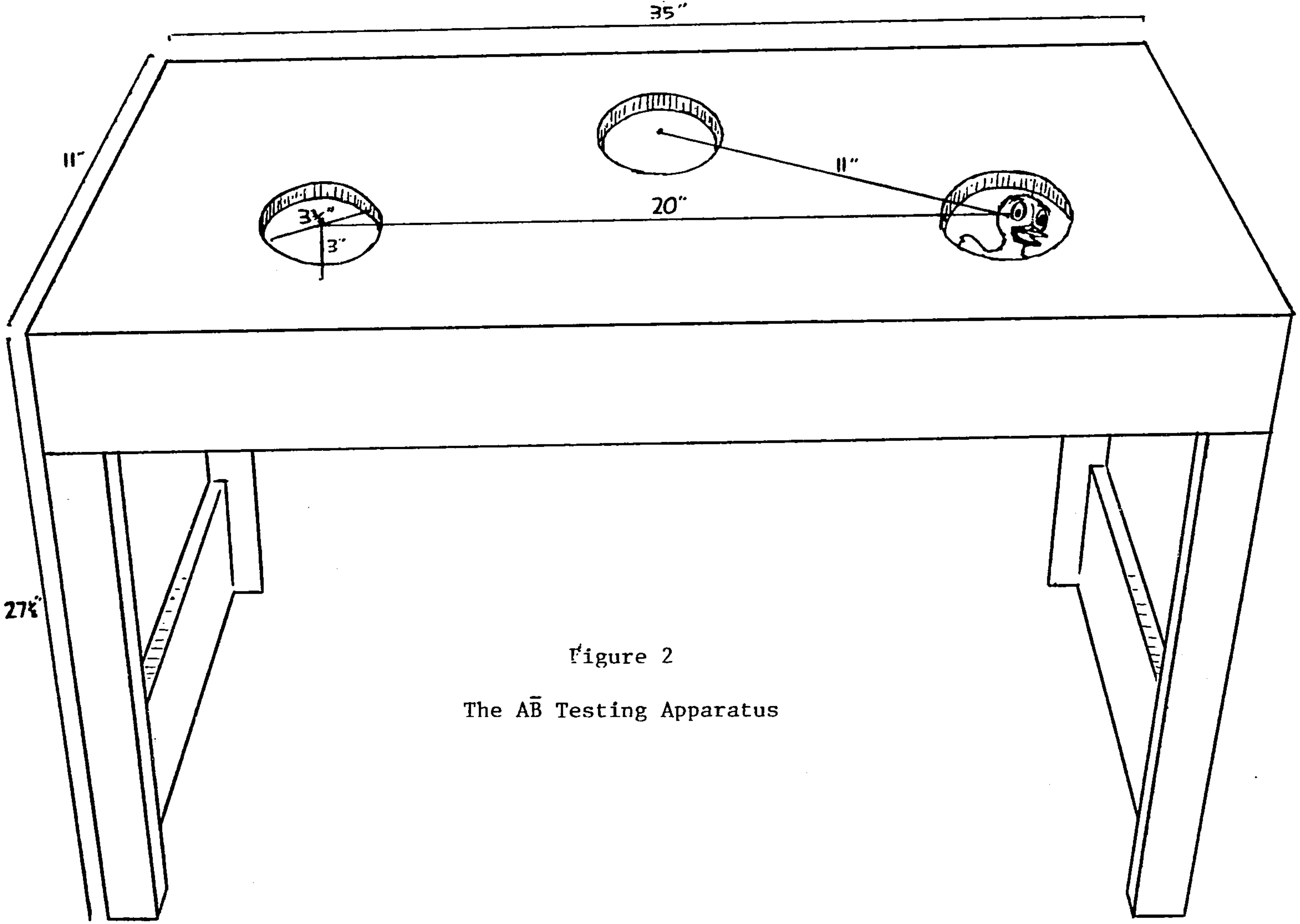


Figure 2

The A$\bar{B}$ Testing Apparatus

then it becomes important to try to keep this straining to an absolute minimum. The disadvantage of seating the baby on a parent's lap is the possibility that the parent will communicate subtle, often unconscious, cues. We tried to impress upon parents the importance of their not affecting the baby's behavior and mentioned specific things which they should try not to do, such as leaning over to look at the correct well (the well in which the toy was placed), or shifting their weight or position during a trial, particularly as the infant is reaching. We realize, however, that there is no way to eliminate altogether the subtle bodily cues that might be communicated between parent and child. We felt in the final analysis that the advantages here outweighed the risk. The experimenter was seated facing parent and child, on the other side of the apparatus.

A large collection of toys was always on hand so that the experimenter could find a toy that was attractive to each infant, and if that toy lost interest after some trials, so that the experimenter could find another toy. Our collection included a set of keys, a rattle, a small teddy bear, a plastic ball, a small green car, etc.

The experimenter signalled the beginning of a trial by holding up a toy to attract the baby's attention and by asking the parent to hold the baby's hands. (Each parent was instructed to hold his or her child so that the torso and the arm, from shoulder to fingertip, were as still as possible.) The experimenter then hid the toy slowly and carefully in one of the wells. Great care was taken to insure that the infant watched the entire hiding attentively. If the infant looked away at all while the toy was being hidden, the infant's attention was recaptured and the hiding repeated. If the infant looked away again, another toy was substituted which captured the infant's attention more successfully and the trial was begun anew. Immediately after the toy was placed in a well, the experimenter covered that well and an adjacent well simultaneously. (The left and right wells were at the far ends of the apparatus and were not adjacent to one another.) We will return in a moment to the fact that all wells were uncovered and visible when the toy was hidden and that the two wells used on a given trial were covered at the same time.

With the covering of the wells, the delay period of the trial began. Delays between the hiding of the toy and permitting the infant to reach for it began at 0 seconds and increased to 15 seconds as an infant became older and demonstrated his or her ability in this experiment. During pretesting, we had tried lowering a screen between the infant and the apparatus so that the infant would not be able to stare at the correct well throughout the delay period. A screen has been used by other investigators studying $A\bar{B}$ and by investigators studying delayed response with monkeys. However, we found the screen to be terribly distracting to the children. Some became frightened by the screen, others engrossed, and most forgot completely that any toy had ever been hidden. Moreover, the screen blocked the experimenter's and the coder's view of the child during the delay period, hampering their ability to monitor his or her behavior. We abandoned the screen in favor of the experimenter counting out loud during the delay. This achieved the goal of making the infant look up. Moreover, infants do not like to be restrained or made to wait, and they can sometimes complain vociferously at this; the counting aloud seemed to distract or amuse them so that their fussing diminished or ceased. Parents were trained so that when the experimenter said "okay," the baby's hands were released and reaching permitted.

A reach was defined as the removal of a cover. If the infant began to reach toward a cover but withdrew his or her hand before touching it, or touched a cover but did not remove it, this was counted only as a prior, or aborted, reach. The crucial criterion for a reach was that a well was uncovered. Similarly, if an infant reached to one well, uncovered it, and then immediately reached to another well without even looking into the first, the infant nevertheless was credited with reaching to the first well uncovered.

If an infant reached correctly, he was usually rewarded with praise and even applause, in addition to the toy. If the infant reached to the wrong well, he was permitted to try to correct himself. That is, the baby was allowed to continue searching until either giving up or finding the toy. However, the baby was <u>not</u> permitted to retrieve the toy or to play with it; infants were only rewarded with the toy if the <u>first</u> place at which they reached was correct. If an infant uncovered the toy during the search following an incorrect reach, at that point the experimenter intervened, removing the toy from the well so that the infant could clearly see it, but not allowing the infant to play with it. If the baby, despite subsequent searching, never found the toy, the experimenter directed his or her attention to the correct well, uncovered it, and showed the toy to the child, but did not permit the child to play with it.

The median number of trials per session was 15, with a range of 10 through 24. The length of an experimental session was determined primarily by the hypotheses being tested on that day.

To control for side preferences, roughly half (13) of the infants received their first testing on A$\bar{B}$ with the initial side of hiding to their left and roughly half (12) were tested with the initial side of hiding to their right. Initial side of hiding was reversed on each subsequent visit. In this manner, roughly half of the sessions for an infant began with the toy hidden to his or her left, and roughly half began with the toy to the right. Similarly, roughly one third of the sessions started with the toy placed in the left well, one third with toy in center well, and one third with toy in right well. This was accomplished in the following way: for trials starting with toy to baby's left, two thirds used the left and center wells with toy in left well ($\underset{\text{toy}}{\bullet}$ $\bullet$ 0), while one third used the center and right wells with toy in center well (0 $\underset{\text{toy}}{\bullet}$ $\bullet$); likewise, for trials starting with toy to baby's right, two thirds used the right and center wells with toy in right well (0 $\bullet$ $\underset{\text{toy}}{\bullet}$), and one third used the center and left well with toy in center well (0 $\underset{\text{toy}}{\bullet}$ $\bullet$).[3]

To control for side preferences of infants tested only once, half of these children were tested with the toy first hidden to the right and half with the toy first hidden to the left. Their side and hand preferences were also independently established by the same procedure used with subjects followed longitudinally.

All of the experimental procedures described above were verified by coders who objectively rated the experimental situation, and the behavior in it, from videotape recordings.[4] Thus, the coders were asked, for each trial, (1) if the baby <u>clearly</u> saw where the experimenter hid the toy, (2) if the baby's hands were held, (3) if the baby showed visible straining during the delay, (4) if the experimenter covered both wells at the same time, (5) if the covers were equidistant from the baby, (6) if the baby looked up, away from the wells, during the delay, and (7) if, at the conclusion of the trial, the baby was clearly shown where the toy had been hidden; using a stop watch, (8) the coder independently judged the length of each delay; using specific concrete criteria (such as "baby reaches for toy" or "baby watches toy attentively"), (9) the coder assessed the baby's level of interest in the toy, both at the outset of a trial and again at its conclusion. All coders were trained for two to four weeks. They were not apprised of the experimental hypotheses, and the questions were worded to minimize bias. For example, instead of saying, "The experimenter meant to cover both wells simultaneously; did she succeed?" the question read, "Did the experimenter finish covering one well after the other?" (choices: Yes, left well; Yes, center well; Yes, right well; No).

Coders were trained to be conservative in their judgments and to confine themselves to objectively observable behavior.[5] Formal training ended when a coder demonstrated an average reliability across all items of .90 or better with the trainer. Reliability was reassessed once each week for as long as the coder continued to rate videotapes. The lowest intercoder reliability for any item discussed in this report is .85; the average is .92. More than a few items had lower reliabilities; we will not refer to these items in discussing the results. For example, coders were asked, "Was the baby reaching for the toy (as opposed to for the cloth or to just continue a movement)?" (Choices: Yes, clearly; Yes,?; Unclear; No, ?; No, clearly). The use of the answers "Yes, ?; Unclear; and No, ?" was not consistent across coders and we, therefore, cannot use these answers. However, "Yes, clearly" and "No, clearly," which were treated as very extreme answers, each had intercoder reliabilities greater than .95, and so the information contained in these answers has been retained and utilized.

The coders' responses indicated that certain aspects of the experiment had successfully remained constant across trials. The item, "Did the baby <u>clearly</u> see where the experimenter hid the toy?," for instance, received the strongest possible affirmative answer on over 99% of the trials. The ratings indicated, however, that we had been less successful in achieving uniformity in other aspects of the experiment. For example, the baby was usually, but not always, seated equidistant from the two wells (equidistant on 82% of trials), and, while a high level of interest in the toy was always sought, it was not always attained (interest was rated as "high" on 85% of the trials). Whenever an item showed any variability across trials, we searched for any relationship it might show to experimental variables or to our results. Some items, such as "equidistant from both wells" showed no relationship with anything that we could detect; other items, such as "level of interest in toy" did seem to affect results and we will discuss this relationship, and all others that proved significant, in the Findings section below.

While the procedure for conducting the A$\bar{B}$ experiment is relatively standard, it is not perfectly so. We would like to take this opportunity to point out the principal ways this study differed from other studies of A$\bar{B}$, and the possible effects these differences may have had on results.

Three aspects of our experimental procedure may have made our version of A$\bar{B}$ more difficult for infants than in some other A$\bar{B}$ experiments. These three aspects are: 1) restraining the infant during the delay period; 2) disrupting the infant's visual fixation on the correct well during the delay by making the infant look up; and 3) covering both wells simultaneously. We chose to physically restrain the children and to interrupt their gaze because other studies of A$\bar{B}$ with infants (Gratch and Landers, 1971; Cornell, 1979; Fox et al., 1979) have shown that straining and visual fixation are ways that the memory requirements of the task may be circumvented. Infants who cannot remember where a toy has been hidden if they sit still or if they look away, perform perfectly at the same, or even longer, delays if they are permitted to maintain some orientation toward the correct well. (Indeed, evidence from the present study confirms this; see the Findings section. Briefly, we found that if an infant stares at or strains toward the correct well during part, or even most, of a delay he is *not* more likely to succeed than if he had not done so. However, when the infant's strain or gaze is *uninterrupted* and maintained *throughout* the delay period, success rate is much higher than on comparable trials where bodily strain or gaze is not thus maintained.)

Some researchers perform the A$\bar{B}$ hiding by uncovering only the well in which they place the toy and then covering that well. The other well remains covered throughout (e.g., Gratch and Landers, 1971; Evans, 1973; Gratch et al., 1974). Because of a study by Harris (1973), we believe that if all other aspects of the experiment are held constant, infants will perform better when this is done than when both wells are covered simultaneously, as was done in the present experiment and in experiments such as those by Butterworth, 1975; Szpak, 1977; Bremner, 1978; and Goldfield and Dickerson, 1981. Harris varied the order in which the wells were covered. He found that when the toy is hidden at B (the second hiding place) infants have a strong tendency to reach to the well that is covered last.[6] That is, on trials where the toy was hidden at B, if Harris covered A first and then B, the infants reached correctly to B, but if he covered B first and then A, the infants made the A$\bar{B}$ error of reaching to A. (Table 5 illustrates the conditions and findings of this study.) We believe that leaving A covered, and only uncovering and covering B, is analogous to Harris' covering A first and then B -- in both cases, B is the last place to be covered -- and we thus believe that investigators using this procedure will find a higher success rate under comparable conditions than investigators covering both wells simultaneously.[7]

Another procedural difference between this study and others is the type of distractor used. We chose to count aloud during the delay; others have lowered a screen between child and hiding places (e.g., Szpak, 1977; Fox et al., 1979). It is still possible for infants to keep the hiding places in their peripheral vision while looking up at the experimenter as she counts and certainly many infants looked down at the apparatus after looking up and/or did not look up until several seconds had elapsed. With the screen, infants are not able to see the apparatus at all during any of the delay. This suggests that the screen may be a more severe distractor and, thus, make the task more difficult, but we know of no actual evidence on the effects of verbal distraction versus interposition of a screen.

We chose not to follow the example of others on two other questions of methodology in order, we hoped, to minimize confounding elements in the experiment. First, we exaggerated the hiding, insisting on the infant's undivided attention more than is sometimes done. For

Table 5

CONDITIONS IN THE HARRIS (1973) STUDY
AND WHETHER OR NOT THEY PRODUCED ERRORS
WITH A ZERO SECOND DELAY

	Cover A First	Cover B First
Hide Toy at A	no	no
Hide Toy at B	no	YES

example, in the film illustrating the Uzgiris-Hunt scale, the comparable hiding is performed far more rapidly. Evans (1973) and Gratch et al. (1974) found different results for infants who actively attended to the entire hiding sequence and those who did not; we did not proceed with a trial until the infant actively attended to the hiding sequence. We did not want it to be said that infants erred because they had not seen where the toy had gone. Second, in our standard procedure we did not reward infants when they erred. Other investigators typically permit the children to play with the toy after every trial regardless of whether the child has reached correctly on that trial or not (e.g., Gratch and Landers, 1971; Evans, 1973; Harris, 1973; Szpak, 1977; Goldfield and Dickerson, 1981). We felt that if reward was not tied to performance, infants would have less incentive to reach correctly.[8]

OPERATIONALIZATION OF THE $A\bar{B}$ ERROR

What, exactly, does the $A\bar{B}$ error look like? The reader has been introduced to the general form of this phenomenon, but what, for example, does it mean to say that infants *tend to err* when the toy is hidden at B? How many err? How consistently? Does this happen only the first time the place of hiding is changed, or each time the hiding place is changed? Once an infant has erred, will he repeat the error on subsequent trials? Are infants simply reaching randomly or are they consistently returning to the old hiding place whenever a new hiding place is used? From what pattern of behavior can one conclude yes, this infant is making the $A\bar{B}$ error today or, no, the behavior observed does not meet the necessary criteria?

Most investigators seem to base their judgment of whether or not the $A\bar{B}$ error has occurred on a single trial, the first trial on which the toy is hidden at B. An infant who errs here is said to have made the $A\bar{B}$ error. An infant who does not is said not to have made the error.

We believe this single trial criterion is insufficient. In its stead, we use a set of four criteria. In order to assert that an infant committed the $A\bar{B}$ error in a given session, we required that both of the first two criteria be met and at least one of the last two. The criteria are:

1) Once the infant has reached correctly, he should continue to reach correctly provided that the experimenter does not change the place of hiding or any other variable.

That is, each time the infant is correct, if that trial is repeated unchanged, the infant should again be correct; he or she should again reach to the same place.

This test provides an important baseline from which to view the infant's performance when the site of hiding is changed. It is a fundamental premise of those who write of the $A\bar{B}$ error that this is not simply random behavior; it has a consistency to it. Errors are supposed to be confined to reversal trials (trials where the site of hiding is reversed) and to unbroken runs of errors following those trials. Errors are not supposed to be sprinkled randomly throughout a session; for then an error would be expected just by chance on one or two reversal trials. If an infant cannot duplicate a correct reach when called upon to do so, we consider his or her performance *worse* than what we are prepared to call the $A\bar{B}$ error.

If, in any given session, an infant made more than one error on all repeat trials following correct reaches, this alone was enough to cause us to refrain from labelling the behavior on that day as an $A\bar{B}$ error.[9]

2) Over the course of the experimental session, the infant must reach to the previous hiding place on at least one reversal trial (on at least one trial where the place of hiding is reversed).

Each session included a minimum of three, and a maximum of five, reversals. Thus, this criterion taken alone would have provided a weaker test of whether the $A\bar{B}$ error occurred than that used by other investigators. They give the infant only one trial, only one opportunity to err. We give the infant 3-5 opportunities, but still require only one error. In order to tighten this criterion, we further required that the infant's performance also pass at least one of the following two tests:

3) When an error does occur on a reversal trial, the same error should be repeated on the next trial, provided that all experimental procedures remain unchanged; or

4) Over the course of the experimental session, the infant must err on at least *two* reversal trials.

Criteria 3 and 4 are minimal tests of whether or not an error on a reversal trial is simply a chance occurrence. If an infant is performing at such a high level that he never errs, or errs on only one trial where the site of hiding is reversed and corrects that error on the very next trial, we consider this performance *too accurate* to say that an $A\bar{B}$ error has occurred. Note that we are still willing to say that an infant committed the $A\bar{B}$ error even if that child did not err on the *first* reversal trial encountered (as long as he errs later), but, by the same token, if this is the *only* trial on which the child errs, we are *not* willing to say the $A\bar{B}$ error has occurred, even though other investigators would.

We have purposely constructed our test of the $A\bar{B}$ error (criteria 1-4) as a wide net that would characterize an infant's performance as constituting the $A\bar{B}$ error even if the infant errs on but two reversal trials, or repeatedly following a single reversal, against a backdrop of otherwise accurate reaching. We believe this best reflects standard descriptions of the $A\bar{B}$ error.

THE PATTERN OF INFANTS' RESPONSES IN $A\bar{B}$

Most of the results to be reported here concern why and when the $A\bar{B}$ error will appear. The next chapter outlines hypotheses about the causes of the $A\bar{B}$ error and presents predictions derived from these hypotheses. Before considering the causes of the $A\bar{B}$ error, however, we would like to present our findings about what the $A\bar{B}$ consists of.

Table 6 illustrates infants' behavior in actual sessions. The top row in the diagram provides hardy examples of the $A\bar{B}$ error; the bottom row illustrates the most attenuated forms of the error which would still pass our test.

If a child's performance within a session was not always as unambiguous as one might have hoped, performance across sessions provides a picture which could hardly be more clear. Across sessions we found:

1) Once children are correct in the $A\bar{B}$ situation, they continue reaching correctly until experimental conditions change.

Across all trials, sessions, and children, when a baby has reached correctly on the immediately previous trial and the present trial duplicates that prior trial in all experimental procedures, the percentage of correct reaches is 79%. That is, on only 21% of all identically repeated trials following a correct reach did any baby ever err. (Of a total of 457 trials, infants were correct on 361 of them.) Comparing this percentage against a baseline expectation of a 50% correct response rate, yields a t value of 13.78, significant at .0001. This is a far cry from random reaching; given the chance to try once more following a

Table 6 : SCHEMATIC ILLUSTRATION OF ACTUAL A$\overline{B}$ SESSIONS

Side Hide = where toy is hidden; Other Well = other well used, i.e., covered, on that trial.
When side hide and other well are the same as on the previous trial, these columns are left blank.
R = right well; C = center well; L = left well
✓ = correct reach. Trials A & B are sight trials; infant is not permitted to reach.
REL = trial was a test of relative versus absolute position, not a reversal trial.
DIF = different covers used on this trial.

Examples of Robust A$\overline{B}$ Errors

MARIAMA, VISIT 4

Trial #	Side Hide	Other Well	Reach	Notes
A	C	R		
B				
1	R	C	errs	
2			✓	
3	C	R	errs	
4			errs	
5			errs	
6			errs	
7			errs	
8			errs	
9			✓	
10	R	C	errs	
11			errs	
12			errs	
13			errs	
14			errs	DIF
15			errs	
16			✓	
17			✓	

MICHAEL, VISIT 12

Trial #	Side Hide	Other Well	Reach	Notes
A	R	C		
B				
1	C	R	errs	
2			errs	
3			✓	
4			✓	
5	L	C	errs	REL
6			errs	
7			errs	
8			✓	
9	C	L	errs	
10			✓	
11			✓	
12	L	C	errs	
13			✓	

TODD, VISIT 9

Trial #	Side Hide	Other Well	Reach	Notes
A	L	C		
B				
1	C	L	errs	
2			errs	
3			errs	
4			✓	
5			✓	
6			✓	
7	L	C	errs	
8			errs	
9			errs	
10			✓	
11	C	L	errs	
12			errs	
13			errs	
14			✓	
15			✓	

Examples of Weaker A$\overline{B}$ Errors

JULIA, VISIT 11

Trial #	Side Hide	Other Well	Reach	Notes
A	L	C		
B				
1	C	L	errs	
2			✓	
3			✓	
4	R	C	errs	REL
5			✓	
6			✓	
7	C	R	✓	
8			✓	
9	R	C	errs	
10			✓	
11			✓	

Never repeats an error.
% correct on repeat trial following an error = 100%.

TODD, VISIT 10

Trial #	Side Hide	Other Well	Reach	Notes
A	R	C		
B				
1	C	R	✓	
2			✓	
3	R	C	errs	
4			errs	
5	C	L	✓	REL
6			✓	
7	L	C	errs	
8			errs	
9			✓	DIF
10			✓	
11	C	L	✓	
12			✓	

Only wrong on 2 out of 4 reversals.

KATE, VISIT 10

Trial #	Side Hide	Other Well	Reach	Notes
A	C	L		
B				
1	L	C	✓	
2			errs	
3			errs	
4			errs	
5			✓	DIF
6			✓	
7	C	L	errs	
8			errs	
9			errs	
10			✓	
11	L	C	errs	
12			errs	
13			errs	
14			✓	
15	C	L	✓	
16			✓	

On trial 2, errs after having reached correctly.

successful trial, infants will succeed again. Butterworth (1977) also reports that when infants reached correctly and the toy was hidden in the same well, they continued to reach correctly over several trials.

The data for each subject in the longitudinal study are presented in Table 7. Performance on repeat trials ranged only from 64% to 100% correct. Three infants never erred during <u>any</u> visit once they had reached correctly.[10]

Table 8 presents the results by subject for only the repeat trial following the <u>first</u> correct reach in any given chain; Table 9 does the same for the repeat trials following <u>two</u> correct reaches in a row.[11] We gave infants up to two repeat trials following a successful trial. (Note, repeat trial #1 is the second trial in a row, and repeat trial #2 is the third trial in a row.) Table 8 answers the question, "What happened on only the first of these repeat trials?" Table 9 answers the question, "What happened on the second of these repeat trials?" That is, can one trust a single correct response as a relatively reliable indicator that the baby knows where the toy is (if tested again, would the infant reach correctly again?), or should we rely only on a minimum of two successive correct reaches (is the percent correct on repeat trial #2 greater than the percent correct on repeat trial #1)?

Percent correct is almost the same after one successful reach as it is after two. The number of correct reaches following the first correct reach in any chain is 79% and the number of correct reaches following any string of <u>two</u> correct reaches is 81% (provided always that all trials being compared are equivalent in all experimental procedures).

Table 7

PERCENTAGE OF CORRECT REACHES ON REPEAT TRIALS FOLLOWING ONE OR MORE CORRECT REACHES

	# Correct	# Total	% Correct
RUSTY	12	18	67
NINA	12	16	75
TODD	17	17	100
SARAH	20	22	92
JANE	16	20	79
TYLER	17	19	89
JULIA	15	15	100
BRIAN	16	25	64
MICHAEL	20	26	77
JACK	10	14	71
LYNDSEY	13	21	62
JAMIE	16	20	80
RACHEL	16	18	89
RYAN	13	18	72
JAMES	16	20	80
ERIN	18	22	82
MARIAMA	10	15	67
KATE	14	22	64
GRAHAM	12	12	100
BLAIR	11	13	85
CHRISSY	14	17	82
ISABEL	16	20	80
BOBBY	12	15	80
JENNINE	14	18	77
EMILY	11	14	79
Total	361	457	

$$\frac{361}{457} = 79\%$$

Average of the Percentages = 80%

Table 8

PERCENTAGE OF CORRECT REACHES ON THE FIRST REPEAT TRIAL FOLLOWING A CORRECT REACH

	# Correct	# Total	% Correct
Rusty	10	16	63
Nina	11	15	73
Todd	16	16	100
Sarah	19	21	90
Jane	15	19	79
Tyler	14	16	88
Julia	15	15	100
Brian	15	24	63
Michael	20	24	83
Jack	9	13	69
Lyndsey	14	18	78
Jamie	14	18	78
Rachel	15	17	88
Ryan	12	16	75
James	15	19	79
Erin	15	19	79
Mariama	9	14	64
Kate	14	20	70
Graham	12	12	100
Blair	10	13	77
Chrissy	11	14	79
Isabel	13	17	76
Bobby	10	13	77
Jennine	13	16	81
Emily	9	12	75
	330	417	$79\% = \frac{330}{417}$

Average of Percentages = 79%

Table 9

PERCENTAGE OF CORRECT REACHES ON REPEAT TRIALS FOLLOWING TWO CORRECT REACHES

	# Correct	# Total	% Correct
Rusty	2	2	100
Nina	1	1	100
Todd	1	1	100
Sarah	0	1	0
Jane	1	1	100
Tyler	3	3	100
Julia	0	0	---
Brian	1	1	100
Michael	0	2	0
Jack	1	1	100
Lyndsey	2	3	67
Jamie	2	2	100
Rachel	1	1	100
Ryan	1	2	50
James	1	1	100
Erin	3	3	100
Mariama	0	1	0
Kate	0	2	0
Graham	0	0	---
Blair	1	1	100
Chrissy	3	3	100
Isabel	3	3	100
Bobby	2	2	100
Jennine	1	2	50
Emily	2	2	100
	32	40	$80\% = \frac{32}{40}$

Average of Percentages = 71%

2) Infants, who have demonstrated their ability to find a hidden toy, are *unable* to find the toy when the place of hiding is changed.

What makes the A$\bar{B}$ error so extraordinary is that, on the face of it, reversal trials should be no more difficult than repeat trials. In both cases, the baby watches as a toy is hidden, the same length of delay is imposed, and the baby can then reach for the toy. We have just seen that on trials following correct reaches, where nothing is changed, the rate of correct response is 79%; yet, on trials following correct reaches, where only site of hiding is changed, the rate of correct response is 34%. A drop of 45% and all we did was change where we put the toy!

Table 10 presents the data for all longitudinal subjects across all testing sessions, looking exclusively at trials which met the following criteria: 1) on previous trial, infant found toy; 2) on the trial in question, the same two wells are used but toy is hidden in the other well; and 3) all other experimental procedures are exactly the same in the two trials.[12]

The difference between the results in Table 7 and the results in Table 10 (the difference between percent correct following a correct reach on a *repeat* trial and the percent correct following a correct reach on a *reversal* trial) yields a t value of 12.59, significant at less than .0001.[13]

Well over 95% of the errors on reversal trials consist of reaching to "A," i.e., to the other covered well, the well at which the toy was hidden on the previous trial. Other classes of errors, in decreasing order of occurrence, are: a reach to both covered wells simultaneously, no reach whatsoever, and a reach to the "third," uncovered well. For

Table 10

PERCENTAGE OF CORRECT REACHES ON REVERSAL TRIALS FOLLOWING ONE OR MORE CORRECT REACHES

	# Correct	# Total	% Correct
RUSTY	6	18	33
NINA	9	20	45
TODD	8	17	47
SARAH	8	15	53
JANE	4	20	20
TYLER	7	19	37
JULIA	6	19	32
BRIAN	4	15	27
MICHAEL	4	20	20
JACK	10	18	56
LYNDSEY	2	15	13
JAMIE	7	21	33
RACHEL	2	21	10
RYAN	8	18	44
JAMES	2	16	13
ERIN	2	18	11
MARIAMA	10	18	56
KATE	5	14	36
GRAHAM	13	18	72
BLAIR	4	14	29
CHRISSY	6	17	35
ISABEL	12	20	60
BOBBY	3	17	18
JENNINE	6	20	30
EMILY	4	14	29
Total	152	442	

$$\frac{152}{442} = 34\%$$

Average of the Percentages = 34%

some reason, a change in the site of hiding complicates things enormously for infants. The prior experience of having previously found the toy at a different place than it is now hidden has a major effect on performance. Most often this disruptive effect appears in the form of the infant reaching back to the old hiding place. On other, more rare occasions, it takes the form of a reach with one hand to the new hiding place as the other hand reaches to the old, refusal to try at all, or a reach to someplace else altogether.

The results of Butterworth's (1977) study of $A\bar{B}$ provide strong confirmation of this point. Infants in that study were randomly assigned to one of three conditions: 1) toy covered by an opaque cover (the standard procedure in $A\bar{B}$ experiments) = covered and hidden; 2) toy covered by a transparent cover = covered and visible; and 3) toy both uncovered and visible. Not surprisingly, Butterworth found that performance in condition 1 was worse than in condition 2 which in turn was worse than in condition 3 (although, interestingly, the number of infants erring on the reversal trial in condition 2 did not differ significantly from either conditions 1 or 3). Of importance to the present discussion, however, is that performance on the reversal trial was significantly worse *in all three conditions* than it had been on trials to the first "hiding" place. That is, even when the toy is visible, indeed, even when it is not covered, there is something about putting a toy in a new place which disrupts the ability of babies to reach directly to where the toy is.[14]

3) Infants err not simply on a reversal trial but on the following trials. If experimental conditions are repeated unchanged, infants continue to err again and again.

Table 11 presents the results for each child, across all trials and sessions, where the baby erred on the previous trial and the present trial duplicated the previous trial. The percent correct is 34%. That is, if incorrect on trial n, given the opportunity to try again on trial n+1, infants repeated their incorrect reach two thirds of the time. This profile of responses differs significantly from chance, where one might expect a rate of correct reaches of approximately 50% (t= 5.65, p= .0001). The difference between the results in Table 7 and the results in Table 11 (the difference between percent correct on repeat trials following a correct reach and the percent correct on repeat trials following an error) is significant at less than .0001 (t= 14.20). Other investigators, too, have found that infants who err on the first reversal trial continue to do so over the next several trials (Gratch and Landers, 1971; Evans, 1973; Butterworth, 1975; 1977; Butterworth and Jarrett, 1982).

This suggests both that infants' errors are reliable, replicable events, not chance occurrences, and that this behavior is resistant to correction. One might expect that after a subject has made a mistake and the experimenter shows him where the toy was, the subject might correct him or herself on the next trial. Not here, however; the toy is again hidden at B, and the subject again searches at A.

If an infant errs when the experimenter hides the toy in a new place, will the infant repeat that error on the next trial? The answer is yes. On 69% of the trials, where the toy was hidden at the new hid-

Table 11

PERCENTAGE OF CORRECT REACHES ON REPEAT TRIALS FOLLOWING ONE OR MORE ERRORS

	# Correct	# Total	% Correct
RUSTY	7	35	20
NINA	15	41	37
TODD	12	36	33
SARAH	9	33	27
JANE	9	31	26
TYLER	14	42	33
JULIA	13	34	38
BRIAN	18	34	53
MICHAEL	16	32	50
JACK	6	21	29
LYNDSEY	13	36	36
JAMIE	3	23	13
RACHEL	10	50	20
RYAN	18	40	45
JAMES	17	42	40
ERIN	9	35	26
MARIAMA	10	33	30
KATE	11	42	26
GRAHAM	15	20	75
BLAIR	9	21	43
CHRISSY	10	38	26
ISABEL	9	30	30
BOBBY	12	40	30
JENNINE	13	23	57
EMILY	4	20	20
Total	281	832	

$$\frac{281}{832} = 34\%$$

Average of the Percentages = 35%

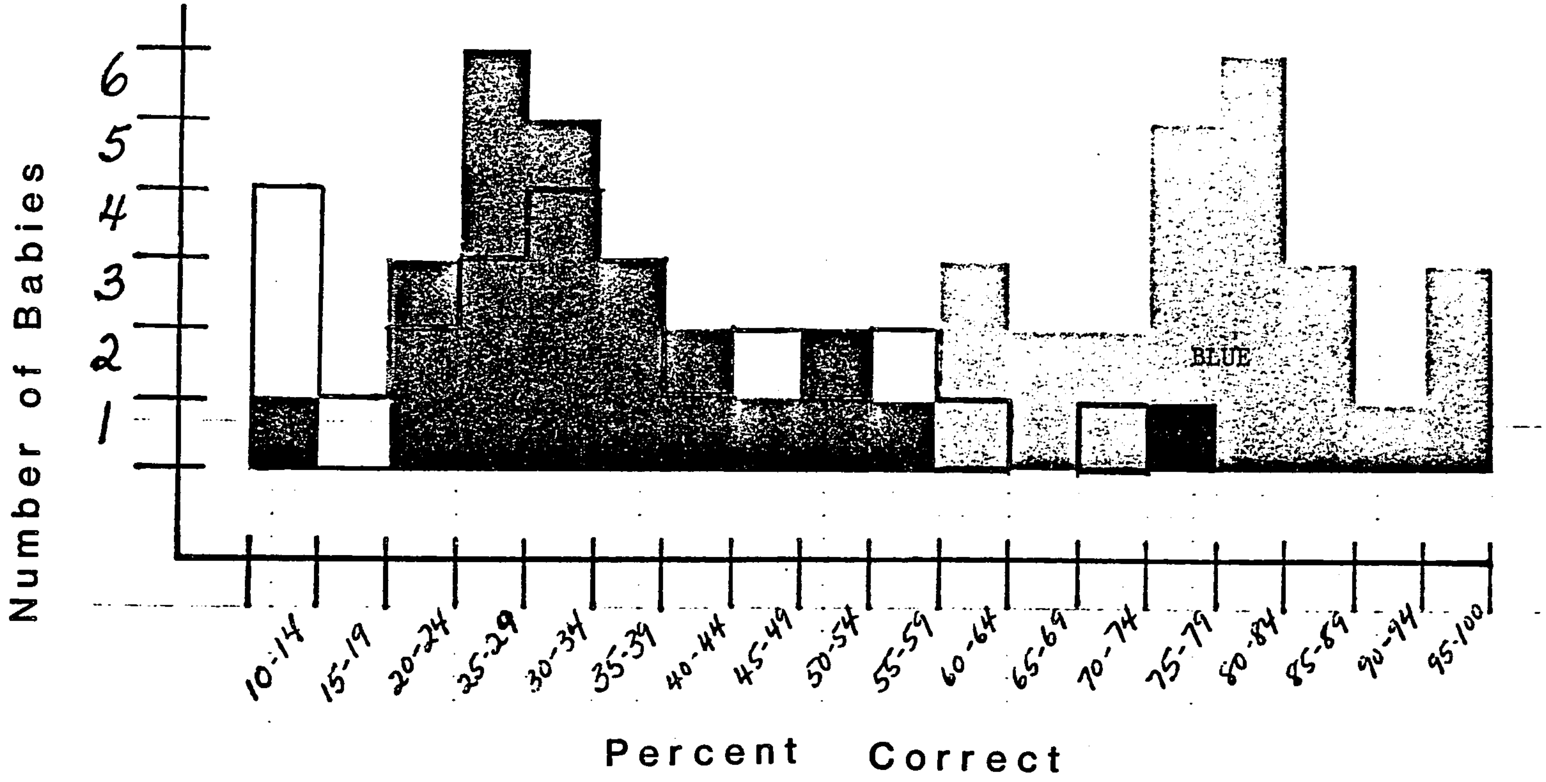
ing place for the *second* time, and nothing is changed from the way the first trial at this hiding place was conducted, the infant errs again. If an infant errs once, will he err again? The answer is yes. If an infant has reached incorrectly, and you present the exact same trial again, 64% of the time the infant will reach incorrectly again. Will the infant do this yet again if you give him a third trial at this new hiding place? The answer, yet again, is yes. On 72% of the second repeat trials following any error the infant continues to reach to the wrong well.

Thus, a pattern is discernible in the errors infants make in the $A\bar{B}$ Experiment. Once they reach to the *correct* well, they keep reaching there, or at least over 457 trials we observed them to do so 79% of the time. Once they make a *mistake*, they continue to make this mistake (over 832 trials they did so 66% of the time).

Figure 3 displays the distributions of rate of correct response on: any repeat trial following a correct reach, any reversal trial following a correct reach, and any repeat trial following an error. Note that there is almost no overlap between the first distribution (the one in blue) and the other two. These three distributions could not have been produced if the infants were responding randomly.

One little boy, Graham, performed consistently better than the other babies. Only Graham showed a rate of correct responses following an error which overlapped with the distribution of those rates following a correct reach. Whereas the median percent correct following an error was 34%, Graham's percent correct was 75%; while the median percent correct on a reversal trial was again 34%, Graham's percent correct here was 72%. However, even for Graham there was a substantial difference

Figure 3: RESPONSE PATTERN CHARACTERIZING THE A$\bar{B}$ ERROR



BLACK = REVERSAL TRIALS FOLLOWING CORRECT REACHES
RED = REPEAT TRIALS FOLLOWING ERRORS
BLUE = REPEAT TRIALS FOLLOWING CORRECT REACHES

between these percentages and his percent correct following a correct reach, which was 100%. (Once correct, he never again erred during all the months of testing, as long as conditions were held constant.) Thus, Graham is an exception, who nevertheless conforms to the general rule. His errors were confined exclusively to reversal trials and to trials following errors.

HYPOTHESES AND PREDICTIONS
ABOUT WHY THIS PATTERN SHOULD BE FOUND

Why do babies make the A$\bar{B}$ error? What accounts for the particular form which this error takes? Under what conditions will it appear?

One popular hypothesis is that the problem here is fragile short-term memory. The infant errs because he has forgotten where the toy was hidden (Harris, 1973, 1974, 1975; Kagan, 1974; Schaffer, 1974; Fox, et al., 1979).

Memory alone cannot be the only cause of the A$\bar{B}$ error, however, because the reaching of infants in the A$\bar{B}$ situation is not random. If a child *forgot* where the toy was hidden, he should search randomly at A or B. Instead, the errors of infants are lawful: 1) Infants do not err on repeat trials following correct reaches. Here they seem to be able to remember, yet the length of delay used is exactly the same as on trials where the same infants err. 2) Errors are confined to very specific kinds of trials: reversal trials, and repeat trials following errors. 3) Infants do not err in random ways, but by doing something very specific: by returning to where the toy had been hidden prior to the reversal. If the only factor controlling an infant's reaching is memory, why should the infant consistently return to the toy's former hiding place? In short, a memory hypothesis predicts random reaching and we find consistency.

Moreover, a memory hypothesis predicts that delay is the crucial variable. It does not predict differential performance across trials if delay is unchanged. However, at a constant delay, (a) infants can reliably find a toy when it is hidden in the same place after a correct reach, but (b) they err when the toy is hidden in a different place after a correct reach. The hypothesis that the problem in the $A\bar{B}$ situation is a simple deficit in short-term memory seems inadequate.

Yet, those who put forward a memory explanation did so for good reason. Results from several studies have firmly established that infants rarely err if their memory is not taxed. The time interval between when a toy is hidden and when an infant is allowed to reach can determine whether or not the $A\bar{B}$ error will occur: a brief delay typically yields no error, while a longer delay will produce the $A\bar{B}$ error. The 10 month olds in Harris's (1973) study, for example, did not err in the no delay condition, but did so when a 5 second delay was introduced. Gratch et al.'s (1974) 9 month old subjects were able to reach accurately with a 0 second delay, but erred with delays even as brief as 1 second. Fox et al. (1979) showed that infants of 7 months will reach accurately at delays of 1 second but err at delays of 3 seconds, while infants of 8 months will succeed at delays of 3 seconds, yet err at delays of 7 seconds. There may be other ways of making the $A\bar{B}$ task more difficult for infants, but certainly increasing the memory demand appears to be one such way. If memory is not the whole answer, it would seem to be part of the answer.

Any interpretation that has no memory component would appear to be just as mistaken as one which relies solely on memory, for how, then, can one account for the fact that increasing the delay interval by but a few seconds will cause infants to err when they otherwise would not? Therefore, just as we rejected the short-term memory hypothesis, we reject two other explanations which have been suggested for the A$\bar{B}$ error which ignore memory: spatial ability -- the frame of reference which locates objects relative to oneself is not yet coordinated in infants with the frame of reference which locates objects relative to other objects (Butterworth, 1975, 1976, 1977; Acredolo, 1978); and response inhibition -- an inability of infants to check their tendency to respond impulsively (Schaffer, et al., 1972; Schaffer, 1974; Bremner and Bryant, 1977). If infants are having trouble locating objects with respect to their left and their right, and perhaps in relating that to spatial position defined by external landmarks, then they should have trouble with the A$\bar{B}$ experiment whether they must wait before reaching or not. Similarly, the response inhibition hypothesis cannot explain why infants can stop themselves from repeating their previously successful response when there is no delay, but cannot do so when there is a delay.

If a deficit in short-term memory, spatial ability, or the ability to check or change one's behavior does not underlie the A$\bar{B}$ error, what does? In the present study, we investigated four possible hypotheses. The experimental conditions were designed so that each hypothesis yielded a unique pattern of predictions. The four hypotheses were:

1) SPATIAL MEMORY.

This combines the memory and the spatial ability hypotheses. It suggests that infants have a specific memory deficit. They will have difficulty remembering where something occurred if the possible places are distinguished only by spatial location. Presumably, if the places look different, e.g., are of different color, there will be no problem.

2) MEMORY + ABILITY TO CHECK OR CHANGE ONE'S BEHAVIOR.

This combines the memory and response inhibition hypotheses. It suggests that when infants are rewarded for reaching correctly, the tendency to repeat this response is strengthened. When infants are sure that the toy is elsewhere they can override this response tendency, but when memory is "stretched" the infant becomes unable to inhibit the behavioral predisposition.

3) TEMPORAL MEMORY.

This suggests that infants have a specific memory deficit in recalling the <u>order</u> in which things have happened. Whereas spatial memory is the memory of "where," temporal memory is the memory of "when." More specifically, this hypothesis predicts that older information will be recalled more easily than newer information.

4) MEMORY + ABILITY TO RELATE TWO THINGS TO ONE ANOTHER.

This hypothesis suggests that infants have difficulty integrating two pieces of information. Accordingly, infants should perform accurately at the A$\bar{B}$ task if any of three conditions is true: (1) they have been given only one item of information (e.g., site of hiding has always been at one particular place); (2) they can rely on a simple, one part rule, such as "Go to the blue cover"; or (3) their memory is not taxed. Whenever no single piece of information can accurately guide reaching across all trials and memory is strained, this hypothesis predicts infants will make mistakes. Further, they should do so by attending to one datum, or one simple rule, and relying on that consistently, essentially ignoring the greater complexity present.

The pattern of predictions for the different hypotheses is illustrated on the next page.

When covers of different colors are used (Condition 1 in Table 12) one well is covered by a blue cotton cloth and the other well by a white terry cloth. The spatial memory hypothesis predicts that different covers will improve performance. it predicts that babies are not able to tag things with spatial location in their memories, but a tag of blue or white should help them remember where the toy has been hidden.

"Landmark" (Condition 2 in Table 12) refers to the use of distinctive covers with the toy always hidden under the blue cover. Here, the blue cover serves as a sign indicating where the toy is located. Instead of needing to remember the toy's location on each trial, the baby need only remember, "Go to blue."

The hypothesis of memory + ability to relate two things to one another predicts that babies cannot remember two part rules ("If toy is hidden under white, search under white. If toy is hidden under blue, search under blue.") But it predicts that babies can remember simple rules, such as, "Go to blue." Thus, this hypothesis predicts that infants will still err when different covers are used, but that they will reach correctly when one of the covers is reliably associated with the toy, as in the landmark condition.

Similarly, "left" and "right" are relational concepts, the relative left or right position of a well is established by considering its location in relation to the other well being used. Absolute position, on the other hand, is independent of any other well. Therefore, the hypothesis of memory + ability to relate two things predicts that infants will reach on the basis of absolute, not relative, position (Condition 3 in Table 12).

Table 12

PREDICTIONS FOR THE $A\bar{B}$ EXPERIMENT

	Hypotheses			
Conditions	Spatial Memory	Memory + Ability to Check or Change One's Behavior	Temporal Memory	Memory + Ability to Relate Two Things to One Another
Different Covers	✓	X	X	X
Landmark	✓	✓	✓	✓
Relative vs. Absolute Position	?	?	?	Absolute
Sight Trials	X	✓	X	X
Reversal Trials: Infants will reach. . .	randomly	consistently to A	consistently to A	consistently either to A or to B

✓ = Infants will reach to the correct well.

X = Infants will err.

Absolute = Infants will reach to the same Absolute Position.

A = Toy's previous hiding place. B = Toy's current hiding place.

For the memory + ability to check or change one's behavior hypothesis, the crucial variables are delay length and whether or not the baby has reached successfully to the first hiding place. If memory is not strained, or the baby has not established a behavioral tendency to reach to the old hiding place, then this hypothesis predicts that no errors will be found. Following this line of reasoning, if the baby's only prior experience before a reversal trial consists of "sight trials," then the baby should be able to reach correctly on the reversal trial. (On sight trials (Condition 4 in Table 12), the baby does not reach. A sight trial is like any other trial <u>except</u> that after the delay period the parent continues to hold the baby's hands while the experimenter reaches to the correct well and retrieves the toy. The child watches, but does not act.) If it is crucial that the baby actually reach and be reinforced for doing so, then sight trials, where no action is permitted, should not disrupt later performance.

Note that although distinctiveness of covers is an irrelevant variable for the hypothesis of memory + ability to check or change one's behavior, a landmark is not. The tendency to go to a blue cover can be built up over trials, just as a tendency to go to a certain location can be thus established. When only one of the covers is blue, and that cover is always over the toy, then the baby's established tendency will always lead him or her to the toy. There is no problem; there is nothing to inhibit; the baby's predisposition will lead to a correct reach. Therefore, this hypothesis predicts that performance will improve when a blue cover is used as a landmark because the inability to check or change behavior will not interfere with performance.

The temporal memory hypothesis contends that babies have a problem remembering which trial happened last, and when confused in this way the older memory wins. Thus, as long as a baby has only seen the toy hidden at one place, he or she has no trouble finding it. But when the toy is later hidden at another place, this hypothesis suggests that the baby cannot remember where the toy was hidden most recently. In this situation, the memory trace that will govern their behavior is the one that was formed first. Sight trials should have as much effect as regular trials; the infant's attention is drawn to a particular well even on sight trials; a memory is formed. Different covers should have no effect; babies are not having trouble telling the wells apart, so making the wells even more distinguishable from one another won't help. Babies should succeed when a blue cover is used as a landmark, however, if they never see the toy hidden under the white cover. Here they do not have to remember whether the toy was hidden under blue or under white most recently; white is not an option, the toy has never been hidden there.

The temporal memory and memory + ability to check or change one's behavior hypotheses can best account for the character of the A$\bar{B}$ error as noted in the previous chapter. Only they predict that errors will take the form of returning to the old hiding place when site of hiding is changed and that this will persist over trials. Temporal memory predicts this because it assumes that memories formed earlier will win over memories formed more recently. Memory + ability to check or change one's behavior predicts this because it assumes that babies have trouble altering their behavior. When there is new information concerning the toy's location, babies will have difficulty stopping themselves from acting according to the old information.

The hypothesis of memory + ability to relate two things to one another predicts that infants will rely on only one piece of information, but it says nothing about which piece. Thus, when the infant has seen the toy hidden at both an old place and a new place, this hypothesis does not specify which piece of information the child will go by. Note that it is consistent with this hypothesis that an infant almost invariably reaches to the old hiding place (i.e., seems to use only that piece of information), but the hypothesis would not have predicted this anymore than it would have predicted consistent use of only the new piece of information.

The spatial memory hypothesis does not predict the consistency we have found in the A$\bar{B}$ situation. It predicts random reaching. It suggests that babies cannot remember spatial location. If the only information available to use in encoding where a toy has been hidden is spatial position, then infants should not be able to remember where the toy has gone and should reach randomly.

Infants in the cross-sectional sample could not be tested on all four conditions outlined here. They were not administered sight trials then he was tested in the A$\bar{B}$ experiment proper. (trials where the infant is not permitted to reach). The main) were not administered to the subjects tested only once. The main reason for this is that we did not know the proper length of delay to use with each of these children. At any given age, there is considerable variability among infants in how long a delay will produce the A$\bar{B}$ error. With the babies studied longitudinally, we had earlier sessions with the same child to guide us in choosing a delay. But with the infants who came into the laboratory only once, we had no such information. We adopted the strategy of beginning with a delay which we thought would probably be too easy for the child. If this proved to be the case, we then increased the delay until the infant began to err.[15] In order to administer sight trials, however, one must know what delay to use at the outset of a session. Sight trials are the very first trials given during a testing session, and they require that the infant has had no prior experience reaching at the wells. The sight trials manipulation only makes sense if one has a good idea of the appropriate length of delay before testing begins. Otherwise, accurate performance could be due to too brief a delay, and errors to too long a delay, rather than to the effect of the sight trials, and sight trials cannot be re-tested later in a session. We, therefore, did not think it possible to administer the sight trials test to the subjects in the cross-sectional sample.

We also chose not to test these children on relative versus absolute position. There is nothing intrinsic to this test which would have made it impossible to give to the babies we saw only once, but so much time was required to determine the proper delay to use with these children that we were left with too few trials to test all of our conditions. We decided to eliminate the test of relative versus absolute position.

Thus, for the subjects in our cross-sectional sample we tried to determine the length of delay which would produce the $A\bar{B}$ error, the character of this error, the effect of different covers and of a landmark, and, as we will discuss later, the effect of hiding food rather than a toy.

Most of the results to be reported pertain to the infants studied longitudinally. When we report results from the infants in the cross-sectional sample, we specify this. Any time we discuss our subjects without specifying which group we are talking about, we are always referring to the infants followed longitudinally.

DIFFERENT COVERS AND LANDMARK

In the standard $A\bar{B}$ procedure, the hiding places look identical, differing only in position. If a white cover is placed over one well and a blue cover over the other, so that the hiding places now differ in color, will this additional cue enable babies to reach correctly? That is, could it be that babies have trouble remembering whether a toy is in the left or right well, but are able to remember that a toy is under a blue or white cover? This is the question addressed in the _different covers_ conditions.

Suppose, on the other hand, that babies cannot remember the color of the toy's hiding place any more than they can remember its spatial position. If this is true, can we eliminate errors by always hiding the toy under a cover of a given color, regardless of which well that cover is over? Suppose, for example, the toy were always hidden under a blue cover. If infants can learn to associate the blue cover with the toy, then they would not have to remember where the toy was hidden on any particular trial; the blue "landmark" would point the way to the toy. The _landmark_ conditions address the question, "Will the performance of infants improve when a reliable color cue is present?" (Note that even if the toy is reliably associated with a certain color, the baby must still learn and remember that association. A memory demand is thus present; but it is of a different kind. Note also that we are using the word "landmark" to mean a visible sign, a sort of arrow, pointing to the toy's location. Once one has learned the meaning of a sign, one does not need to remember where the toy is when the sign is present; one has simply to look at the sign.)

To answer these two theoretical questions, we investigated five more precise questions:

1) If an infant who has just reached to the wrong well, and we repeat that trial, but now put a blue cover over the correct well and a white cover over the wrong well, will the infant still err?

(This manipulation is called ERROR WITH SAME COVERS, REPEAT WITH BLUE OVER TOY.)

If the infant does not err here, there are two possible explanations: 1) using a blue cover over the toy and a white cover over the other well helped; 2) the baby would have reached correctly anyway (the manipulation was irrelevant). We performed three tests to discriminate between these explanations.

The first test compared the infant's performance here with comparable trials when no manipulation was introduced (when same covers continued to be used). If after 1 error, or x number of errors, infants do not typically correct themselves, but when different covers are used they do correct themselves after the same number of errors, then it is unlikely that the use of different covers was irrelevant.

Another way to determine which explanation is correct is to present another trial after manipulation #1, this time reverting back to identical covers. The sequence of trials would be: trial 1 -- identical covers; trial 2 -- different covers; trial 3 -- identical covers, with all other aspects of trials 1-3 remaining constant. Remember that the sequence of performance we wish to understand is trial 1-failure, trial 2-success. Is this success due to chance or to the single variable we changed? Our second test focused on trial 3. If infants err here, after having just succeeded with different covers, then it is likely that the different covers were responsible for their success. For when different covers are removed, the infants are no longer able to reach correctly. This test formed the second question we investigated:

2) Will an infant who has just reached correctly with a blue cover over the toy and a white cover over the other well still reach correctly if this trial is repeated with two identical blue covers?

(This manipulation is called CORRECT WITH BLUE OVER TOY, REPEAT WITH SAME COVERS.)

Our third test of the utility of different covers was to present the sequence of trials 1-3 once again, but now with different covers on trial 3. That is, instead of reverting back to identical covers, we repeated trial 2 unchanged. If a blue cover is still placed over the correct well and a white cover over the empty well, will infants be able to repeat their successful performance? If they are able to do so, this would make it less likely that their correct reach on trial 2, the first different covers trial, was an accident, and it would suggest that infants are not merely alternating their reaches between wells. (Note that since question 1 looks for a correct reach with different covers following an error with identical covers, and question 2 looks for an error with identical covers following a correct reach with different covers, if we found this, one might argue that it was attributable to a tendency to alternate reaches.) Thus question 3 asks:

3) If an infant has just reached correctly with a blue cover over the toy and a white cover over the other well, if this trial is repeated unchanged, will the infant still reach correctly?

(This manipulation is called CORRECT WITH BLUE OVER TOY, REPEAT WITH

BLUE OVER TOY.)

If the answers to questions 1, 2, and 3 show that performance improves when a blue cover is placed over the correct well and a white cover over the other, there are still two possible explanations: (1) Babies are able to use different covers to discriminate between the two wells and to keep track of where the toy has gone. They can remember whether the experimenter hid the toy under white or blue. (2) After many trials with two blue covers, babies have learned to associate the toy with a blue cover. They do not remember where the toy has gone, but when only one of the covers is blue, they use that cover as a landmark signalling the well to which they should reach.

In order to discriminate between these two explanation we need trials where the blue cover is <u>not</u> over the toy. Will babies still reach to the toy, as explanation 1 would predict, or will they still reach to the blue cover, as explanation 2 would predict? Questions 4 and 5 present the conditions under which we investigated this:

4) If an infant has just reached correctly when same covers were used, if this trial is repeated, except the white cover is over the correct well and a blue cover is over the wrong well, will the infant still reach correctly?

(This manipulation is called CORRECT WITH SAME COVERS, REPEAT WITH WHITE OVER TOY.)

5) If an infant has just reached to the empty well when same covers were used, if this trial is repeated, except the white cover is over the toy and a blue cover is over the other well, will the infant still err?

(This manipulation is called ERROR WITH SAME COVERS, REPEAT WITH WHITE OVER TOY.)

The five questions used to test the effects of Different Covers and

Landmark, and the chain of reasoning which generated them, are summarized in Figure 4.

Manipulation #1: ERROR WITH SAME COVERS,
REPEAT WITH BLUE OVER TOY

Following trials on which they erred, all infants were tested with a blue cover over the toy and a white cover over the other well. All other conditions were held constant. Each child received an average of 15 such trials, with no more than 4 administered within a single session.

If one did not know anything about these children, one would have to compare their performance here with a baseline prediction of a 50% correct response rate. However, over the course of the study, there were 832 trials on which the infants erred and were then presented with the same trial again. These trials provide a more accurate baseline against which to compare performance during this manipulation. We found the rate of correct response over the 832 trials was 34%. About two thirds of the time after an infant had erred and nothing was changed the infant erred again. (Table 11 presented these results.)

In manipulation #1, where an infant had erred with identical covers, and the trial is repeated with a single change (different covers are used, blue over toy), the frequency of correct reaching is 58%. (See Table 13.) Comparison of 58% with the baseline of 34% yields a t value of 5.75, significant at .0001.[16] (Fifty-eight percent was arrived at by dividing the total number of trials by the total number of correct reaches. Some children received more trials than others, however, and this procedure gives more weight to their performance than to that of

Diagram 4: THE TESTS OF DIFFERENT COVERS AND LANDMARK

1) ERROR WITH SAME COVERS, REPEAT WITH BLUE OVER TOY

If infants are correct with blue over toy, the possible explanations are:

a

The use of different covers (blue over toy) enabled the infants to reach correctly.

b

The infants would have reached correctly anyway; the manipulation was irrelevant.

c

The infants reached correctly due to a tendency to alternate reaches between wells, not because of the manipulation.

In order to discriminate between these explanations, we performed three tests:

1) Comparison of performance on:

Error with same covers, repeat with same covers
versus
Error with same covers, repeat with blue over toy

2) CORRECT WITH BLUE OVER TOY, REPEAT WITH SAME COVERS

3) CORRECT WITH BLUE OVER TOY, REPEAT WITH BLUE OVER TOY

If tests 1, 2, and 3 confirm explanation a, two further explanations still remain to be considered:

Effect is due to Different Covers:
Babies can remember whether the toy is hidden under blue or white under conditions where they cannot remember whether the toy is hidden to the left or right.

Effect is due to Landmark:
After long experience with two blue covers, babies come to associate a blue cover with the toy. When only one cover is blue, they use that as a marker indicating the toy's location.

In order to discriminate between these two explanations, trials where the blue cover is <u>not</u> over the toy were administered. Thus, we performed the following two tests:

4) CORRECT WITH SAME COVERS, REPEAT WITH WHITE OVER TOY

5) ERROR WITH SAME COVERS, REPEAT WITH WHITE OVER TOY

Table 13

PROBABILITY OF REACHING CORRECTLY IN THE DIFFERENT COVERS AND LANDMARK CONDITIONS

	Blue Over Toy on Repeat Trial Following an Error with Identical Covers			Identical Covers on Repeat Trial Following a Correct Reach with Blue Over Toy			Repeat Trial Following a Correct Reach, Blue Over Toy on Both Trials			White Over Toy on Repeat Trial Following Correct Reach with Identical Covers			White Over Toy on Repeat Trial Following an Error with Identical Covers		
	# Correct	# Total	% Correct	# Correct	# Total	% Correct	# Correct	# Total	% Correct	# Correct	# Total	% Correct	# Correct	# Total	% Correct
RUSTY	8	12	67	2	6	33				2	6	33			
NINA	8	12	67	3	5	60							1	6	17
TODD	9	13	69	7	7	100	2	2	100						
SARAH	9	14	64	5	5	100	4	4	100						
JANE	4	20	20	2	4	50							3	6	50
TYLER	6	17	35	2	6	33				2	6	33	3	6	50
JULIA	10	11	91	5	7	71				5	6	83			
BRIAN	7	17	41	3	4	75	1	3	33						
MICHAEL	12	16	75	6	9	67							0	6	00
JACK	12	12	100	2	8	25	3	4	75						
LYNDSEY	4	13	31	3	3	100							2	6	33
JAMIE	9	12	75	6	9	67				3	6	50			
RACHEL	9	21	43	3	6	50	3	3	100						
RYAN	15	20	75	7	10	70							0	6	00
JAMES	7	17	41	3	6	50				5	6	83			
ERIN	9	18	50	3	8	38				2	6	33			
MARIAMA	6	18	33	2	3	67				4	6	67			
KATE	13	19	68	2	6	33	5	7	71						
GRAHAM	9	12	75	5	7	71	2	2	100						
BLAIR	12	14	86	7	10	70				4	6	67	0	6	00
CHRISSY	6	13	46	4	6	67							2	6	33
ISABEL	7	13	54	2	4	50	2	2	100						
BOBBY	8	12	67	3	6	50							0	6	00
JENNINE	8	12	67	5	6	83							2	6	33
EMILY	7	12	58	4	5	80	1	2	50						
Totals	214	366		97	157		23	29		27	48		13	60	
	$\frac{214}{366}$ = 58%			$\frac{97}{157}$ = 62%			$\frac{23}{29}$ = 79%			$\frac{27}{48}$ = 56%			$\frac{13}{60}$ = 22%		
	Average of Percentages = 60%			Average of Percentages = 62%											

children who received fewer trials. An alternative procedure, which assigns equal weight to all children, involves calculating percentage of correct reaches individually for each child, then averaging these percentages. This yields a rate of correct responding of 60%.)

Thus, the answer to the first question is yes. The performance of infants improved when a blue cover was placed over the correct well and a white cover over the other well. The remaining four questions investigate why performance was improved.

Manipulation #2: CORRECT WITH BLUE OVER TOY, REPEAT WITH SAME COVERS

Following a trial on which they reached correctly with different covers (blue over toy), all infants were tested with identical covers. Except for the change of covers, all conditions of the experiment were held constant. Each baby received an average of 6 such trials, with no more than 3 administered within a single session.

When one has no other information, the best guess about how a child might perform on a trial where there are only two possible outcomes (right or wrong) is that the average percent of trials on which the child will reach correctly is 50%. In this study, we have other information so we can improve upon this estimate. On 457 trials we observed how infants performed after they had just reached correctly with same covers and the trial was repeated unchanged. On these trials we found that the probability of a correct reach was 79%. (See Table 7.)

When a baby has reached to the correct well with a blue cover over the toy and a white cover over the other well, and that trial is repeated with two blue covers, the rate of correct responding is 62%.

(See Table 13.) This differs significantly from our empirical baseline of 79% ($t=4.02$, $p<.005$).[17] (The mean of each child's proportion of correct trials under this manipulation is 62% as well.)

Thus, the answer to question #2 is no. When identical covers are used, infants tend not to be able to replicate the correct reach they just made with different covers.

Note that infants were right 62% of the time and we still say they tended to fail to be correct as often as one might expect. We are able to say this because we know that these babies usually repeat a correct response 79% of the time, and 62% is significantly less than 79%.

Note also that while it is impressive that in manipulation #1 infants were correct on 58% of the trials, in manipulation #2 it is unimpressive that infants were correct on 62% of the trials. This is because manipulation #1 looked at trials following errors. We know that infants usually continue to err on such trials. When an error trial is repeated with identical covers, infants are correct only 34% of the time. Therefore, it is impressive that when the only change made in this procedure was to use different covers (blue over toy) on the repeat trial, the frequency of correct responding increased to 58%. On the other hand, manipulation #2 looked at trials following correct reaches. We know that infants seldom err on such trials. When a correct trial is repeated with identical covers, infants are correct 79% of the time. Therefore, when the only change made in this procedure was to use different covers (blue over toy) on the first trial, and the frequency of correct responding dropped to 62%, we say that infants are performing worse here than they normally do after a correct trial.

Manipulation #3: CORRECT WITH BLUE OVER TOY, REPEAT WITH BLUE OVER TOY

Manipulation #3 tests whether our results thus far might be attributable to some tendency to alternate responses rather than to the use of different covers. Following trials on which they reached correctly with the blue cover over the correct well (white over the other), 9 infants were tested on the identical trial again.[18] No condition was varied over these two trials. Each of these children received an average of 3 such trials, with no more than 2 within a single session.

Note, what we hope to find here is that infants will be able to replicate their previous reach. A failure to do so would cast doubt on the reliability of their successful performance on the prior different covers trial and would provide support for the alternating responses interpretation. The question of interest is not, "Can infants repeat a higher percentage of correct reaches with different covers than they do with identical covers?" Infants reliably reach to the correct well when a correct identical covers trial is repeated. We will be happy if they can do the same here. Thus, the question of interest is, "Can infants reach correctly when a different covers trial is repeated?"

As seen in Table 13, the percentage of correct reaches on these repeat trials was 79%. This is equal to the percentage of correct reaches observed earlier when an identical covers trial was repeated, and like that percent it is significantly better than chance (t= 3.20, p<.05). The answer to the third question, therefore, is yes. When infants reach correctly with different covers (blue over toy), they are capable of repeating that performance on the next trial (as long as conditions remain constant).

To summarize the results reported thus far, from the answers to questions 1, 2, and 3 we know two important things. One, the performance of infants significantly improves when a white and a blue cover are used and the blue is placed over the toy, compared with performance when two identical blue covers are used. Two, this is not due to chance, nor to the fact that performance would have improved anyway at the point when distinctive covers were introduced, nor to a possible tendency to alternate reaches from one well to the other; performance improves <u>because</u> of the change in covers.

We are able to say this because: (1) infants reached correctly following an error significantly more often when distinctive covers were introduced (blue over toy) than they do ordinarily (when identical covers continue to be used) -- 58% vs. 34% correct following an error; (2) infants were not able to replicate their correct reach when identical covers were again substituted for distinctive covers nearly as often as they can normally reproduce a correct reach -- 62% vs. 79% correct following a correct reach; and (3) infants <u>were</u> able to replicate this correct reach if we continued to use distinctive covers (blue over toy) -- 79% correct following a correct reach.

Now that we know that the manipulation had an effect, why did it have an effect? Could it be that these infants were not able to remember whether a toy was hidden to the right or left, but could remember whether it was hidden under blue or white? Or, had the infants learned over trials to form an association between a blue cover and the toy? Could they have been using the single blue cover on different cover trials as a landmark, and rather than keeping track of where the toy had gone were always going to blue? As long as the blue cover and the toy are always in one and the same place, it is not possible to discriminate between these explanations. Therefore, we experimented with the white cover over the toy.

Manipulation #4: CORRECT WITH SAME COVERS, REPEAT WITH WHITE OVER TOY

Following identical cover trials on which they reached correctly for the toy, 8 infants were tested with a white cover over the toy and a blue cover over the empty well. All conditions, other than color of cover, were held constant. Each of these children received 6 such trials, with no more than 2 administered within a single session.

We know that infants who have just reached correctly will reach correctly 79% of the time on the next trial. When the trial is repeated with a white cover over the toy, however, the percentage of correct responses is only 56%. This is significantly worse than these same children perform when identical cover trials on which they have been correct are repeated unchanged ($t= 3.34$, $p= .01$). The performance of these children deteriorated when a white cover was placed over the toy. The answer to question 4 is no; after reaching correctly with identical covers, infants perform worse with distinctive covers (white over toy) than one should expect.

Manipulation #5: ERROR WITH SAME COVERS, REPEAT WITH WHITE OVER TOY

Following identical cover trials on which they had erred, 10 infants were tested with a white cover over the correct well and a blue cover over the empty well. Except for the change of covers, all conditions were held constant. Each of these babies received 6 such trials, no more than 2 within a single session.

Infants who have just erred tend to err again if they are once more presented with the same trial. Their success rate on such repeat trials is only 34%. Recall that using distinctive covers, with blue over toy, helped here. It brought the success rate up to 58%. Using distinctive covers, with white over toy, however, only serves to make matters worse. The success rate drops from 34% to 22%. This is significantly worse than these same 10 children perform when identical cover trials on which they have reached wrongly are repeated with identical covers still in use (t= 2.24, p= .01). (An arcsin transformation was used because so many percentages here were under 20%.) Again, performance deteriorates when distinctive covers (white over toy) are used. The answer to the fifth question, thus, is no; although infants usually continue to err after having done so with identical covers, they are even more prone to err again if a white cover is placed over the toy.

We have now seen that performance improves when distinctive covers (blue over toy) are used; yet it deteriorates when the cover over the toy is white. Thus, improvement in the blue over toy condition is not due simply to the use of covers of different color (nor to simply a change, any change, which might serve to make babies more attentive). The improvement is due specifically to the fact that when covers of two different colors are used we put the blue one over the toy.

We propose that this is true because, after repeated experience with two blue covers over months of testing, the infants had learned to associate a blue cover with the toy. When there was only one blue cover (the other cover being white), the infants relied on this learned association to guide their reach. Thus, (1) when the only blue cover was over the toy, even though the infants had just reached to the other well on the previous trial, they reached to the blue cover on 58% of these trials (when we should have expected only 34% of the reaches to be there); (2) when the only blue cover was over the empty well, even though the infants had just reached to the correct well on the previous trial, they now erred by reaching to blue on 44% of these trials (when we should have expected only 21% of the reaches to be there); (3) when the only blue cover was over the empty well, and the infants had just reached to that empty well on the previous trial, they now reached to the blue cover on 78% of the trials (when we should have expected only 66% of the reaches to be there). When presented with a choice between blue and white, infants reached to blue. They did so more than one would expect by chance, and they did so regardless of under which cover the toy was hidden. We propose they did so because they had learned to associate a blue cover with finding the toy.

Although scholars such as Butterworth (1975; 1977; 1978) have suggested that the A$\bar{B}$ error is a specifically spatial problem. This does not appear to be the case. Infants continue to err when discriminable covers are used. If infants simply have trouble remembering right versus left, then when color is available for use in remembering where the toy has been hidden, performance should improve; it does not. After much experience with covers of a certain color, however, infants do use that color as a marker specifying where to reach. Thus, although Piaget (1954) and others had thought that the physical appearance of the hiding places is irrelevant, we now see that under certain circumstances physical appearance can be a potent factor in determining where an infant will search for a toy. Indeed, rather than returning to the toy's previous hiding place (as infants are so wont to do), we see that infants will reach to the "familiar" cover regardless of which well that cover is over.

Note that in the identical covers condition a blue cover was over the empty well as often as over the toy, and on such trials infants reached to the empty well far more often than they reached to the well containing the toy. (They erred on about twice as many trials as they reached correctly; all reaches were to a blue cover.) Yet, the association which the infants formed was blue _with_ toy, not blue _no_ toy.

Other Findings with Different Covers.

The _character_ of the infants' behavior when different covers were used also persuaded us that the infants were reaching to the blue cover intentionally. For example, it was more common for infants to hesitate and to stop themselves from reaching to one well and reach instead to the other well when distinctive covers were used than when identical covers were used. These "prior reaches" were quite rare on identical cover trials (occurring only 4% of the time); with distinctive covers they occurred 15% of the time. The probability that one would find this difference by chance is less than .10 ($t = 1.88$). Prior reaches were particularly common on distinctive cover trials when the final reach was to the blue cover (18% of such trials), rather than on trials where the infant chose to reach to the white cover (11% of such trials).

A typical instance of a prior reach on a distinctive cover trial was as follows: On the previous trial, the infant reached to, let us say, the left well. Now, the white cover is placed over the left well. Repeating the previous performance, the baby starts to reach to the left well, but then stops him or herself, takes a look at the white cover or looks back at the blue cover, turns, and reaches instead for the blue cover, removing it.

In addition, infants tended to look back and forth from one covered well to the other more often when distinctive covers were used than when identical covers were used. This suggested to those of us watching the experiment that the infants noticed a difference between the blue and white covers and were comparing the covers to one another. Perhaps the infants, expecting to see two blue covers, looked to an fro out of surprise at having their expectation violated.

We cite the increased incidence of prior reaches and of looks between wells simply as further evidence that the babies <u>noticed</u> the change in covers and that the effect of the different covers manipulation was not produced for some extraneous reason. One might have predicted that, the white cover being novel, infants would reach to the white cover more often than to the familiar, and thus boring, blue. Indeed, when infants did reach for the white cover there is reason to believe they were sometimes going for the cover and not for the toy, at least on trials where they stared at the white cover throughout the delay, and on removing the cover continued to look at <u>it</u> rather than immediately looking in the well. (Typically, infants waste no time before looking in the well and retrieving the toy.) That infants rarely reached to the white cover emphasizes the strength of the association of the blue cover with the toy. Infants normally prefer the novel stimulus to the familiar one. If they reached to the familiar stimulus here, it must have been for some reason powerful enough to override their tendency to reach for what is new.

Finally, all results reported thus far apply to the babies followed longitudinally. The effect of different covers was also tested with infants who were studied only once. This group of children showed _no effect_ of different covers. Their behavior on trials where one blue cover and one white cover were used did not differ from that observed when two identical blue covers were used.

Twenty of these children were tested under manipulation #1: On two occasions after each of these children had erred, we presented the same trial to them again, keeping all conditions constant except that we substituted for the identical covers a blue cover over the toy and a white cover over the other well. They reached incorrectly on 75% of these trials. This was not significantly different from their performance when an error trial was repeated with identical covers; they erred on 64% of such trials.

Ten subjects from the cross-sectional sample were tested on manipulation #4: After two trials on which they reached correctly, we presented the same trial to them again, but we put a white cover over the toy instead of using two blue covers. They repeated their correct reach on 80% of these trials. This does not differ significantly from their performance on a repeat trial following a correct reach when identical covers remained in use; here they reached correctly 71% of the time.

Finally, 10 cross-sectional subjects were tested on manipulation #5: After two trials on which these children had erred, we presented the same trial to them again, changing nothing except for putting a white cover over the toy instead of using two blue covers. Here they erred on 65% of the trials. On comparable trials with identical covers these same 10 infants erred 62% of the time. The difference between 65% and 62% is not significant.

Thus, neither an effect of different covers nor an effect of blue as a landmark was evident with the subjects seen only once. We propose that the cross-sectional subjects did not show a preference to reach to blue (over white), while the longitudinal subjects did, because the cross-sectional subjects had not had enough experience with trials where two blue covers were used to build up an association of blue with the toy.

Indeed, in the cross-sectional sample there was no elevation in the number of prior reaches nor the number of looks to and fro between wells when different covers were introduced. These babies showed no evidence that the color of the covers was a relevant variable for them; they seemed not to notice, or not to care.[19]

In conclusion, we have found that in the A$\bar{B}$ paradigm, infants were able to make use of a landmark, i.e., a blue color cue. They were able to learn to associate the blue cover with the toy and to use that knowledge to guide their behavior. We found no evidence that the infants were able to remember whether the toy had been hidden under the blue or the white cover. They always reached to the blue cover. They did not reach to the white cover even when the toy was hidden under it. They reached to the blue cover regardless of where the toy had been hidden.

Consulting the patterns of predictions generated by the hypotheses we set out to test (Table 12), we see that these results are not in accord with the predictions of the Spatial Memory hypothesis. The Spatial Memory hypothesis proposed that infants could not use information about right or left to remember where a toy was hidden, but infants would be able to use non-spatial information, such as color, to keep track of the toy's location on each hiding. This prediction was not confirmed. We found no evidence that infants remembered the color of the toy's hiding place. Our test may have been unfair, however, because it pitted the blue cover as a landmark against the use of color as an aid in remembering the toy's whereabouts. A better test of different covers would perhaps have been to introduce two new colors (e.g., red and white). The present data demonstrate that infants of at least 8 months can make use of a color landmark but the data are equivocal on infants' ability to make use of different covers.

Other investigators, who have differentiated the two hiding places by the color of the cover as well as by position, have generally found that the addition of different covers aided performance. Infants of 9 months, who erred when same covers were used, reached correctly when covers of different color were used (Bremner, 1978; Butterworth and Hicks (cited in Butterworth, 1978)). Infants below 9 months, however, are not able to benefit from different color cues (Goldfield and Dickerson, 1981). When less salient cues are used, even 9 month olds are not able to benefit, as when the surface on which each well is located is a different color but the wells and their covers are of the same color (Bremner, 1978).

Other investigators have also shown that infants of 8 months or more can perform quite well when a landmark reliably marks the reward's location. Infants of 6 months show some profit from the addition of a landmark, but much less so than older babies. For example, Butterworth and his colleagues (1982) used an apparatus which was one color on one side and another color on the other. Either side of the apparatus could be either color on any given trial. Covers of different color were also used. When Butterworth and colleagues hid the toy consistently in the well with a particular background color and under a particular color, the errors previously seen in their 8-10 month old subjects disappeared (despite the fact that side of hiding varied). (Butterworth et al. did not include conditions where background color was consistently associated with the toy but same color covers were used nor a condition where color of cover alone marked the toy's location against a homogeneous background.)

Acredolo (1978) trained 6 and 11 month old infants to expect the appearance of an entertaining person to their right or left. After they had learned to look to the proper window in anticipation of the person, Acredolo rotated the children 180 degrees. When no landmark was present infants of both 6 and 11 months repeated the head turn movement which had been successful before the rotation but now faced them toward the window which would remain empty. When the correct window was marked by a large yellow star, however, significantly more 11 month olds turned in the correct direction after the rotation, while the 6 month olds behaved as in the no-landmark condition. Acredolo and Evans (1980) varied the salience of the landmark and found that 9 month olds performed as well as 11 month olds when a prominent landmark was used and somewhat less well when less obvious markers werer used; 6 month old infants showed a small gain when the most salient landmark was used.

Cornell (1979) performed the Stage V Object Permanence Test with 9 month old infants. (This task is like $A\bar{B}$, except that in $A\bar{B}$ the infant sees the toy hidden at a particular location, while here the infant sees the toy placed in a container which is then moved to a particular location.) Cornell used containers of different shape and color. He found that infants could perform well when the toy was always hidden in the same container (although position varied) or when the toy was always moved to the same place (although container varied). That is, when one piece of information (container or position) reliably signalled the toy's whereabouts, the infants performed well. When neither container or position were consistently associated with the toy, so that infants had to remember where the toy had been placed on each trial, they performed poorly. Performance was best when the toy was always placed in the same container and position, but if either of these alone could be counted upon to indicate the toy's location then 9 month old babies could make use of that information.

RELATIVE VS. ABSOLUTE POSITION

How is location encoded by a baby? Is it a specific place, such as the center well? Or is it a relative position which depends on the context, such as the well to the left of the other well? Suppose, for example, well A is to the right of well B. When the infant reaches back to well A, is the intent to reach to well A in particular, or is it to reach to the relative right?

In order to determine whether infants tend to reach to the same absolute position or to the same relative position, we used an apparatus with three possible hiding places. When we covered the center and left wells, the center well was to the relative right; when the center and right wells were covered, the center well was to the relative left.

Following trials on which they had reached to the center well, all infants were tested with a change of wells (either from center and left to center and right, or vice versa). Each baby received an average of 13 such test trials. A reach to the center well on one of these test trials would be a reach to the same absolute place. A reach to the other covered well would be a reach to the same relative position.

(Piaget conceived of the A$\bar{B}$ error as the repetition of a particular action which had been successful in the past, and others more recently [e.g., Webb et al., 1972] have speculated that infants are merely repeating a simple motor response. It should be noted that, in the present experiment, if an infant repeats the past movement, the reach will be to the center well. In the present experiment, a reach to the same absolute place is equivalent to a repetition of the previous motor pattern.)

Three examples of our experimental procedure are provided on in Table 14.

In sequence 1, the test trial is trial 4. The baby had been consistently reaching to the center well; on trial 4, the toy is hidden in the center well; but now the baby reaches to the right well, the same relative position as the reach on trials 1-3.

In sequence 2, the location of the toy remains constant, but the location of the baby's reach changes as the well to the relative left changes.

Whereas sequences 1 and 2 demonstrate a reach to the same relative position, sequence 3 demonstrates a reach to the same absolute location. On both trials here, the toy is hidden to the relative right, but regardless of where the toy is, the baby reaches to the center well.

The results for the test trials are provided in Table 15. Across all infants, the total number of these trials was 328. On 162 trials (or 49%) the reach was to the same relative position; on 166 trials (or 51%) the reach was to the same absolute position. Infants showed no tendency to reach to either the same absolute or the same relative position.

Other investigators have obtained similar results. Butterworth (1975) found that roughly half of his 9 month old subjects reached to the same relative position and half to the same absolute position. Cornell and Heth (1979) trained infants to turn to the left or right to see a novel pattern. Then they rotated the children 180 degrees. Almost all infants of 4 months turned their heads the same way after the

TABLE 14

EXAMPLES OF TEST TRIALS FOR RELATIVE VERSUS ABSOLUTE POSITION

SEQUENCE 1

Trial	Left	Center	Right
1		toy ↑	___
2	___ ↑	toy	

On both trials here, the child reached to the well to the left of the other well covered.

Thus, the child reached to the same relative position.

SEQUENCE 2

Trial	Left	Center	Right
1	___	toy ↑	
2		___ ↑	toy

On both trials here, the child reached to the center well, even though it was to the right relative to the other well on trial 1, but to the relative left on trial 2.

This, then, demonstrates a reach to the same absolute position.

Underscores indicate the wells covered.
Arrows indicate to which well the baby reached.
The last trial in each sequence is the test trial; note its two characteristics: 1) on prior trial, baby reached to center well; and 2) there is a change in which wells are covered.

Table 15

PERCENTAGE OF REACHES TO THE SAME RELATIVE OR ABSOLUTE POSITION

	Number to Relative Position	Number to Absolute Position	Number Total	Percent to Relative Position			Significance Level at Which Observed Percentage Differs from 50%*
RUSTY	10	2	12	.83			.02
NINA	14	2	16	.88			.002
TODD	9	6	15		.60		ns
SARAH	8	4	12		.67		ns
JANE	8	1	9	.89			.02
TYLER	10	4	14	.71			.06
JULIA	8	8	16		.50		ns
BRIAN	3	11	14			.21	.02
MICHAEL	3	9	12			.25	.05
JACK	2	6	8			.25	.10
LYNDSEY	6	10	16		.38		ns
JAMIE	8	2	10	.80			.04
RACHEL	2	13	15			.13	.003
RYAN	6	5	11		.55		ns
JAMES	1	15	16			.06	.0002
ERIN	12	3	15	.80			.01
MARIAMA	3	11	14			.21	.02
KATE	3	12	15			.20	.01
GRAHAM	9	0	9	1.00			.002
BLAIR	12	3	15	.80			.01
CHRISSY	10	4	14	.71			.06
ISABEL	8	8	16		.50		ns
BOBBY	3	12	15			.20	.01
JENNINE	3	7	10		.30		ns
EMILY	2	8	10			.20	.04

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* Determined by Cumulative Binomial Distribution

Source: Hays, Statistics for the Social Sciences. N.Y.: Holt, Rinehart, & Winston, 1973.

rotation. However, among 8 and 12 month old infants tested, one half repeated the same movement and one half turned in the opposite direction to face the same absolute location.

What does this mean for individual children? Do more children tend to reach to the relative or absolute position? Or are reaches to one or the other equally divided among children just as they are over trials, pooling all children? Nine infants showed a significant tendency to reach to the same relative position; nine showed a significant tendency to reach to the same absolute position; and seven divided their reaches equally between relative and absolute position.[20] Thus, reaches to relative or absolute position are equally divided between children just as they are over trials.[21]

Most children (18 out of 25) showed a significant tendency to reach to the same relative or to the same absolute position; most children did not equally divide their reaches.[22] Among the 18 children who showed a clear preference, did they display this preference consistently over visits? Two of these 18 infants did not receive enough trials within individual visits for consistency over visits to be assessed. (Note that test trials on which the baby reached to both wells simultaneously or did not reach at all, had to be eliminated from analysis, for here it was not possible to assign the reach to either the relative or absolute category.) The other 16 infants received at least 4 test trials on a maximum of 4 and a minimum of 2 visits.

The criteria used to determine preference within a session were: for 4 test trials, all 4 reaches were to relative or absolute; for 5 test trials, a minimum of 4 reaches to relative or absolute; for 6 test trials, a minimum of 5 reaches to relative or absolute; and for 7 test trials, a minimum of 5 reaches to relative or absolute. Twelve of these sixteen subjects (75%) showed a consistent tendency to reach either to the same relative or absolute position. This is significant at p=.03 when tested against the cumulative binomial distribution. Six of these children consistently reached to the center well, while the other six consistently reached to the same relative position. Thus, when the data are pooled across subjects, reaches to the same relative position are seen about as often as reaches to the same absolute position. However, when individual children are considered, the more common pattern is for most reaches to be relative or absolute; most children did not equally divide their reaches.

This finding is important because Butterworth (1975; 1978), who tested a cross-sectional sample of 9 month old infants, also found about half the children reached to the same relative position and about half reached to the same absolute position. He concluded from this that each child has an "equiprobable" tendency to reach one way or other: sometimes child x will reach one way; on other occasions child x will reach the other way. Butterworth did not have data on children's performance over repeated testings. In this study, where such data have been collected, we see that Butterworth's generalization is not justified. While across children the tendency is equally divided, within a given child it is not.

When analyses were done for differences across age, one difference was significant. Infants below 9 months showed a significant tendency to reach to the same absolute position, while the number of absolute and relative reaches was roughly equal among infants 9 months or older.[23]

We have evidence on only 8 babies below the age of 9 months. They were given a total of 44 test trials before they turned 9 months. On 32 of these trials (or 73%), they reached to the same absolute position (the center well). This is significantly more than one would expect by chance ($x^2 = 9.09$, $p < .005$). Looking at individual children, 6 of the 8 (or 75%) reached more often to the center well than to the same relative position. (See Table 16.)

For infants at or above 9 months age, 134 reaches on 284 trials (or 47%) were to the same absolute position. If one looks only at the 8 infants for whom we have evidence below 9 months, one finds that of 76 test trials administered to them from the age of 9 months on, they reached to the same absolute position on 37 (or 49%). Testing the difference between the pattern of these 8 children's responses below 9 months (75% to same absolute position) and the pattern of their reaches from 9 months on (49% to same absolute position) yields a chi square value of 6.59, significant at less than .02. Moreover, the other 17 children, at 9 months of age and older, reached to the same absolute position on 47% of the test trials (97 trials out of a total of 208). The difference between these children's performance (47% to absolute position) and the performance of the eight who were also tested below 9 months (49% to absolute position) is not significant. Therefore, the difference found between styles of reaching below 9 months and at or above 9 months cannot be attributed to testing a biased group of infants below 9 months of age, who were generally more prone to reach to absolute position at any age.

Infants of 9 months, thus, appear capable of relating one well to the other and responding on the basis of relative position. Not all infants of 9-12 months respond on the basis of relative position, but

Table 16

PROBABILITY OF REACHING TO THE SAME RELATIVE OR ABSOLUTE POSITION, FOR INFANTS YOUNGER THAN NINE MONTHS

	# to Relative Position	# to Absolute Position	# Total	% to Relative Position
NINA	0	3	3	0
TYLER	0	4	4	0
JULIA	1	8	9	11
BRIAN	0	8	8	0
RACHEL	4	0	4	100
JAMES	2	5	7	29
KATE	4	0	4	100
CHRISSY	1	4	5	20
	12	32	44	

$$\frac{12}{44} = 27\%$$

the ability appears to be there. Infants below 9 months, on the other hand, show a marked absence of relative reaching.

Different Covers

Do children who differ in their tendency to reach to relative or absolute position also differ in their ability to make use of a landmark? In order to determine whether an individual child was able to make use of the blue landmark when distinctive covers were used, showing a pattern of responses significantly different from what one might expect by chance, we compared each child's performance in the condition "Error on Previous Trial, Repeat with Blue Over Toy" to that child's performance under the condition "Error on Previous Trial, Repeat with Same Covers," testing each of these 25 within-child comparisons individually using chi square. We are prepared to say that a child who performed significantly better in the former condition was reliably able to make use of the blue landmark.

Of the nine children who showed a significant preference for relative over absolute position: 7 clearly made use of the blue landmark; 1 performed ambiguously; 1 did not make use of the blue landmark. The observed distribution of 7 children using the landmark and 1 not doing so is significantly different from what would be expected by chance ($x^2 = 8.0$, $p < .01$). Among children who tended to reach to the relative position, there was a significant tendency to use the blue cover to guide reaching when presented with a choice between one well covered by blue and one well covered by white.

Of the nine children who show a significant preference for absolute position: 3 clearly made use of the blue landmark; 4 performed ambiguously; 2 clearly did _not_ make use of the blue landmark. Those children who showed a significant tendency to reach to absolute position did _not_ show a tendency to utilize the landmark.

Color Pitted Against Relative Position

For all infants we tested the strength of the tendency to reach to the blue cover (when the choice was blue or white) against the strength of the tendency to reach to the same relative position. Which of these tendencies might prove stronger?

We did not find that all of our subjects had a tendency to reach to the same relative position. For the subjects who did not, it is not meaningful to pit relative position against a color cue. Therefore, we analyzed the results only for the 9 subjects who consistently reached to the same relative position.

Subjects received 4 tests of color versus relative position such as the test illustrated in Table 17. Note that in the sequence of trials illustrated, the infant has been reaching to the left on trials 1-4. On the test trial, the well to the relative left is covered by the white cover; the infant reaches to the far right.

On 25 of the 36 test trials, infants overrode their tendency to continue to reach to the same relative position and reached to the blue cover. Testing this using chi square, we found this to be significant at less than .02 ($x^2 = 5.44$). When color is pitted against relative position, infants reach to the cover of the "familiar" color rather than to the same relative position.

Table 17: EXAMPLE OF TEST FOR REACHING TO THE SAME RELATIVE POSITION VERSUS REACHING TO THE BLUE COVER ON DIFFERENT COVER TRIALS

Trial	Left	Center	Right
1	toy ↑	___	
2	toy ↑	___	
3	___ ↑	toy	
4	___ ↑	toy	
5		white	toy ↑

Underscores indicate which wells were covered.

The word "white" appears where a white cover was used.

Arrows indicate the well to which the infant reached.

The test trial is trial 5.

Cornell (1979), in the Stage IV Object Permanence Experiment mentioned in the preceding chapter, found that infants made fewer errors when the toy was consistently hidden in a particular container than when it was consistently hidden at a particular location. Here, infants appeared to be more inclined to respond on the basis of color and shape than on the basis of position.

Random vs. Lawful Behavior

Do children who differ in their tendency to reach to relative or absolute position also differ in the lawfulness

Once a child has committed the A$\bar{B}$ error, he tends to continue to do so as long as conditions remain unchanged. Once a child has reached correctly, he tends to continue to do so as long as conditions remain unchanged. We would have labelled the reaching random if the conditional probability of a correct reach in these two conditions had been equal. The larger the difference between these two proportions, the more consistent and lawful the behavior.

The average percent of correct reaches on repeat trials following an error for subjects who preferred relative over absolute position was 31% correct. Their average percent correct on repeat trials following a correct reach was 82%. The difference between these two percentages is 51%.

For those children who tended to reach to <u>absolute</u> position, the average percent of correct reaches on repeat trials following an error was 33% correct. Their average percent correct on repeat trials following a correct reach was 73%. The difference between these two percentages is 40%.

Thus, the children who tended to reach to the same relative position showed more lawfulness in their behavior in the standard A$\bar{B}$ situation than did the children who reached more often to absolute position. We say their behavior was more lawful because the difference between the frequency of correct response following a correct reach and the frequency of correct response following a wrong reach was larger among relative-reachers (51%) than among absolute-reachers (40%).

We find ourselves with two groups of children: one group who tend to reach to the same relative position, who seemed to have learned to associate a blue cover with the toy, and who replicate their correct reaches and their errors with considerable consistency; and another group who tend to reach to the same absolute position, who showed no evidence, as a group, of having learned the association of blue cover with toy, and who respond more randomly in the A$\bar{B}$ situation. Perhaps the first group is more developmentally advanced. Perhaps they were more engaged in the A$\bar{B}$ experiment, and therefore attended more carefully. Perhaps, but note that they are no more accurate in their reaches (33% vs. 36% correct after a correct trial, and 85% vs 74% correct after an error trial), and we will see evidence shortly that the delays (the memory strain) which they were able to tolerate are no greater than what we find among the infants of the second group. We do not know why we found infants performing in these two ways. We suggest this as a question for future investigation.[24]

To conclude this chapter, we would like to compare the results reported here with the predictions of the four hypotheses we set out to test. (See Table 12.) The only hypothesis which generated a prediction about relative versus absolute position was the "Memory + Ability to Relate Two Things" hypothesis which predicted that babies would reach to the same absolute position because they would be unable to relate two points in space to one another. We found no overall tendency among the infants studied to reach to either relative or absolute place. However, we did find an age difference. Infants below 9 months reached to the same absolute position more consistently than did older children. We view this as in accord with the "Memory + Ability to Relate Two Things" hypothesis. If what is maturing at 6-12 months includes the ability to relate two things to one another, then one would expect that toward the beginning of this age range infants would reach to absolute position and as they grew older they would begin to respond more often on the basis of relative position.

SIGHT TRIALS

Can infants learn by watching as well as by doing? Will information acquired only by observation influence behavior in the same way as information acquired through acting? Specifically, will the $A\bar{B}$ error occur whether an infant reaches on "A trials" (trials where the toy is hidden at the first hiding place) or simply watches the experimenter reach and retrieve the toy at A?

To address this question, infants were tested on "sight trials" on all visits following the first session in which they demonstrated the ability to find a hidden object. The sight trials procedure was as follows:

On the first trial of a session, the parent was instructed to restrain the child's hands throughout the entire trial. The hiding and delay phases of this trial were identical to those on other trials. However, unlike other trials, after the delay the child was <u>not</u> permitted to reach. Instead, the experimenter called to the child, "Look, this is where the toy was. It was right here," and while doing so uncovered the correct well, holding the toy up, over the well in clear view of the infant. The experimenter then handed the toy to the infant, and the infant was released and permitted a brief play period with the toy. This procedure was repeated on the next trial. Thus, each infant on each visit was given two opportunities to watch the experimenter hide and retrieve the toy at a particular well. Following these two trials, the place of hiding was reversed (i.e., the toy was hidden in the well that had been covered, but empty, during the two sight trials), and the infant was permitted to reach following the delay period.

All infants received one half of their sight trials with the toy hidden in the well to the left, and half with the hiding to the relative right; on one third of these trials, the toy was hidden in the left well, one third in the center, and one third in the right. This procedure is described more fully in the "Materials and Procedure" chapter.

Thus, on every visit (once an infant could find a hidden object) there was one test of the effect of watching alone. The infant's performance on the reversal trial following two observation trials was the test.[25]

We eliminated from analysis any visit on which, during the sight trials: (a) the infant loosed him or herself from the parent's grasp and reached to the correct well; (b) the parent held the child so weakly that the child was able to make a clear reach to a well even with the parent holding on; or (c) the parent mistakenly released the child's hands after the delay period and the child reached for the toy. If sight trials are meant to be a test of the effect of watching alone, then sight trials where the child has clearly acted should not be included in the analysis.[26]

Of the 148 trials on which we tested the effect of sight trials, we found that the infants erred by reaching to the previous hiding place on 51% of the trials, reaching correctly on 49% of the time. These results are presented in Table 18. (If one calculates this instead by taking the average of each child's average performance after sight trials, the percent correct is 48%, instead of 49.) Overall, the children were right about half the time, and wrong about half the time -- chance

Table 18

PERCENTAGE OF CORRECT REACHES ON REVERSAL TRIALS FOLLOWING TWO SIGHT TRIALS

	# Correct	# Total	% Correct
RUSTY	3	5	60
NINA	0	7	0
TODD	2	6	33
SARAH	2	5	40
JANE	5	7	71
TYLER	3	7	43
JULIA	4	6	67
BRIAN	4	7	57
MICHAEL	4	6	67
JACK	0	4	0
LYNDSEY	4	7	57
JAMIE	3	4	75
RACHEL	4	8	50
RYAN	1	6	17
JAMES	4	7	57
ERIN	2	5	60
MARIAMA	1	5	20
KATE	3	5	60
GRAHAM	4	6	67
BLAIR	1	5	20
CHRISSY	5	8	63
ISABEL	4	7	57
BOBBY	2	6	33
JENNINE	4	5	80
EMILY	3	5	60
Total	72	148	

$$\frac{72}{148} = 49\%$$

Average of Percentages = 48%

performance. (Seven children were correct on more than 60% of these test trials; 7 children reached to the previous hiding place on more than 60% of these trials; and 11 children divided their reaches roughly equally.)

Evans (1973) found that sight trials were as effective in producing errors on the reversal trial which followed as were trials where the infant had actually reached and found the toy. However, "as effective" meant that roughly half, or slightly more, infants failed on the reversal trial. That confirms the result reported here -- infants were correct on approximately one half of the reversal trials following sight trials.

On reversal trials following <u>reaches</u> by the infant, the percent correct was 34%. The difference between that performance and performance after sight trials (48% correct) is significant ($t = 12.59$, $p < .0001$), suggesting that infants err more often if they have reached and found the toy at one place and then the toy is hidden in another than if they simply see the toy hidden in the first place, but never reach there. Reaching seems to matter; watching, by this analysis, seems not to matter.

But there is another way to analyze these results. When we examined the data on sight trials, we were looking at only one reversal trial on each visit. When we compared this to reversal trials following reaches, we were looking at *several* trials on each visit. What would we find if we looked only at the *first* reversal trial following a correct reach across all visits? Or the *second* reversal trial in each visit? Or the *third*?

We find rates of correct responding that approximate what we found after sight trials. The percent of correct reaches on the <u>first</u> trial on which side of hiding is reversed following the infant's successful reach to the first hiding place is 42%; percent correct the <u>next</u> time side of hiding is reversed following a correct reach to the prior hiding place is 50%; and percent correct on the <u>third</u> reversal is 47%. (See Table 19.) None of these values differs significantly from the percentage of correct reaches following sight trials, 49%. Infants do no differently after simply watching than they do after reaching. Watching, by this analysis, appears to have the same effect as acting.

It is appropriate to compare reversal trials following correct reaches to a baseline of performance on repeat trials following correct reaches, for the former differ from the latter solely in the site of hiding. (That is, reversal trials differ from the repeat trials in only one variable [where the toy is hidden]. They are equal on all other variables: in both cases, delay, color of covers, etc., remain constant from trial 1 to trial 2, and in both cases the baby has reached correctly on trial 1. The evidence from repeat trials tells us what babies do when the site of hiding is not changed. If the results from reversal trials differ from this, we conclude that the one variable we changed had an effect on infants' behavior. The appropriate comparison for the effectiveness of a manipulation is what happens in the identical situation minus that single manipulation.) If we compare 42%, 50%, and 47% (the percentage correct on the first, second, and third reversal after a correct reach) to 79% (the percentage correct on repeat trials following a correct reach), we find that each of these t-tests is significant at $p< .01$. It is less clear whether it is appropriate to compare performance on the reversal trial following sight trials to that on

Table 19

PERCENTAGE OF CORRECT REACHES ON THE FIRST, SECOND, AND THIRD REVERSAL TRIALS WITHIN A SESSION

	First Reversal	Second Reversal	Third Reversal
Rusty	57	43	31
Nina	40	60	70
Todd	43	61	67
Sarah	45	67	65
Jane	33	50	25
Tyler	33	60	70
Julia	40	30	50
Brian	36	30	20
Michael	31	42	20
Jack	45	65	70
Lyndsey	37	20	20
Jamie	27	30	15
Rachel	29	55	10
Ryan	37	65	50
James	28	20	50
Erin	31	15	33
Mariama	48	60	75
Kate	42	45	20
Graham	71	75	90
Blair	30	50	20
Chrissy	42	30	67
Isabel	65	75	45
Bobby	32	15	33
Jennine	40	60	25
Emily	50	50	50
Mean =	42%	50%	51%

repeat trials following correct reaches because infants do not reach on the sight trials. This comparison (49% vs. 79% correct), however, is also significant at $p < .01$.

What, then can one conclude? Does information acquired by watching influence behavior in the same way as information acquired through acting? The performance of infants on the reversal trial following sight trials closely resembles performance on any particular reversal trial following an actual correct reach. After sight trials, as on all other reversal trials, infants perform significantly worse than they do after they have just reached correctly and nothing is changed. Yet, the percentage correct on any particular reversal, including the reversal following sight trials, is roughly 50%. Therefore, we cannot say that infants are likely to err after sight trials any more than we are able to say they are likely to err on any one particular reversal.

This brings us to an important point. Other investigators, as noted in the chapter on "The Operationalization of the $A\bar{B}$ Error," have typically relied on infants' performance on a single reversal trial in their determination of whether or not the $A\bar{B}$ error has occurred. While two studies have found the error in most children using this criterion (Schuberth, et al. (1977), found that 11 out of their 12 subjects erred on this reversal trial, and Gratch and Landers (1971) found that 10 out of the 13 babies they studied reached incorrectly on this trial), we are not surprised that most investigators have only found the error in about half of the infants they tested (Gratch and Landers, 1971; Bower and Patterson, 1972; Evans, 1973; Butterworth, 1975, 1977, 1978). We, too, found only about one half of the subjects in this study erring on the first reversal trial. We believe that looking at only one particular trial is too small a window on behavior in the $A\bar{B}$ experiment. The general conclusion among scholars, based on these previous experiments, has been that only about half the children make the $A\bar{B}$ error (after reaching). Based on the results of the present study, we believe this to be an erroneous conclusion. All of the infants in the present study made the $A\bar{B}$ error, and did so repeatedly, based on the four criteria outlined earlier. They did not necessarily err on a particular trial, but over several trials one finds a consistent pattern of errors.

In the next chapter, we will explore in greater detail our finding of the $A\bar{B}$ error in all children over several months, and the finding of others that the $A\bar{B}$ error occurs in only about 50% of the children and disappears after a few weeks.

In conclusion, we turn once again to the predictions generated by the hypotheses under consideration. (Please refer back to Table 12.) The hypothesis, "Memory + Ability to Check or Change One's Behavior," suggested that babies might reach to a toy's previous hiding place (instead of its current one) because the act of reaching coupled with a reward builds up a tendency in the children to repeat that act, and the children are unable to inhibit or override that tendency. This hypothesis, thus, predicted that it was crucial for the $A\bar{B}$ error that the infant actually reach to A; watching alone would be insufficient. We conclude that that prediction has been weakly disconfirmed by the data. It appears that watching has an effect equal in magnitude to that produced by reaching, but we acknowledge ambiguity in interpreting the data. It should also be noted that if babies learn by watching alone, then the learned association between the toy and the well in which it was placed on the two sight trials must be overridden on the reversal trial by the memory of where the toy has most recently been placed. That is, errors on reversal trials might still be attributable to problems in inhibiting earlier associations.

DELAY LENGTH

This study is the first to investigate the AB̄ error from the age when an infant can first find a hidden object until one year. We did not know if the error would disappear during this period or if its character would change. Certainly, other studies had suggested it might be an ephemeral phenomenon (Gratch and Landers, 1971). We did know that if we were to attempt to investigate this error over several months, we would have to impose longer delays between hiding and retrieval as the infants grew older. Studies by Fox et al. (1979) and Szpak (1977) had shown that, with increasing age, infants cease making the AB̄ error unless the delay interval is lengthened. Therefore, because we wanted to explore the characteristics of the AB̄ error over many months, we chose to increase the length of delay over those months.

Before we report the length of delay which infants could tolerate at each age and individual differences in this memory ability, it is important that we demonstrate first that our results on delay by age are not simply an artifact of the experimental design. Did we find that older infants could tolerate longer delays (could remember over longer periods) only because we tested them at longer delays, or because there is a genuine age difference in memory ability? Similarly, could the slope of this delay by age function have been made steeper or flatter by simply increasing the delays faster or slower? Finally, were observed differences between children of the same age in the length of delay each could tolerate a product of arbitrary experimenter choice, or do they reflect real differences in memory ability? Because these are reasonable questions, we will address them before presenting the findings on age and individual differences in memory. Our answer to these questions consists of evidence that we were not free to select duration of delay arbitrarily; delays within only a narrow range produce the A$\bar{B}$ error. Our choice of delay length was constrained by this range.

In order to assess the appropriateness of the delay lengths used, we posed two questions:

1) If an infant is making the A$\bar{B}$ error at a given delay, will he stop erring if we <u>reduce</u> the delay by 2 or 3 seconds? That is, how brief a delay can we use and still observe the A$\bar{B}$ error?

2) If an infant is making the A$\bar{B}$ error at a given delay, will his or her behavior become so random that we can no longer call it the A$\bar{B}$ error if we <u>increase</u> the delay by 2 or 3 seconds? That is, how long a delay can one use and still observe the A$\bar{B}$ error?[27]

Thus, we increased or decreased the delay within a single visit and observed its effect on performance. We were concerned, however, that there might be an order effect. The order effect might be that babies perform better as a testing session progresses <u>or</u> that babies get tired or bored as a session progresses and their performance deteriorates. Therefore, we decided to counterbalance order of presentation when testing the effect of delay length.

To investigate question #1, for roughly one half of the children the first half (N= 13) of the testing session was performed at a delay interval sufficiently brief so that the infant did not err. For the second half of the session, a delay 2 or 3 seconds longer was used. Our prediction: During the second half of these sessions the behavior of the infants would conform to the criteria for the A$\bar{B}$ error.

For the other half of the subjects (N=12), the first part of a testing session was performed with a delay length sufficiently long to produce the A$\bar{B}$ error. During the second half of the session, we used a delay 2 or 3 seconds shorter. Our prediction: During the second half of these sessions the infants would reach to the correct well too consistently for it to be said they committed the A$\bar{B}$ error.

All infants were tested on question #1. Half of the infants received the shorter of the two delays first and half received the longer of the two delays first.

During each half session, 3 to 4 reversal trials were administered. No reversal trial was administered until the infant reached correctly at the toy's hiding place prior to the reversal. The first correct reach at any hiding place was always followed by a repeat trial for confirmation. An infant's performance was deemed "too good" to be called an A$\bar{B}$ error if: (a) the child made <u>no</u> errors (for half sessions containing under 10 trials); or (b) the child made no more than <u>one</u> error (for half sessions of 10 or more trials).

Eighteen infants (72%) behaved in accord with our predictions. They displayed the A$\bar{B}$ error at the longer of these delay lengths and committed no errors at the shorter delay. Seven infants (28%) failed to confirm the predictions. The probability of finding 18 confirmations on 25 tests is .02 (using the cumulative binomial distribution). Hypothesis 1 is thus confirmed; at delay lengths sufficiently long to produce the A$\bar{B}$ error, a reduction of 2 or 3 seconds in delay eliminates most errors. (Table 20 presents the protocols from two actual sessions where Hypothesis 1 was tested.)[28]

Of the seven infants who failed to conform to our predictions,

Table 20: SCHEMATIC ILLUSTRATION OF ACTUAL SESSIONS TESTING THE PREDICTIONS:

NO ERRORS AT SHORTER DELAY
A$\bar{B}$ ERROR AT LONGER DELAY

Side Hide = where toy is hidden; other well = other well used (i.e., covered) on that trial. When side hide & other well are the same as on the previous trial, these columns are left blank.

R = Right Well; C = Center Well; L = Left Well. ✓ = Correct Reach

Trials A & B are Sight Trials; infant is not permitted to reach. Delay is given in seconds.

JACK - VISIT 6

Trial #	Side Hide	Other Well	Reach	Delay
A	R	C		3
B				
1	C	R	✓	
2			✓	
3	R	C	✓	
4			✓	
5	C	R	✓	
6			✓	
7	R	C	errs	5
8			errs	
9			✓	
10	C	R	✓	
11			✓	
12	R	C	errs	
13			✓	
14			errs	
15			errs	
16			✓	
17	C	R	✓	
18			✓	

JANE - VISIT 5

Trial #	Side Hide	Other Well	Reach	Delay
A	C	L		8
B				
1	L	C	✓	
2	C	L	errs	
3			errs	
4			errs	
5			✓	
6	L	C	errs	
7			✓	
8	C	L	errs	
9			errs	
10			errs	
11			✓	5
12			errs	
13			✓	
14			✓	
15			✓	
16	L	C	✓	
17			✓	
18	C	L	✓	
19			✓	
20	L	C	✓	
21			✓	

three did so because they still made the $A\bar{B}$ error when the delay was decreased. The other four infants did not perform as predicted because they still made no errors when the delay was increased by 2 or 3 seconds. In fact, all four infants still performed perfectly when we increased the delay another 2 or 3 seconds. (In two cases, this meant consistently flawless performance at 0 seconds, at 2 seconds, and finally at 5 seconds. In another, no errors were made with delays of 3, 5, and even 7 seconds. In the fourth case, the delay started at 12 seconds, was increased to 15 seconds, and finally to 18 seconds -- and still no errors.) The performance of these four infants was truly impressive; on that single day of testing, they seemed immune to error.

There was no order effect. Among the 13 infants who received the shorter delay at the beginning of the visit, 9 behaved as predicted (70%) and 4 did not. Among the 12 who received the longer delay at the beginning of the visit, 9 behaved as predicted (75%) and 3 did not. (See Table 21.)

A change of 2 seconds was no less effective than a change of 3 seconds. Of the 15 infants tested with a change in delay length of 2 seconds, 10 confirmed our prediction and 5 did not. Of the 10 infants tested with a change of 3 seconds, 7 confirmed our predictions and 3 did not.

We also performed two further tests of question #1. First, we reasoned that in addition to counterbalancing the effect of order between subjects, an attempt should be made to counterbalance it within the same subject. Therefore, we selected 5 infants who had been tested using "shorter delay first" and 5 infants who had been tested with "longer delay first", and we re-tested them using the order they had not

Table 21

TESTS OF PREDICTIONS:

INFANTS WILL MAKE THE $A\bar{B}$ ERROR AT THE LONGER DELAY
INFANTS WILL NOT ERR AT THE SHORTER DELAY

	Prediction Confirmed	Prediction NOT Confirmed	Total
Order of Presentation			
SHORTER DELAY FIRST (Prediction = Infants will make $A\bar{B}$ error when delay is increased.)	9	4	13
LONGER DELAY FIRST (Prediction = Infants will not err when delay is reduced.)	9	3	12
TOTAL	18	7	25

previously received.[29]

The results of these tests, presented in Table 22, confirm the results obtained for order of presentation of delay counterbalanced across subjects. Our prediction was confirmed on 16 out of the 20 visits on which these 10 infants were tested. (This is significant at less than .005 using the cumulative binomial distribution.) There is no order effect, no effect of first or second testing, and no interaction between order and testing. This can be seen by a repeated measures analysis of variance of these results where both order of delay presentation within session and first and second testing are within-subject variables:

	Degrees of Freedom	Sum of Squares	F	Significance Level
Order	1	0.20	1.14	.30
Testing	1	0.20	1.14	.30
Order x Testing	1	0.00	0.00	1.00

Second, testing the effect of delay length within a visit confined us to a small number of trials (roughly, ten). In order to increase the number of trials used in our test, we decided to perform the test across visits. Therefore, for about one half the subjects (N=12), following a visit on which they committed the A$\bar{B}$ error, on the <u>next</u> visit we used a delay that was <u>shorter</u> by 2 or 3 seconds. Our prediction: On these visits, the infants would not err.

This prediction was <u>not</u> confirmed. On 5 of these visits the infants performed perfectly, but on 7 visits the infants still made the A$\bar{B}$ error. Thus, on only 42% of the tests was the prediction confirmed.

Table 22

TESTS OF PREDICTIONS:

INFANTS WILL MAKE THE A$\bar{B}$ ERROR AT THE LONGER DELAY
INFANTS WILL NOT ERR AT THE SHORTER DELAY

ORDER OF PRESENTATION COUNTERBALANCED WITHIN SUBJECT (N=10)

	SHORTER DELAY FIRST (Prediction: Infants will make A$\bar{B}$ error when delay is increased.)		LONGER DELAY FIRST (Prediction: Infants will not err when delay is reduced.)		TOTAL	
	Prediction Confirmed	Prediction NOT Confirmed	Prediction Confirmed	Prediction NOT Confirmed	Prediction Confirmed	Prediction NOT Confirmed
FIRST TESTING	3	2	4	1	7	3
SECOND TESTING	4	1	5	0	9	1
TOTAL	7	3	9	1	16	4

If an infant is making the A$\bar{B}$ error and, on that same day, you reduce the delay by 2 or 3 seconds, the errors will disappear. But if you do so 2 weeks later, errors still appear. Why this should be is unclear, but it is likely that the performance of an infant on a given day is partially a function of transient factors such as degree of wakefulness, physical comfort, and "motivation."

It does not appear to matter whether the 2 or 3 seconds is subtracted from a delay of 15 seconds, 8 seconds, or 3 seconds. In all cases it appears equally effective in eliminating errors. Table 23 presents these results for all 35 within-visit tests (one for each of the 25 children, and the repeat test for 10 of the children).

The 15 infants who were tested on question #1 under only one order of delay presentation were tested on question #2, "If an infant is making the A$\bar{B}$ error, will an increase of 2 or 3 seconds in the delay produce behavior that is so random it can no longer be called the A$\bar{B}$ error?"

Again, we chose to counterbalance the order in which the delays were presented. During the first half of the testing session for eight infants we used a delay interval long enough to produce the A$\bar{B}$ error. The second half of these sessions was performed with a delay longer by 2 or 3 seconds. Our prediction: During the latter half of these sessions, the behavior of the infants would deteriorate below that needed to meet the criteria for the A$\bar{B}$ error.

For the other seven infants, the session started with a delay long enough to produce random reaching. During the second half of the session, a delay shorter by 2 or 3 seconds was used. Our prediction: During the second half of these sessions, the behavior of the infants would

Table 23

NUMBER OF SUBJECTS CONFIRMING OR DISCONFIRMING PREDICTION OF $A\bar{B}$ ERROR AS A FUNCTION OF DELAY LENGTH

Length of Delay (in seconds)			Hypothesis Confirmed ($A\bar{B}$ Error at Longer Delay; No Error at Shorter Delay)	Hypothesis NOT Confirmed
LONGER DELAY		SHORTER DELAY		
2 or 3	---	0	5	1
5 or 6	---	2 or 3	8	5
7 or 8	---	5	5	0
10	---	7	5	0
12	---	10	4	1
15	---	12	0	1

conform to the criteria for the A$\bar{B}$ error.

Ten of the babies behaved as predicted; five did not. Ten confirmations on fifteen tests is significant at only .09 (using the cumulative binomial distribution). (Table 24 presents the protocols from two of these testing sessions.)

Two of the five children failed to confirm our predictions by continuing to show the A$\bar{B}$ error at the longer delay. The other three children did not perform as expected in that their behavior was still severely disrupted when we reduced the delay.

The behavior of the thirteen infants who showed a serious impairment of performance with the longer delay differed from the behavior normally observed during A$\bar{B}$ testing in several ways. (1) They were often unable to reach correctly again on a repeat trial following a correct reach. (2) Their performance on repeat trials following errors showed unusually marked perseveration. Their strings of errors were extremely long. (3) Often searching ceased altogether. They refused to try, or forgot what it was they were supposed to do. (4) They complained. Often the infants cried or fretted to express their displeasure with our test.

There was no significant effect for order of presentation of the delay. With the "shorter first" order, our predictions were confirmed on 6 our of 8 tests. With the "longer first" order, our predictions were confirmed on 4 out of 7 tests. (See Table 25.)

We believe that if we tested more subjects, our prediction would have been confirmed with the "shorter first" order but <u>not</u> with the "longer first" order. The longer delay was too upsetting for the babies. They became so frustrated (or so aggravated) that even when we

Table 24: SCHEMATIC ILLUSTRATION OF ACTUAL SESSIONS TESTING THE PREDICTIONS:

A$\bar{B}$ ERROR AT SHORTER DELAY
RANDOM REACHING AT LONGER DELAY

Side Hide = where toy is hidden; other well = other well used (i.e., covered) on that trial. When side hide & other well are the same as on the previous trial, these columns are left blank.

R = Right Well; C = Center Well; L = Left Well. ✓ = Correct Reach

Trials A & B are Sight Trials; infants is not permitted to reach. Delay is given in seconds.

REL = Trial was a test of relative versus absolute position, not a reversal trial.

DIF = Different covers used on this trial.

ONE = Only one cover used on this trial.

TYLER -- VISIT 7

Trial #	Side Hide	Other Well	Reach	Delay	Notes
A	L	C		1	
B					
1	C	L	✓		
2			✓		
3	L	C	errs		
4	C	R	✓		REL
5	R	C	errs		
6			errs		
7			✓		
8			✓		
9	C	R	errs	3	
10			errs		
11			errs		
12			errs		
13			errs		
14			errs		
15			NONE		
16			NONE		
17			NONE		
18	R	C	errs		
19	C	R	✓		
20			errs		
21			✓		
22	R	C	errs		
23			✓		
24			errs		

MARIAMA -- VISIT 6

Trial #	Side Hide	Other Well	Reach	Delay	Notes
A	L	C		5	
B					
1	C	L	errs		
2			errs		
3			✓		
4			errs		DIF
5			errs		DIF
6			errs		
7			✓		
8			errs		
9			errs		ONE
10			NONE		
11	L	C			
12			errs		
13			NONE		
14			✓	3	
15			✓		
16	C	L	errs		
17			✓		
18	L	C	✓		
19			✓		
20	C	L	errs		
21			errs		
22			✓		
23			✓		

Table 25

TESTS OF PREDICTIONS:

INFANTS WILL REACH RANDOMLY AT THE LONGER DELAY
INFANTS WILL MAKE THE A$\bar{B}$ ERROR AT THE SHORTER DELAY

	Prediction Confirmed	Prediction NOT Confirmed	Total
<u>Order of Presentation</u>			
SHORTER DELAY FIRST (Prediction = Infants will reach randomly when delay is increased.)	6	2	8
LONGER DELAY FIRST (Prediction = Infants will make A$\bar{B}$ error when delay is reduced.)	4	3	7
TOTAL	10	5	15

reduced the delay period we could not bring their performance back up. Indeed, the three infants who failed to improve when the delay was reduced were tested with yet another reduction of 2-3 seconds in delay. (In one case, the delay was reduced from 12 seconds to 10 seconds to 7 seconds. In another, from 7 seconds to 5 seconds to 3 seconds. In the third, from 5 seconds to 3 seconds to 1 second.) In <u>no</u> case did these further delay reductions help. We had lost the infants for that day.

The absolute length of the delay does not appear to affect these results. It does not matter whether one adds 2 or 3 seconds to a delay of 3 seconds or to a delay of 10 seconds. (See Table 26.)

Our predictions about the effect of increasing the delay by 2 or 3 seconds beyond that needed to produce the A$\bar{B}$ error were, thus, only modestly confirmed. We found a tendency for infants to reach randomly and to display other signs of distress with the increased delay.

This result, in combination with the robust finding that a reduction of 2 or 3 seconds eliminates the A$\bar{B}$ error, establishes a rather narrow range for the length of delay that will yield the error. On those visits where we observed the A$\bar{B}$ error, the delay chosen must have been appropriate to that child, at least within the bounds specified by this range. Also, children tested at longer delays performed no more poorly (indeed, sometimes better) than children tested at shorter delays. (We will present the analysis demonstrating this later in the chapter when we discuss individual differences in length of delay.) Differences in the length of delay infants could tolerate reflect genuine differences in memorial ability.

Age Differences in Length of Delay Necessary to Produce the A$\bar{B}$ Error.

Table 26

BREAKDOWN OF NUMBER OF SUBJECTS CONFIRMING HYPOTHESIS #2 BY DELAY LENGTH

Length of Delay (in seconds)			Hypothesis Confirmed (Randomly Reaching at Longer Delay; $A\bar{B}$ Error at Shorter Delay)	Hypothesis NOT Confirmed
LONGER DELAY		SHORTER DELAY		
2 or 3	---	0	2	1
4 or 5	---	2 or 3	4	1
7	---	5	1	1
10	---	7 or 8	2	1
12	---	12	1	1

The delays used on each visit for all children followed longitudinally are summarized in Figure 5. Each box in the diagram represents a visit. The number written inside a box indicates the length of delay in seconds at which the $A\bar{B}$ error occurred on that visit. A blackened box indicates performance was <u>too accurate</u> to be termed an $A\bar{B}$ error. Striped boxes denote visits where performance was <u>too poor</u> to be an $A\bar{B}$ error.

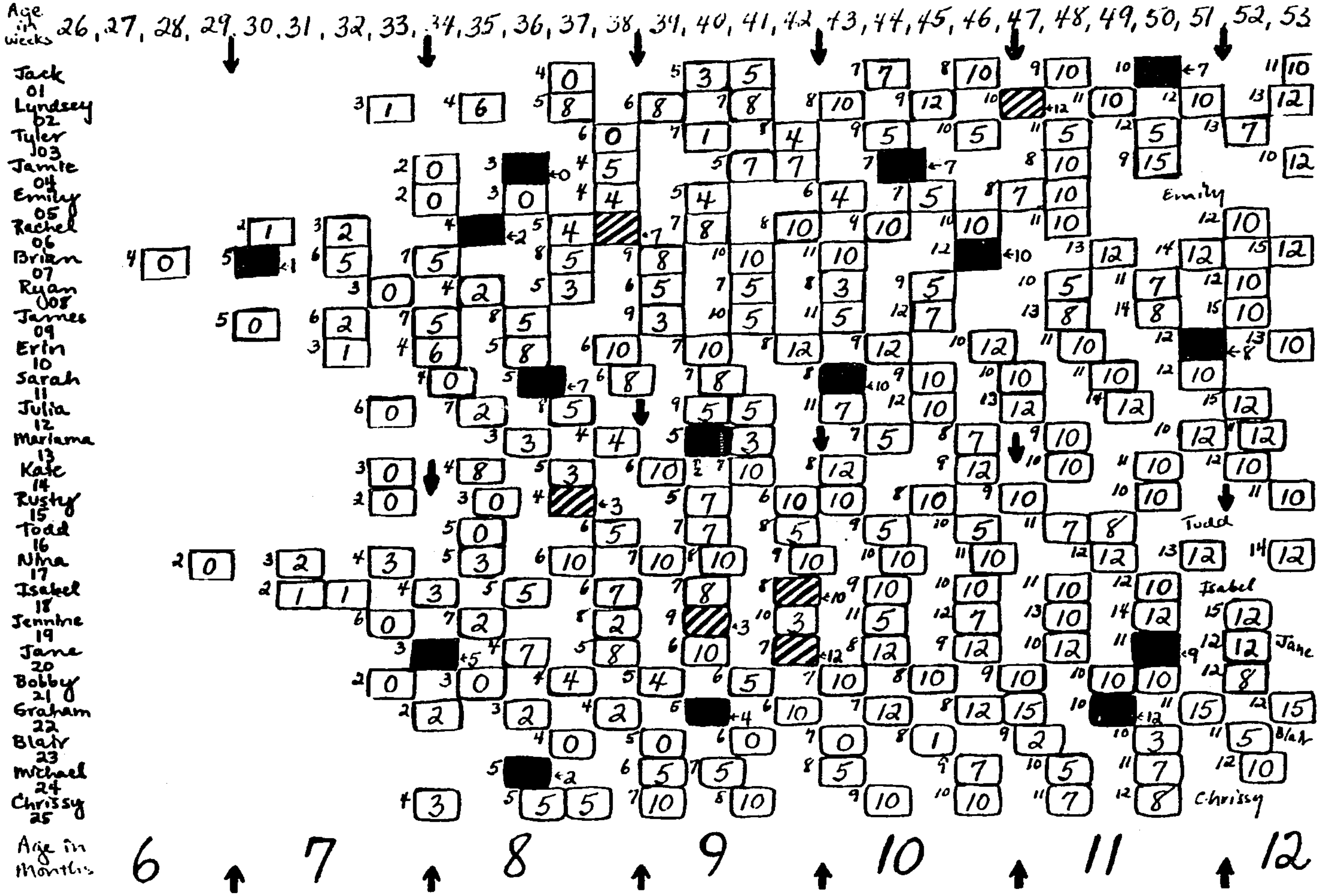
The first thing to note in Figure 5 is that the $A\bar{B}$ error occurred on most visits; few boxes are black or striped. This is not what one would have expected based on the published work on $A\bar{B}$. Other investigators, studying cross-sectional samples of children, report observing the $A\bar{B}$ error in only one half of their subjects. As Butterworth wrote in 1975, summarizing his own findings, "In none of the experimental conditions did the number of infants making an [$A\bar{B}$] error differ significantly from chance."

Yet, <u>all</u> infants followed longitudinally in the present study made the $A\bar{B}$ error, as Figure 5 shows. We will shortly discuss several reasons for this discrepancy in findings.

Another reason for few black or striped boxes in Diagram 8 is that the $A\bar{B}$ error occurred repeatedly over sessions for each subject. This error is not transient. Again, our work disagrees with earlier work. Other longitudinal studies of $A\bar{B}$ used a constant delay, or a narrow range of delays. They found the error to disappear within a month or two (e.g., Gratch and Landers, 1971). Using a much larger range of delay (0-15 seconds), we were able to observe the $A\bar{B}$ error throughout the second half of the first year of life. From the age at which the $A\bar{B}$ error first appears until at least 12 months of age (when testing was

Figure 5: LENGTH OF DELAY USED AT EACH VISIT

Legend: Each box represents a visit. Number outside box to upper left indicates number of that visit. Early visits, where the child is not yet committing the A$\bar{B}$ error, are not pictured here. Number inside box = A$\bar{B}$ error occurred at that length of delay on that visit. Blackened box - virtually errorless performance (delay written to right). Striped box = performance too poor to be called A$\bar{B}$ (delay written to right).



stopped), infants make the A$\bar{B}$ error repeatedly, as long as the delay interval is gradually incremented as the infants grow older. Thus, the A$\bar{B}$ error has a longer life than previous investigators had suggested.

The delay needed to produce the A$\bar{B}$ error at each age is summarized in Figures 6 and 7 and Table 27.[30] Note that the range of delay needed for the A$\bar{B}$ error at each age is quite large. Infants of the same age differ a good deal in how long each can remember where a toy has been hidden. The other side of this coin is that the age at which a given delay produces the A$\bar{B}$ error varies a great deal across infants. One can also see from Figure 5 that the period of efficacy for any single length of delay is brief for each child.

It is little wonder that previous investigators have found the A$\bar{B}$ error in only about half of the infants tested and, without continuing to increase the delay interval, found the A$\bar{B}$ error to disappear after a month or so. Figure 6 illustrates the problem in selecting a single delay length for children of a particular age. If one uses a standard delay for all children, it is likely to be too short for many children to err at all and too long for many others to show the consistency of behavior characteristic of the A$\bar{B}$ error. Moreover, even a delay that produces the A$\bar{B}$ error in a particular child will not continue to do so for very long. The memory of the infant improves steadily over these weeks. Each child presents a "moving target" if one is hoping to hit the A$\bar{B}$ error at a particular length of delay. In addition, many investigators used a single trial criterion of absence or presence of the A$\bar{B}$ error. By this criterion, the A$\bar{B}$ error occurred only about half the time even in the present study. It is important to note, however, that by tailoring the delay to the child and by using a criterion that looks

Figure 6

DISTRIBUTION OF DELAY LENGTHS AT WHICH A$\bar{B}$ ERROR OCCURRED OVER THE PERIOD OF 7-12 MONTHS OF AGE.

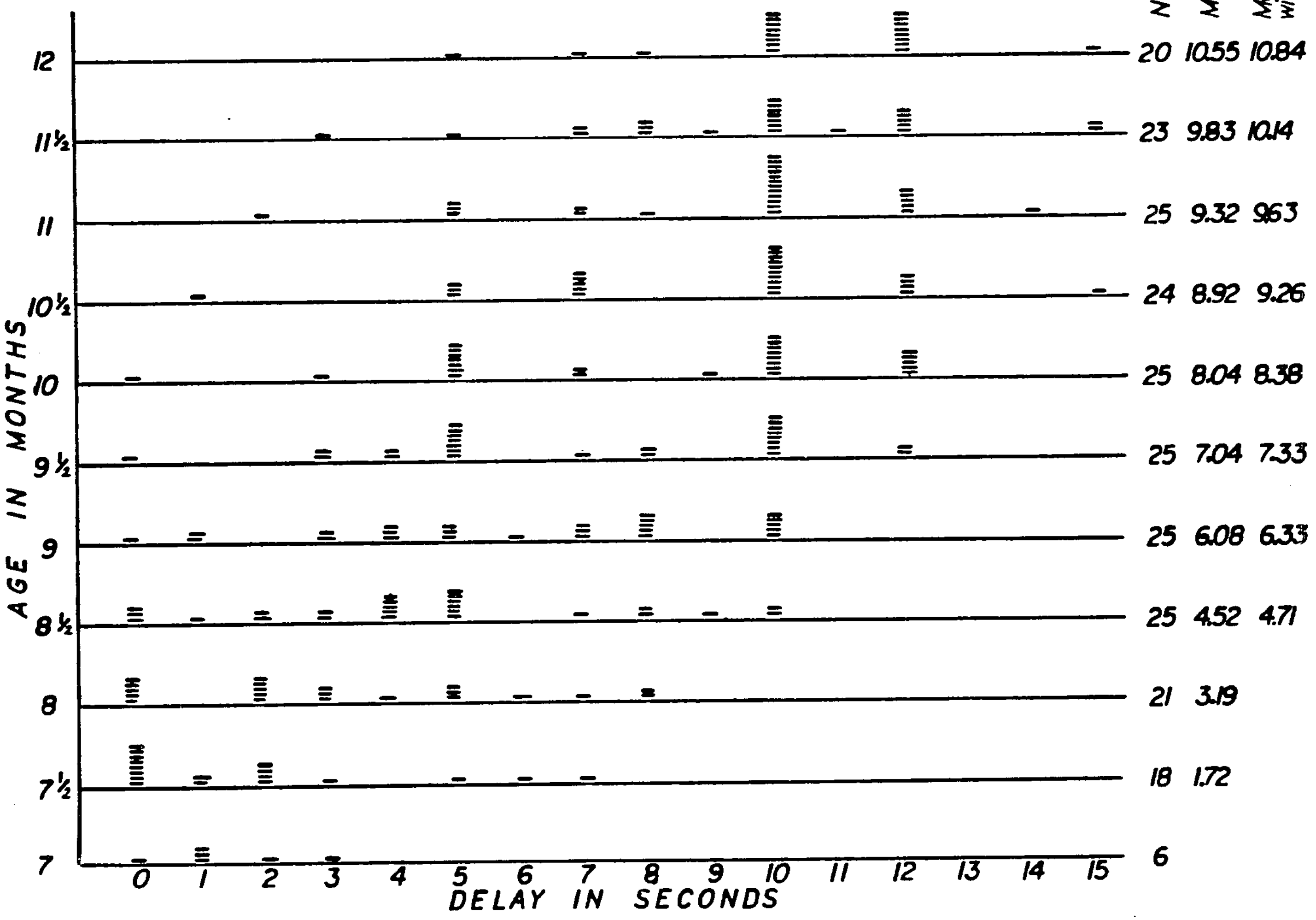


Figure 7: Delay at Which $A\bar{B}$ Error Occurs by Age

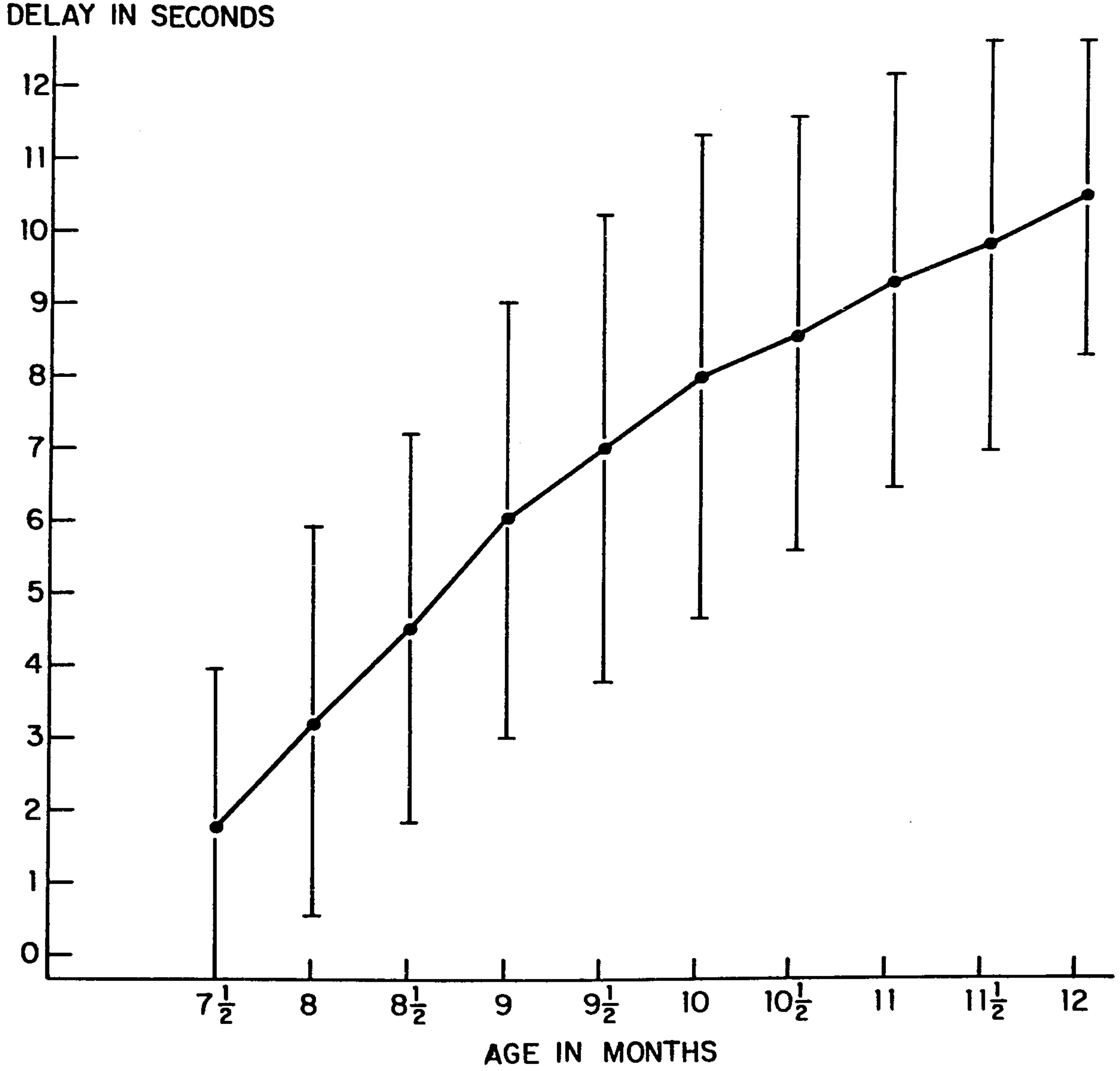


Table 27

DELAY LENGTH PRODUCING $A\bar{B}$ ERROR AT EACH AGE

AGE IN MONTHS	AVERAGE DELAY AT WHICH $A\bar{B}$ ERROR OCCURRED	CHANGE IN DELAY FROM PREVIOUS 2 WEEKS
7½	1.72 (N=18)	--
8	3.19 (N=21)	+1.51
8½	4.52 (N=25)	+1.56
9	6.08 (N=25)	+ .96
9½	7.04 (N=25)	+1.24
10	8.04 (N=25)	+1.00
10½	8.92 (N=24)	+ .88
11	9.32 (N=25)	+ .40
11½	9.83 (N=23)	+ .51
12	10.55 (N=20)	+ .72

at performance over several trials, the A$\bar{B}$ error is found in all children (not simply 50%) and remains for many months.

There appears to be no evidence of a sudden "jump" or discontinuity in the length of delay needed to produce the A$\bar{B}$ error. Rather, the duration of delay necessary for the error increases gradually and continuously. This can be seen in Figure 7 and Table 27. At 8 months of age, the average length of delay needed to produce the A$\bar{B}$ error was 3.9 seconds. At 9 months, this had increased to 6.4 seconds, at 10 months 8.5 seconds, and at 11 months 9.6 seconds. Large increases in the delay appropriate for individual children did occur occasionally, however. The largest of these were: (1) an increase over a 2 week period from the A$\bar{B}$ error with a 0 second delay to perfect performance with a 7 second delay, shown by Sarah when she was 8 months old; and (2) an increase over 2 weeks from 0 seconds to 8 seconds in order to produce the A$\bar{B}$ error, shown by Kate between 7-1/2 and 8 months of age.

<u>Dependence of Measured Memory Ability on Motivational Factors</u>.

Performance is an imperfect indicator of ability. Increases in an infant's desire for what is hidden increase the length of delay which the infant can tolerate. On all trials discussed thus far, a toy was used as the reward. On 90% of these trials, the infant's level of interest in the toy was judged as "high." We would like to present evidence here that the results presented on delay length are specific to these two aspects of the experimental situation. One finds different results on delay if (a) one uses a toy that the infant shows "little" interest or "extremely high" interest in; or (b) one hides food rather than a toy.

We determined the baby's level of interest from the video coder's answers to the items given below. The possible answers to each item were: Absent, Present, Extreme, and not applicable (uncodable).

At the outset of the trial -- when toy is presented, the baby:

- Watches toy attentively
- Smiles upon seeing toy
- Vocalizes happily
- Bounces up and down
- Tries to grab toy
- Bangs table excitedly.[31]

At the close of the trial -- after the toy is uncovered, the baby:

- Watches toy attentively
- Smiles upon seeing toy
- Vocalizes happily
- Bounces up and down
- Tries to grab toy

(If not permitted to have the toy:)

- Disappointed/upset at not being allowed to have toy

(If permitted to have toy:)

- Plays with toy
- Maintains interest in toy throughout play period
- Reluctant/unwilling to relinquish toy.[32]

The baby's level of interest in the toy was judged as "high" if 2 or more of these behaviors were rated as present at the outset and 3 or more as present at the end of the trial (unless the more stringent criteria for "extremely high" were also met). Level of interest was judged as high on 85% of the trials. Level of interest was judged "extremely high" if, either at the outset of the trial <u>or</u> at the trial's close, (a) any behavior received a rating of extreme, or (b) no behavior was rated as absent and at least 5 behaviors were rated as present (the other behaviors being judged not applicable). If the criterion for "extremely high" was met either at the beginning or end of a trial, level of interest in the toy for that trial was said to be "extremely high." Only 4% of all trials received a rating of "extremely high" level of interest in toy. Level of interest was judged as "low" if either at the outset <u>or</u> the end of a trial, only one or fewer of the behaviors was present. If this criterion was met either at the beginning or close of a trial, level of interest in the toy for that trial was said to be "low." On 11% of all trials, level of interest was rated as "low."

On repeat trials following errors, the average percentage of correct reaches was 34%. If one breaks this down by level of interest in toy, you find:

Low Interest. . . . . 28% correct (N=101)
Mean of each child's % correct= 29

High Interest . . . . 34% correct (N=756)
Mean of each child's % correct= 34

Extremely High Interest . . . . 48% correct (N= 33)
Mean of each child's % correct= 46

Thus, babies tended to perform better when they were more interested in the toy, but these differences are not significant at even the .10 level (chi square = 3.55). (The observed value for each cell was calculated by averaging the observed percentage for each child. Thus, each child was counted only once per cell.) What happens, however, if we have been testing a child at a delay interval appropriate for one level of interest and the child's level of interest changes? (This can happen, for example, if the child becomes bored with a toy or if a new toy is introduced which excites the child's interest.) Here one finds on repeat trials following errors, that the percentages of correct reaches are:

Decreased Level of Interest . . 25% correct (N= 92)
Mean of each child's % correct= 25

No Change in Interest . . . . . 33% correct (N=711)
Mean of each child's % correct= 34

Increased Level of Interest . . 54% correct (N= 87)
Mean of each child's % correct= 52

These differences are significant at the .05 level (chi square = 6.30). Table 28 summarizes the findings on level of interest in toy and change in level of interest. Thus, at a given delay, performance was poorer when level of interest in the toy decreased and performance improved when level of interest increased.

This effect can also be seen from the 295 repeat trials following errors where we introduced a new toy. On 236 of these trials, there was no change in level of interest from that demonstrated on the previous trial. However, on 59 of these trials, there was an increase in interest (either from low to high, from high to extremely high, or, in three cases, from low to extremely high). On the 236 trials where there was no change in level of interest, infants erred as often as on the comparable trials where the same toy was used again (36% correct with different toy, 32% correct with same toy). However, on the 59 trials

Table 28

PERCENTAGE OF CORRECT REACHES ON REPEAT TRIALS FOLLOWING ERRORS BY LEVEL OF INTEREST IN TOY AND CHANGE IN LEVEL OF INTEREST

	CHANGE IN LEVEL OF INTEREST IN TOY FROM PREVIOUS TRIAL									
	INCREASED INTEREST			NO CHANGE IN INTEREST			DECREASED INTEREST			
LEVEL OF INTEREST IN TOY	Total No. of Trials	No. of Correct Reaches	$\frac{\text{Correct}}{\text{Total}}$	Total No. of Trials	No. of Correct Reaches	$\frac{\text{Correct}}{\text{Total}}$	Total No. of Trials	No. of Correct Reaches	$\frac{\text{Correct}}{\text{Total}}$	total
Extremely High	21	13	.62	12	3	.25	--	--	---	.48
High	66	34	.52	660	213	.32	30	8	.27	.34
Low	--	--	---	39	13	.33	62	15	.24	.28
Totals	87	47	.54	738	246	.33	92	23	.25	.34

where level of interest was increased the percentage of correct reaches increased to 52%. (See Table 29.) If one compares 52% to an expected value of 34% (the overall percentage of correct reaches on such trials), and one performs a chi square test on this, one finds this difference to be significant at less than .02 (x2 = 6.39).

Two previous studies have looked at the effect of a change in the toy on the A$\bar{B}$ error. Evans and Gratch (1972) found that the A$\bar{B}$ error was as likely to occur with a new toy as with the old toy. Schuberth et al. (1978), however, found that infants were less likely to err on the first B trial (the reversal trial) and less likely to continue erring on the subsequent repeat trials if a different toy were introduced than if the same toy were used throughout.

Our work suggests an explanation for these contradictory findings. A new toy will improve performance if there is a marked increase in motivation for, or interest in, the toy. It will <u>not</u> improve performance if the baby does not want the new toy any more than he wanted the old toy. Indeed, the crucial variable is interest in toy, not whether the toy is same or different. Thus, we suggest that the finding of Schuberth et al. may well be an artifact of the fact that a change in toy was correlated with a change in level of interest. The A$\bar{B}$ error appears equally likely to occur when the same toy or a new toy is used, as long as the toys do not differ markedly in their level of interest for the infant.

If our infants had been tested with rewards they cared significantly less about than the toys we used, we would probably have needed shorter delays to produce the A$\bar{B}$ error at each age. Similarly, if a significantly higher level of interest could have been maintained consistently, then, at each age, the infants might have been able to remember over longer delays than we found to be the case. Although, with the subjects studied longitudinally, we have no data specifically demonstrating that the $A\bar{B}$ error occurred at different delay lengths as a function of level of interest, we do have such data from subjects in the cross-sectional sample.

When testing one of these cross-sectional subjects we could not find any toy that would spark the baby's interest. Out of desperation, we tried hiding a small piece of arrowroot cookie. It worked; the baby's level of interest could not have been higher. We then tried this with a few other subjects. We began these testing sessions with a toy, established the length of delay at which they would make the $A\bar{B}$ error, and then switched to hiding a small piece of cookie. The infants now performed perfectly and we found we had to increase the delay by several seconds in order to produce the $A\bar{B}$ error. At this point, we decided to begin systematically testing the difference in performance with a toy as the reward and with food as the reward. We decided against using food with the subjects tested longitudinally. By now many of the longitudinal subjects had already been tested for several months with toys. Food seemed to so dramatically affect the length of delay that infants could tolerate that we feared the use of a food reward would complicate between-subject comparisons and the description of delay changes over age.

Twenty-one subjects from the cross-sectional sample were tested with food as the reward (18 with arrowroot cookies or similar edibles which the parent happened to have brought along and 3 with a bottle of milk). These sessions always began with a toy as the reward. The

Table 29

PERCENTAGE OF CORRECT REACHES FOLLOWING ERRORS WITH AND WITHOUT A CHANGE OF TOY

	Number of Correct Reaches	Total Number of Trials	Percentage of Reaches that were Correct
TOTAL	305	897	34%
SAME TOY	194	602	32%
DIFFERENT TOY			
Increased Level of Interest in Toy	30	59	52%
Unchanged Level of Interest in Toy	81	236	36%
TOTAL	111	295	38%

length of delay necessary for the A$\bar{B}$ error was determined. Then we hid food instead of the toy. If the infant reached correctly over 3 reversal trials, we increased the delay by 2 or 3 seconds. If performance remained perfect, we increased the delay again, and if the child still did not err, yet again.

The average increase in length of delay needed to produce the A$\bar{B}$ error when the child was searching for food rather than for a toy was 3 seconds. Every one of the 21 subjects reached perfectly when food was used at the same delay length at which they had just made the A$\bar{B}$ error when a toy was used. Seven subjects made the A$\bar{B}$ error with food with an increase of 2 or 3 seconds over the delay needed with a toy. Nine subjects made the A$\bar{B}$ error with food when the delay was increased by 4 or 5 seconds. Four did not make the A$\bar{B}$ error with food until the delay had been increased by 6 seconds, and one little girl never made the A$\bar{B}$ error after we began using food as the reward (up to an increase in delay of 6 seconds). These results are summarized in Table 30.

Thus, the delay length needed to produced the A$\bar{B}$ error with food is several seconds longer than is needed to produce the error with a toy. This is because infants are more highly motivated to get food than they are to get a toy. We hypothesize a similar difference in length of delay needed to produce the A$\bar{B}$ error would be found if one used a beloved toy and a toy only moderately interesting to a child. If one replicated our longitudinal study with food as the reward, rather than toys, one might well find the infants able to tolerate longer delays at each age level, however we predict that the shape of the delay x age function would not vary. The lengths of delay which we found infants could tolerate are undoubtedly specific to our experimental situation;

Table 30

DELAY LENGTH NEEDED TO PRODUCE THE $A\bar{B}$ ERROR WHEN FOOD IS HIDDEN RELATIVE TO DELAY LENGTH NEEDED WHEN A TOY IS HIDDEN WITHIN THE SAME TESTING SESSION

	Delay Needed to Produce $A\bar{B}$ Error		
	With Toy Reward	With Food Reward	Increment in Delay Needed to Reinstate Error When Food Reward Substituted for Toy Reward
Nathan	1	3	2
Andrew	1	5	4
Kathryn	1	5	4
Matthew	2	5	3
Sarah	3	7	4
Bobby	3	9	6
Joseph	3	7	4
Rebecca	3	5	2
Bridget	5	10	5
Peter	5	11	6
Amy	5	7	2
Howard	5	7	2
Ian	5	11	6
Reshad	5	10	5
Amelia	5	11	6
Ulie	6	10	4
Melissa	7	*	*
Kyla	7	10	3
Ian	7	12	5
Neil	8	12	4
Jennifer	8	12	4

* Even when delay was increased to 13 seconds, Melissa did not commit the $A\bar{B}$ error when food was used. A delay longer than 13 seconds was not tried.

change the situation and you are likely to find the measured memory ability of infants will change as well.[33]

Sex Differences in Length of Delay Tolerated

Did the children who seemed to be able to tolerate a longer delay show any other signs of superior performance? Or, perhaps, had we overtaxed the memory of some infants by overly long delays or made the task overly easy for other infants by not challenging their memories sufficiently? If this were the case, the performance of the infants tested at the longer delays should have been worse that that of the infants tested at the briefer delays.

In general, girls could tolerate longer delays than boys. This can be seen in Table 31 and Figure 8. Regression analysis revealed that the sex difference here is significant at $p< .0001$, and can be accounted for equally well by the hypothesis that girls and boys start out equal at 7-1/2 months but the memory of girls improves faster (Model 2 below) or by the hypothesis that by 7-1/2 months the memory of girls is already superior and from 7-1/2 - 12 months improvement proceeds at an equal rate in males and females (model 3 below).

We tested this using 4 regression models of the delay x age function:

1) single slope and intercept for all children, male and female
2) different slopes for males and females, but equal intercepts
3) constant slopes, but different intercepts for males and females
4) slope and intercept vary with sex

Models 2 and 3 accounted for the data significantly better than did Model 1 (Model 2 vs. Model 1: $t= 6.21$, $p < .0001$; Model 3 vs. Model 1:

Table 31

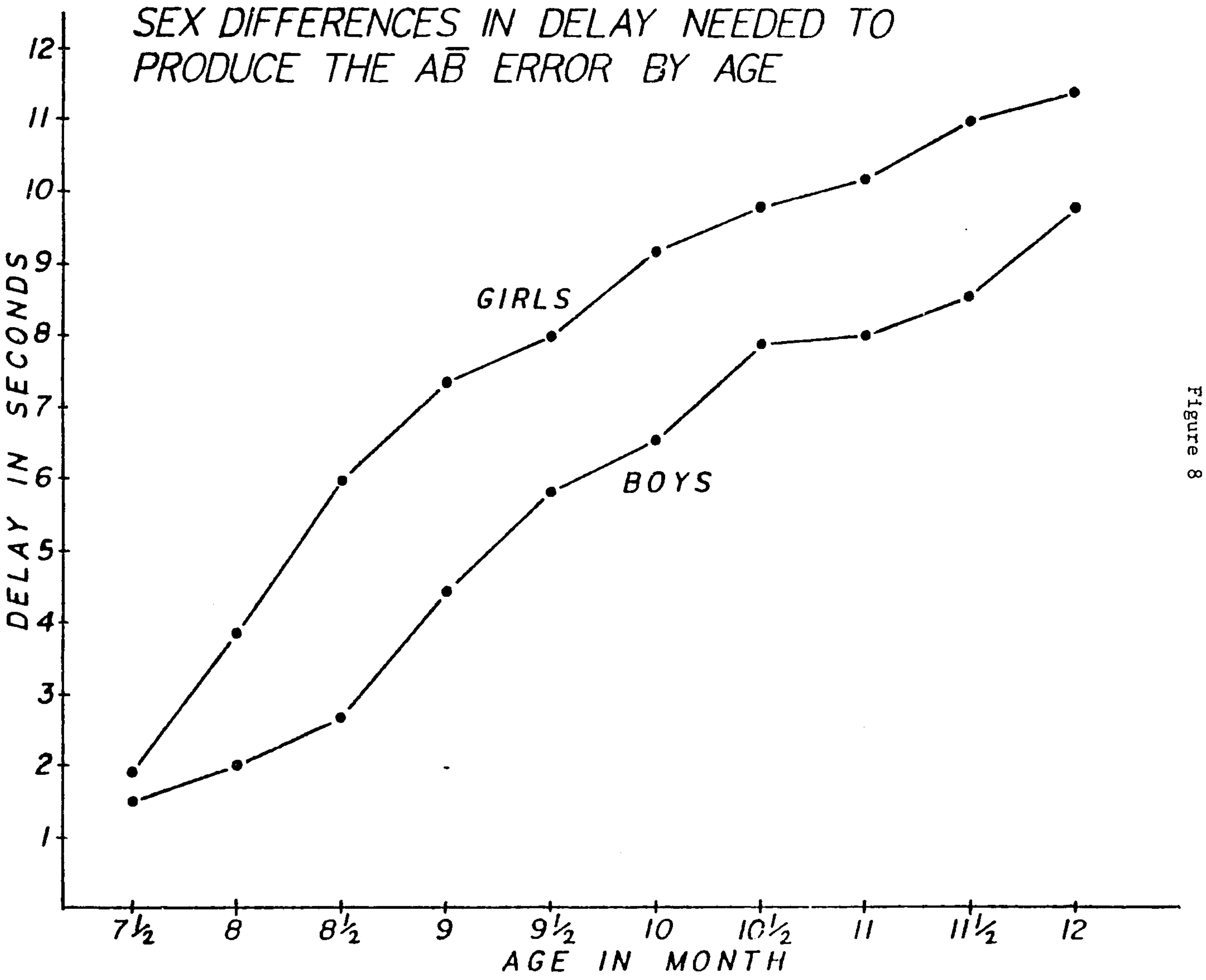
AVERAGE LENGTH OF DELAY (IN SECONDS) AT WHICH
A$\bar{B}$ ERROR OCCURRED AT EACH AGE, BY SEX

AGE IN MONTHS	GIRLS (N=14)*	BOYS (N=11)*	BOYS WITHOUT BLAIR (N=10)*
7½	1.92 (N=12)	1.50 (N=6)	**
8	3.79	2.00 (N=7)	**
8½	6.00	2.64	2.90
9	7.36	4.45	4.90
9½	8.00	5.82	6.40
10	9.21	6.55	7.20
10½	9.77 (N=13)	7.91	8.60
11	10.21	8.00	8.60
11½	11.00 (N=12)	8.55	9.10
12	11.40 (N=10)	9.77 (N=10)	10.22 (N=9)

*Unless otherwise indicated.

**Blair did not begin to make the A$\bar{B}$ error until 8½ months of age.

Figure 8



SEX DIFFERENCES IN DELAY NEEDED TO PRODUCE THE A$\overline{B}$ ERROR BY AGE

$t= 15.88$, $p < .0001$), but a comparison of Models 2 and 3 with each other did not yield a significant difference. Model 4 was not a significant improvement over Models 2 and 3 and could therefore be rejected (Model 4 vs. Model 2: $t= 0.45$, n.s.; Model 4 vs. Model 3: $t= 0.41$, n.s.). See Table 32.

In what other ways did the performance of the girls and boys differ?

Girls start to make the $A\bar{B}$ error at an earlier age than do boys. Eighty-six percent of the girls were making the $A\bar{B}$ error by 7-1/2 months, while only 55% of the boys were doing so at this age. By 8 months, all the girls were now showing the $A\bar{B}$ error, while 36% of the boys had yet to do so. This suggests that the girls may have been maturing faster than the boys, and is in accord with the plethora of evidence showing faster rates of development in girls. One can see from Table 31 that the average delay used with boys of 11 months of age was equal to the average delay the girls needed at 9-1/2 months, and by 12 months the boys were at the average length of delay which the girls had reached by 10-1/2 months.

The median percentage of correct reaches on repeat trials following a correct reach was 79% for both boys and girls. (See Table 7.) The average rate of correct responding on reversal trials was roughly equal across the sexes (36% for the boys and 33% for the girls)(Table 10). On reversal trials following sight trials (Table 18), both boys and girls reached correctly 48% of the time. Looking at the difference in proportion of correct reaches on repeat trials following errors when identical covers were used (Table 11) and when different covers were used (blue over toy) (Table 13), one finds that the average difference here was .24

Table 32

REGRESSION ANALYSIS OF
DELAY AS A FUNCTION OF AGE
FOR BOYS AND GIRLS

MODEL 1: NO SEX DIFFERENCES

	SSE	1887.559	F RATIO	191.96
	DFE	229	P	0.0001
DEP VAR: DELAY	MSE	8.242615	R SQUARE	0.4560

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	P
Intercept	1	-11.613945	1.358543	-8.5488	0.0001
Age	1	1.905652	0.137542	13.8551	0.0001

MODEL 2: EQUAL SLOPE, SEX DIFFERENCES IN INTERCEPT

	SSE	1614.127	F RATIO	131.06
	DFE	228	P	0.0001
DEP VAR: DELAY	MSE	7.079502	R SQUARE	0.5348

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	P
Intercept	1	-11.296312	1.260085	-8.9647	0.0001
Age	1	1.970687	0.127897	15.4084	0.0001
B	1	-2.203199	0.354511	-6.2147	0.0001

MODEL 3: EQUAL INTERCEPT, SEX DIFFERENCES IN SLOPE

	SSE	1613.9	F RATIO	131.10
	DFE	228	P	0.0001
DEP VAR: DELAY	MSE	7.078509	R SQUARE	0.5349

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	P
Intercept	1	-12.203381	1.262524	-9.6659	0.0001
AgeB	1	-0.222420	0.035772	-6.2178	0.0001
Age	1	2.063465	0.129962	15.8775	0.0001

MODEL 4: SEX DIFFERENCES IN SLOPE AND INTERCEPT

SSE	1612.695	F RATIO	87.14
DFE	227	P	0.0001
MSE	7.104383	R SQUARE	0.5352

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	P
Intercept	1	-11.770022	1.645321	-7.1536	0.0001
AgeB	1	-0.116531	0.259604	-0.4489	0.6539
Age	1	2.019608	0.168204	12.0069	0.0001
B	1	-1.059467	2.572592	-0.4110	0.6809

for boys and .26 for girls. Thus, both sexes appeared to show the effect of a blue landmark to approximately the same degree. On the test of relative versus absolute position, 4 boys were relative reachers, 5 were absolute reachers, and 2 showed no preference. Among the girls, 5 were relative reachers, 4 were absolute reachers, and 5 showed no preference. Again, we find no sex difference in the data.

The only comparison which yielded any sex difference at all was for performance on repeat trials following errors (Table 11). Here, the proportion of correct reaches by boys was .40 and for girls .29. This difference is not significant, but it does suggest that the boys were somewhat less likely to continue erring than were the girls. The strings of perseverative errors were longer for the girls. Babies tend to perseverate when they are pushed beyond their ability. We found this to be one of the behavioral responses of the children when we increased the delay 2-3 seconds above that required for the $A\bar{B}$ error. If the girls had shown other signs of impaired performance we would worry that, indeed, the delays used with the girls had been longer than they should have been and the seeming sex difference in memory might be experimental artifact. However, since the performance of the girls is worse on only this one measure (and even here the difference is not significant), the weight of evidence seems to suggest that the difficulty of the task was approximately equal for girls and boys, even though the girls were tested at consistently longer delays.

If one compares the delay at which a given child was tested during a given two week interval with the average delay used at that age, one finds that 12 children[34] were tested at delays consistently longer than the average, 9 children[35] were tested at delays consistently shorter than the average, and 4 children[36] were not consistently tested at either longer or shorter delays. Did the performance of the 12 longer delay babies differ from that of the 9 shorter delay babies?

The average age of onset of the $A\bar{B}$ error among the children tested at the longer delays was 32 weeks, while for the children tested at the shorter delays it was 35 weeks. Again, we find a suggestion of a difference in rate of maturation.

No comparison between children tested at delays of different lengths yielded a significant difference. For example, on repeat trials following correct reaches, infants tested at longer delays reached correctly 79% of the time; those tested at shorter delays reached correctly 81% of the time. On reversal trials (Table 10), both groups of children were correct on 34% of the trials. We find no evidence that the children who seemed able to remember over longer intervals showed superior performance in other ways as well and no evidence that the children tested at longer delays showed signs of inferior performance which would have resulted had we used inappropriately long delays.

Age of Onset and Delays of "0" Seconds

We found the average age for the first appearance of the $A\bar{B}$ error to be 7-1/2 months (33 weeks, 6 days). Indeed, 12 of the 25 children first showed the $A\bar{B}$ at exactly 7-1/2 months. The range was 6 months (28 weeks, 3 days) to 8-1/2 months (38 weeks, 5 days). (Results are summarized in Table 33.) Gratch and Landers (1971), who also followed infants longitudinally, found the average age of onset of the $A\bar{B}$ error to be 8 months.

Table 33

AGE AT WHICH A$\bar{B}$ ERROR FIRST APPEARS

AGE IN MONTHS	NUMBER OF CHILDREN FIRST MAKING A$\bar{B}$ ERROR AT EACH AGE	TOTAL NUMBER OF CHILDREN WHO HAVE MADE A$\bar{B}$ BY EACH AGE (INCLUSIVE)
6	1	1
6½	1	2
7	4	6
7½	12	18
8	3	21
8½	4	25
TOTAL	25	

We did _not_ find the A$\bar{B}$ error with a delay of 0 seconds in all of our subjects, but we did find it in 15 of the 25 children. (This can be seen from Figure 5.) (Piaget (1952) reports finding the error with no delay, but Gratch and Landers (1971) and Gratch et al. (1974) report that while infants erred with delays of 1-5 seconds they did not err with no delay. It should be noted, however, that in these studies no distractor was used during the delay, nor were the infants restrained. When Harris (1973) distracted the infants by covering the empty, but previously correct, well last, infants erred even with a 0 second delay. Refer back to Table 5. Brody (1981) trained infants on a Delayed Response task similar to A$\bar{B}$. She found that 8 month olds could perform well at a delay of 250 milliseconds, but failed at delays as brief as 3 seconds.) These results demonstrate that the A$\bar{B}$ error will occur with a "0" second" delay. However, even with a "0" second delay memory appears to be a central part of the problem for the infant. In order to have absolutely no delay between hiding and retrieval, the infant cannot be restrained. We chose to restrain our infants because, when infants are permitted to strain, the A$\bar{B}$ task becomes overly easy for them. The delays we call "0" seconds were actually 0.2-0.8 seconds in duration. We were able to find no way to restrain the infants and to reduce the delay below .2 seconds.

Therefore, there was a delay, albeit small, over which infants in the "0" second delay condition had to remember where the toy had been hidden. More than once, the infants who erred here would begin to reach toward a well and then stop themselves, as if they had forgotten why they had started to reach. Other times, they would reach and remove a cover, but then not look in the well; instead, they would look up with a confused or embarrassed expression on their faces and drop the cloth, or they would become interested in the cloth forgetting the toy. When these infants were not restrained, and could reach with no delay at all, they rarely erred. (On 44 reversal trials and repeat trials following errors these infants were not restrained. Their torsos were held back during the hiding, but their arms were not held. They erred on only 17 of these trials. Recall, the average error rate on these kinds of trials is 66%.)

These results are in accord with observations from sessions where longer delays were used. We tried to minimize the infant's ability to strain during the delay, but on some trials infants managed to maintain a bodily orientation toward the correct well anyway. On repeat trials following errors and on reversal trials, where the strain was unbroken, the percentage of correct reaches was 39%. This is significantly better than performance when the children did not strain or did not sustain the strain until the very end of the delay, where percent correct was 31% (matched sample $t = 2.81$, $p = .01$). This difference of only 8% is significant because the standard deviations around the mean are small (for $\bar{x} = .39$, sd = .07, for $\bar{x} = .31$, sd = .12).

It was not possible in the 0 second delay condition to say something to make the children look up (as was done with all other delays). However, sometimes the infants looked up on their own, distracted by the act of covering. Success rates on such trials (where visual fixation to the correct well was broken) plummeted. The infants were generally correct when they kept looking at the correct well.

Again, this is similar to the results with longer delay intervals. Here, the children did not err if they maintained a fixed gaze at the well containing the toy. Errors appear primarily on those trials where the infants are distracted. We examined this during pretesting by speaking on one half the trials to make the infants look up and remaining silent during the delay periods on the other trials so that the infants could continue looking at the correct well. We found that at delays sufficiently long to produce the A$\bar{B}$ error when the experimenter spoke, the infants performed almost flawlessly when visual fixation was unbroken. In the longitudinal study, we did not attempt to test this systematically, but we do have data on trials where infants resisted the experimenter's efforts to make them look up. These were trials where, despite the experimenter's best verbal enticements, the infant's eyes remained glued to the place of hiding. The babies were correct on 53% of such repeat trials following errors and reversal trials. This is significantly better performance than on comparable trials when their gaze was broken, where percent correct was 28% (matched sample $t = 7.51$, $p < .0001$). Others, too, have found that when infants continue to fixate on the correct well they reach correctly (Gratch and Landers, 1971; Cornell, 1979). Szpak (1977) and fox et al. (1979) report that infants were able to perform well at much longer delays when a screen was not used than when it was.

Thus, errors with a delay of 0 seconds appear to be no different in kind from the errors that occur with longer delays. Whatever causes the A$\bar{B}$ error with longer delays is also responsible for the error in the 0 delay condition. Specifically, memory is a factor with all delays -- several seconds or "0" seconds.

Behaviors Seen Prior to the A$\bar{B}$ error

It had been our interpretation of the published research on $A\bar{B}$ that once infants can find a totally covered object when one hiding place is used, they make the $A\bar{B}$ error. Piaget, for example, has said that the characteristic behavior of Stage 3 Object Permanence is the ability to retrieve a partly hidden[37] object, but not a totally hidden one. Stage 4 is characterized by the $A\bar{B}$ error. We were surprised, therefore, to find that for about one quarter of our subjects there was at least one visit where they could find a totally covered object when a single hiding place was used, but performed too poorly when two hiding places were used for their behavior to be called the $A\bar{B}$ error.

Six of our 25 subjects, on the first visit in which they were able to find a totally hidden object when only one well was covered, failed to demonstrate the $A\bar{B}$ error when two covers were used.[38] (One infant continued to perform thusly on the next visit as well.) All of these infants failed to demonstrate the $A\bar{B}$ error because they did not perform well enough to meet the criteria for the error. They either reached randomly, or more commonly, never reached at all. Sometimes the infants looked back and forth between the two covers, clearly confused. Occasionally, they cried.

In order to understand what this behavior might mean, it is helpful to look at the behaviors in younger babies.

Younger babies can find a partly hidden, but not a totally hidden, object. Their inability to find a totally covered object is an extraordinary phenomenon to observe. We found, for example, that if in reaching for the partly covered object, the infant accidentally pushes it all the way under the cover, he will immediately give up the attempt to get the object. Infants are not able to retrieve the toy even though they themselves pushed it under the cover.[39] Gratch and Landers (1971) report that if a 6 month old is holding an object and you toss a cloth over the object and the infant's hand, the infant seems no longer to know that he is holding the object.

The most commonly given explanation for this phenomenon is "out of sight, out of mind"; once the infant can no longer see something, he forgets that it exists. Our observations do not support this conclusion, however. Babies of 5 or 6 months often react with seeming indifference if the toy is taken away from them even if it is still visible. Infants a little older often showed prolonged search, although they seemed to have no idea of where to look. The notes made by different coders on the behavior of different children sound quite similar:

> "Looks around as if looking for toy, but makes no effort to remove the cover."
>
> "Clearly after toy, but doesn't know where it is, searches randomly."
>
> "Knows what she is looking for, but she's just guessing. No memory of where toy is."
>
> "Search-like behavior, but no uncovering."

Sixteen of our subjects displayed this behavior on at least two trials, and often over several trials.

Another common behavior seen at this stage was crying, sometimes wailing, at the toy's disappearance. One little boy showed this reaction in particularly dramatic form. He bawled horribly as soon as the toy was covered, and continued to do so as long as the toy was not visible. He refused to be placated by other toys, but stopped crying instantly when the toy was partly uncovered.

Thus, the 16 children who seemed to search for the toy and the one little boy who continued to cry until the toy reappeared, seemed to remember what they wanted, but to forget, or not understand, where it was hidden or how to regain it.

Although 8 of our subjects showed no particular signs of memory of the toy (they stared up at the experimenter expressionless, found something else with which to amuse themselves, or halted their crying and fussing when offered an alternate toy), we believe the behavior of the other 17 children calls the "out of sight, out of mind" explanation into question.[40]

Each infant at this stage, when unable to find the toy, was given two cues by the experimenter. The experimenter put her hand underneath the cover and squeaked or rattled the toy. If this failed to aid the infant, the experimenter moved the toy back and forth underneath the cover in addition to making noise with it. Not one of the 25 infants was ever aided by either of these cues. No infant ever tried to reach under the cover, or remove the cover, in response to the sound or to the sound plus movement. We also tried placing large toys (a toy dump truck or a children's radio) on the flat tabletop and covering it with a cloth. These created large "bumps" underneath the cloth. Again, this did not aid any infant who could not otherwise find a totally covered object. Yet, in all instances, as soon as the toy was uncovered, the infant reached for it straight away. Failure to retrieve the toy was not due to lack of interest in the toy.

Why do babies, at this stage, fail:

1) . . .to realize they are holding an object if their hand and the object are covered?

2) . . .to retrieve a toy which they themselves have just pushed under a cover?

3) . . .to retrieve a covered toy that is emitting sound?

4) . . .to retrieve a toy that is moving beneath the cover?

5) . . .to retrieve a toy that is bulging beneath the cloth?

We suggest that part of the problem for these children is an inability to integrate contradictory sensory information. When the visual information available to them is in conflict with that from any other sense, they ignore the other sensory information and act on the basis of the visual information alone. In #1 above, the information available to the child's hand contradicts the evidence of his eyes. In #3 above, there is auditory information specifying the toy's location, but there is no visual evidence of the toy. In #4 and #5, there is indirect visual evidence but the child still cannot see the toy. This explanation will receive support in the section that follows, which describes the "Object Retrieval" Experiment.

But when a child can find a hidden object but is not yet making the A$\bar{B}$ error. Squeaking and rattling the toy under the cover does seem to tell the infant where the toy is located.[41] Second, infants who can only retrieve a partly covered object typically retrieve the object by grabbing the object and pulling it out, instead of uncovering it. They usually act only directly on the toy. This has been noted by Gratch and Landers (1971), and we observed the same in the present study as well. Infants at the intermediate stage (between success only with partly hidden and the A$\bar{B}$ error) retrieve a partly hidden toy by uncovering it. They act on the cover. We find the behavior seen here to be reminiscent of the behavior seen in children who are committing the A$\bar{B}$ error when they are tested at delays 2 or 3 seconds longer than the delay needed to produce the error. The refusal to reach and the random reaching seen here are also present when older infants are tested at too long a delay. Whereas a sound cue does not aid an infant who is not mature enough to find a hidden object, it does appear to aid infants at the later intermediate level and infants who are making the $A\bar{B}$ error. (Three of our infants discovered during $A\bar{B}$ testing that if they kicked the table during the delay the toy would rattle and they would know where to reach. So successful was this strategy that we were forced to use only rubber squeak toys, a cloth clown, and other toys which would not rattle in testing these children.)[42]

Memory does not seem to be a central part of the problem for infants who cannot find a hidden object. A tendency to ignore the evidence available to other senses when this contradicts the evidence available to vision does seem to be a part of the problem. From the point when infants can find a hidden object, vision seems to be less dominant. (If they are holding a covered toy, they know they are holding it. If they hear a toy they cannot see, they can use that sound cue in locating the object.) And, memory limitations now appear to be part of the problem when infants fail to find a toy.[43]

Another way of conceiving of the problem for infants who cannot retrieve a hidden object is that they are not capable of means-end behavior. The uncovering of a hidden object involves an indirect route to a goal, i.e. doing one thing in order to obtain another. When infants' knowledge of the location and continued existence of a hidden object is assessed by a method which does not require means-end behavior, infants below 6 months score well. On visual tracking tests they seem to anticipate the reappearance of a moving object on the other side of a tunnel (Bower et al., 1971) and when they see an object placed behind a screen they show surprise (increased looking time) when the screen's motion is not stopped by the occluded object (Baillargeon, 1982). On the other hand, even when the object is visible through a transparent cover many of these infants fail to retrieve it (Gratch and Landers, 1971; Bower and Wishart, 1973; Butterworth, 1977). It is not that they have forgotten that the object is there; it is that they are unable to form or execute a plan of action for regaining it.

Changes in the Character of the $A\bar{B}$ Error over Age

The character of the $A\bar{B}$ error does not change over age. Percent correct following 1) a correct reach on repeat trials, 2) a correct reach on reversal trials, and 3) an incorrect reach on repeat trials does not vary over age. The major change with age is in the length of delay needed to produce the $A\bar{B}$ error. Longer delays are needed with older children. However, errors, once they occur, follow the same pattern at all ages.

If an infant 9 months or older reaches to the wrong well, he will try to uncover another well. $A\bar{B}$ is usually done with only two hiding places, so it is not clear whether the infant is correcting himself or reaching more randomly. However, it is clear that, if given the chance, he will try a second well if his first reach does not produce the toy. At 7-8 months, on the other hand, when the $A\bar{B}$ error first appears, infants do not reach to another well if their initial choice is incorrect. (See Table 34. Note the large differences between infants

Table 34

Percentage of Trials on which Infant Failed to Uncover Other Well Following an Incorrect Reach
(Ns = Number of Trials on Which Infant Erred)

	Age in Months												
	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
Jack	----	----	----	----	----	100% N=3	33% N=3	80% N=5	0 N=4	0 N=3	0 N=5	----	50% N=2
Lyndsey	----	----	----	83% N=12	20% N=10	0 N=2	13% N=8	13% N=8	0 N=10	----	8% N=12	0 N=6	0 N=3
Tyler	----	----	----	----	----	0 N=13	0 N=9	0 N=9	0 N=11	0 N=8	0 N=6	0 N=11	0 N=6
Jamie	----	----	----	90% N=10	----	0 N=7	0 N=7	14% N=7	----	----	0 N=4	0 N=9	0 N=10
Emily	----	----	----	100% N=5	13% N=8	0 N=8	13% N=8	0 N=5	0 N=6	0 N=10	50% N=2	----	----
Rachel	----	----	100% N=5	21% N=14	----	0 N=9	----	0 N=14	0 N=8	7% N=15	0 N=11	0 N=10	14% N=14
Brian	----	100% N=4	----	10% N=10	10% N=10	14% N=7	0 N=5	38% N=8	13% N=8	----	14% N=7	14% N=7	0 N=6
Ryan	----	----	----	88% N=8	25% N=4	0 N=3	0 N=5	9% N=11	0 N=13	0 N=8	0 N=4	11% N=9	25% N=4
James	----	----	67% N=9	50% N=4	25% N=4	0 N=6	0 N=5	0 N=9	37% N=8	0 N=10	10% N=10	0 N=3	0 N=2
Erin	----	----	100% N=8	75% N=8	25% N=4	0 N=7	0 N=8	0 N=4	0 N=6	20% N=5	0 N=7	----	0 N=6
Sarah	----	----	----	----	50% N=10	----	10% N=10	0 N=8	----	0 N=7	10% N=10	0 N=6	----
Julia	----	----	----	50% N=6	0 N=8	0 N=9	20% N=10	0 N=10	0 N=7	0 N=8	0 N=10	11% N=9	0 N=10
Mariama	----	----	----	----	100% N=3	27% N=11	----	82% N=11	0 N=8	0 N=6	0 N=9	11% N=9	0 N=3
Kate	----	----	----	60% N=5	80% N=10	18% N=11	40% N=5	0 N=5	0 N=8	0 N=9	22% N=9	14% N=7	0 N=5
Rusty	----	----	----	100% N=7	80% N=10	----	0 N=11	0 N=6	25% N=8	0 N=8	0 N=10	0 N=5	0 N=4
Todd	----	----	----	----	75% N=8	25% N=8	10% N=10	10% N=10	0 N=4	0 N=5	0 N=9	0 N=4	----
Nina	----	100% N=8	100% N=5	60% N=5	0 N=7	10% N=10	0 N=4	0 N=5	14% N=7	0 N=8	0 N=3	0 N=7	11% N=9
Isabel	----	----	75% N=8	14% N=7	0 N=5	0 N=6	33% N=6	0 N=4	0 N=8	0 N=9	8% N=12	0 N=4	0 N=4
Jennine	----	----	----	31% N=13	50% N=10	0 N=9	----	25% N=8	0 N=6	0 N=10	0 N=6	25% N=8	0 N=2
Jane	----	----	----	80% N=10	33% N=6	0 N=5	33% N=6	----	0 N=8	0 N=8	10% N=10	----	0 N=6
Bobby	----	----	----	60% N=5	33% N=6	50% N=8	25% N=4	0 N=7	10% N=10	10% N=10	0 N=4	0 N=2	0 N=6
Graham	----	----	----	67% N=6	100% N=3	0 N=3	----	0 N=2	100% N=2	100% N=3	----	17% N=6	33% N=3
Blair	----	----	----	----	----	67% N=3	70% N=10	0 N=5	33% N=6	20% N=5	0 N=7	0 N=4	11% N=9
Michael	----	----	----	----	0 N=4	0 N=3	0 N=5	0 N=8	0 N=3	0 N=9	0 N=4	0 N=6	0 N=4
Chrissy	----	----	----	0 N=4	75% N=4	0 N=6	33% N=6	10% N=10	20% N=5	0 N=4	25% N=4	0 N=6	25% N=4

below 9 months and above 9 months on the frequency of second reaches.) Gratch and Landers (1971) noticed a similar pattern in their longitudinal study. Infants early in the second half of the first year are easily distracted; it is hard for them to maintain an orientation toward a goal.

SECTION 2

THE OBJECT RETRIEVAL EXPERIMENT

METHODS

Object Retrieval consists of a very straightforward problem. A toy the infant very much wants is placed within easy reach in an open box. The child's task is simply to get the toy. Considerable latitude is permitted in how the infant may attack the problem and no time limit is imposed.

Difficulties arise because 1) the infant must reach around the box to get to the toy (in this sense, it is a detour task) or he must move the box out of the way so that access to the toy is unobstructed (in this sense, it requires means-end behavior), and 2) although the toy can be seen through various sides of the transparent box, the hand can only reach through the single open side (in this sense, it is similar to other tasks presenting contradictory information to the eye and the hand, as in the visual cliff experiment).

Testing was conducted in the Infant Study Laboratory at Harvard University. The infant was seated on the parent's lap, to maximize feelings of contentment and security, in front of a plain wooden table, 27-1/2" high with a table surface 20" x 24-1/2". The parent's chair was adjusted so that the infant's shoulders were 4" - 5" above the tabletop on all visits. The tabletop was constructed of two wooden boards of equal size. A wooden strip, 1" wide, extended down the middle of the tabletop from front to back joining the two wooden boards. Care was taken to insure that the midline of the table, the wooden strip, was aligned to the baby's midline at the start of testing and at the start of each trial. The experimenter sat opposite parent and child.

Three boxes were used: transparent, 6" x 6" x 2"
transparent, 4-1/2" x 4-1/2" x 2-1/2"
opaque, 4-1/2" x 4-1/2" x 2-1/2"

The boxes were made of Plexiglas, with the sides bonded chemically and by strong adhesive tape. Infants exert great force on the boxes, and the boxes had to be sturdy in construction. All open edges were taped as well to protect infants from accidentally cutting themselves. The tape was clear, but still served to make the edges of the box more noticeable. The opening of each box was sufficiently large for the infant's hand to enter it easily if properly aimed.

Each box could be placed so that the front, top, left, or right side was open. All boxes had four closed sides. Thus, when the front or side (left or right) was open the box had no bottom, and when the top was open the box had no back. (See Figure 9.)

Dimension of box, within orientation of opening, was counterbalanced across children and visits. After the first visit, orientation of opening was also counterbalanced across children and visits. The orientation of the box on the first trial of the first visit for all children was top-open. This was the orientation which pretesting had shown infants find easiest. Half the children received the 6 x 6" x 2" box (the shallow box) and half received the 4-1/2" x 4-1/2" x 2-1/2" box (the deep box) on this first trial. After some trials, the transparent box not previously used was introduced. Thus, half the children were first administered the shallow box and then the deep, while the other half first received the deep and then the shallow box. After the top-open trials, trials with the opening at the front were administered. Again, half the infants received the shallow box first and half the deep

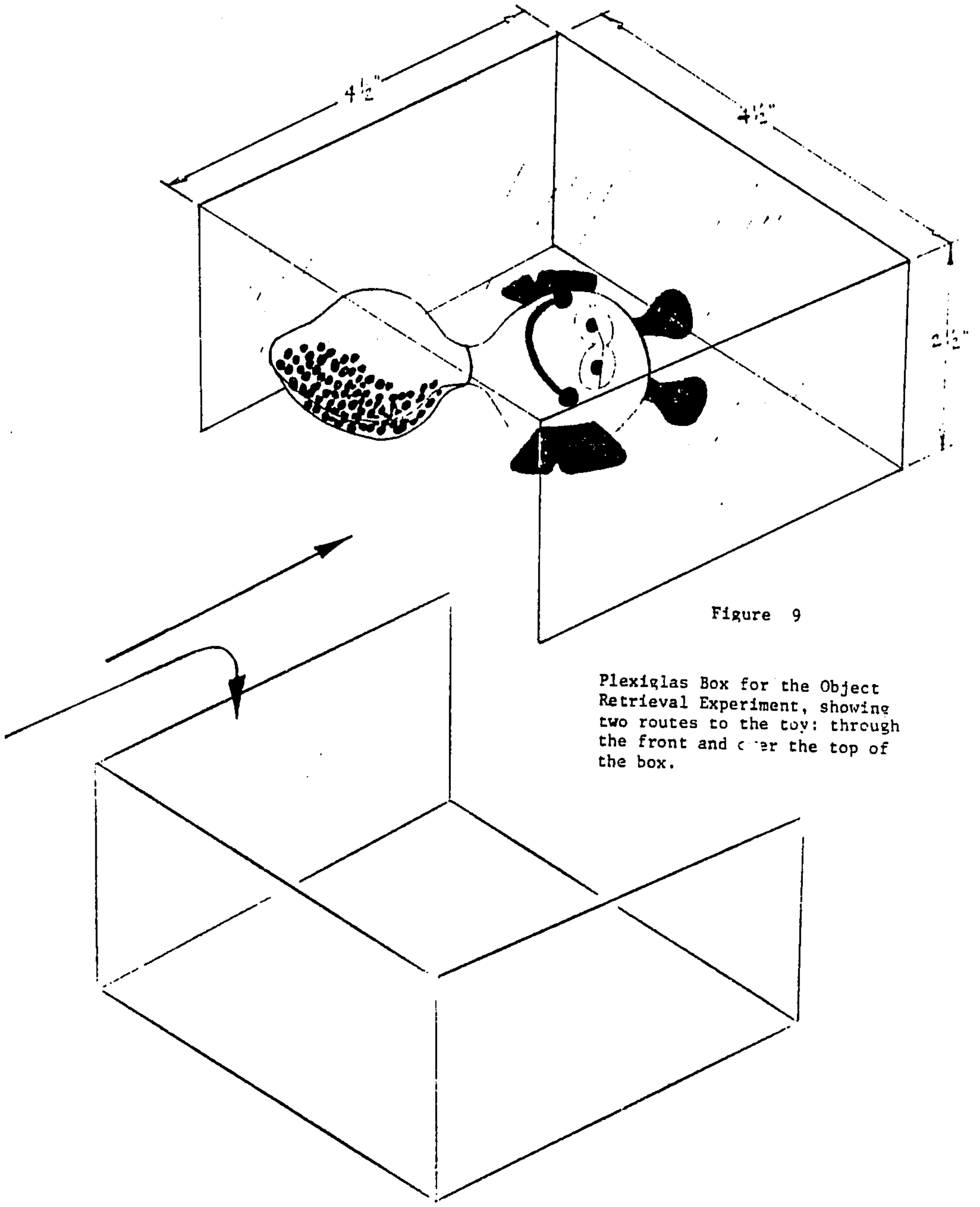


Figure 9

Plexiglas Box for the Object Retrieval Experiment, showing two routes to the toy: through the front and over the top of the box.

box; then this was reversed for the later trials.

On the second visit, half the children were tested first with the orientation at the front, then at the top. The other half received top-open trials first. For each orientation, half the children were presented the shallow box first and half the deep box. Each child received the boxes in the reverse order of visit #1 for each orientation of the opening.

On all visits, trials of a particular orientation of the opening were given in a block, usually consisting of six trials. Then the orientation was changed, and the next several trials were all at this new orientation. Within orientation of opening, first one transparent box was used and then the other. The order in which the boxes were presented was reversed across sessions.

The boxes were not used with the left or right side open on the first two visits. This decision was made because pretesting had indicated that the side-open orientation was much more difficult for infants. We did not want to present the infants with too frustrating a task for that frustration might carry over and impair performance even when the top or front of the box was open. A second consideration was that younger infants could not be tested for as long a period as older infants, partly because their concentration is shorter, but also because the task is much more difficult for them and each trial more demanding.

We found that performance with the side-open orientation lagged behind performance on trials where the opening was at the top or the front until the last months or weeks of testing. This may be an artifact of our decision to begin testing later for the side-open orientation. Only further experimental work can determine whether the side-open orientation is intrinsically more difficult or whether our testing procedure caused the lag in performance.

It should be possible to administer the side-open orientation even to 5-6 month old infants. Infants at this age tend to reach with an overarm arc and which lands them at the top of the box or with a two-handed sidearm arc which lands them at the right and left sides of the box. The sidearm reach would, thus, be well adapted to an opening at the side. Also, the side-open orientation might be made easier by displacing the box far to the side so that the infant can readily see in the opening. (Although young infants find it easier to reach near the midline.) Thus, we do not consider the testing procedure adopted here to be the only procedure feasible.

On the first visit where the side-open orientation was introduced, all children were administered left-open trials after testing on the front and top. We started testing with the left-side open before the right because our laboratory was arranged so that the video camera and coder were behind a one-way mirror located to the infant's left. Thus, left-open trials were easier to see and to code than right-open trials. Overall, more trials were administered with the opening to the left than to the right. This may also have been partially responsible for the lag in performance on side-open trials. More infants preferred their right hand than their left. Although we found no significant differences in performance on the right and left (and therefore often collapse these these two categories into a general side-open category in our analyses) it is possible that if we had introduced the opening to the right first infants might have performed better at the side-opening at an earlier age.

The order of testing from this point on was as follows (F = front-open trials, T = top-open trials, etc.):

	13 children	12 children
1st visit on which side-open trials were administered ...	F, T, L	T, F, L
2nd visit	R, L, T, F	F, T, R, L
3rd visit	F, T, L, R	L, R, T, F
4th visit	R, L, F, T	T, F, R, L
5th visit	T, F, L, R	L, R, F, T
6th visit	same as 2nd visit	same as 2nd visit
7th visit	same as 3rd visit	same as 3rd visit
8th visit	same as 4th visit	same as 4th visit
	etc.	etc.

Both transparent boxes were always used for each orientation, with the order of their presentation reversed across visits. Note that this is not a fully counterbalanced design, for example, top- and front-open trials always occur together, as do left- and right-open trials.

We have not analyzed the effect of the order in which the trials were presented. In general, we treat each trial as an independent event, ignoring whether it occurred early or late during a session and ignoring the orientation of the opening on preceding trials. It should be noted, however, that infants often took longer to retrieve the toy on the first trial at a given orientation than they did on the following trials at that same orientation, even though the first trial was usually designed to be easier than subsequent trials. This was particularly true when front-open trials were presented after a series of side-open trials. Here, infants often persisted in checking and rechecking the left and right sides of the box, ignoring the front.

In addition to the two transparent boxes, a white opaque box equal in size to the deep transparent box was used on roughly 70% of the visits. The opaque box never appeared on the first trials for any orientation. It was used either after all transparent box trials for a given orientation of the opening, or in the middle of the transparent box trials. Experience with the opaque box appeared to have some facilitative effect on subsequent transparent box trials with the same orientation of opening. This will be discussed in the results section.

Pretesting had shown that the difficulty of a trial depended to a large extent on whether the infant could see the opening of the box and whether he could see the toy through this opening. The task parameters which most directly affect this are:

1) proximity of toy to opening (the deeper the toy is in the box, the more difficult the trial);
2) distance of box from baby (the closer the box, the more likely the infant will see the toy through the top of the box; the farther the box, the more likely the infant's line of sight to the toy will be through the front); and
3) distance of box from baby's midline (for example, right-open trials can be made easier by displacing the box toward the left).

Thus, these task parameters can be manipulated to control the difficulty of a trial. We did so in order to begin each session with trials on which the infant could succeed rather easily, progressing to trials that pushed the limits of his ability.[43] It is impossible to overemphasize the importance of beginning with trials sufficiently easy so that the infant believes success on the task is possible. This is particularly important the first time an infant is tested. If the experimenter tries to give an infant too difficult a task too early, the infant will often refuse to participate or will try briefly or half-heartedly, even if easier trials are presented later. Young babies have good recognition memory, and if the experimenter has made the task too difficult for a baby, that child will often remember on subsequent testings 2 or 3 weeks later that he did not like this task and the experimenter will have to overcome the baby's initial resistance.

On the other hand, the baby's attention span and the allotted time for an experimental session put a constraint on the number of trials that could be administered. If one wants to obtain the highest performance of which a child is capable, one cannot dawdle too long with easy trials. A balance must be struck between the need to avoid overtaxing the infant and the need to push the limits of what he is capable, and between the need to avoid overwhelming the infant by presenting too difficult a trial too early and the need to present the difficult trials early enough that attention does not wane by the time they are administered.

We attempted to strike this balance by using a titration method (Goldman et al., 1975). The first one or two trials, for each orientation of the opening, were presented at roughly the highest level of difficulty at which that infant had performed with that orientation on the previous visit (on first visits, we began with extremely easy trials). If the infant succeeded on these trials, we increased the difficulty of the next trial. If he succeeded again, we increased the difficulty further. If the infant failed, the experimenter presented "clues" to the infant. Most trials ended in successful retrieval, either without the aid of the experimenter or after some intervention. If an infant was distressed by a trial, we reduced the difficulty of the next trial to bring him back into the "game." Once back in the game, we gradually increased the difficulty of the trials. If an infant succeeded with experimental intervention, the same trial was often repeated without intervention to see if he might now succeed on his own.

In general, we obtained better performance at younger ages than have other experimenters using similar tasks. We attribute this to the titration method and to the intervention of the experimenter. Other investigators have presented all their trials at one, or at most two, levels of difficulty. We believe that gradually increasing the level of difficulty across trials is the best way to build the child's confidence and at the same time present him with a challenging task. If an infant could not retrieve the toy on his own, other investigators have rarely intervened to help him out. We found that if we aided an infant on one trial, he could often succeed on the next on his own.

At the outset of each trial the experimenter held up a toy to attract the infant's attention. Front- and side-open trials began by the experimenter placing the toy on the table and then placing a box over the toy. Top-open trials began by the experimenter placing the toy in the box out of sight of the infant, and then placing box and toy on the table. At the outset of all trials, the parent restrained the baby's hands until box and toy were in place.

A large collection of toys was on hand, including several brightly colored squeak toys, a variety of rattles, Lego building blocks, a small cloth clown, a metal cup, and a set of keys. We attempted to maintain a high level of interest in the toy, and changed the toy whenever there was an indication that interest might be waning. Thus, we attempted to control for level of interest, not for toy. Toy changes occurred between trials, never during a trial.

With box and toy in place, the infant's hands were released, and a trial began. The experimenter held the box by the upper back corners, left and right. Both parent and experimenter offered words of encouragement throughout a trial, and praised the child happily after a retrieval, but the parent was not permitted to provide any specific advice by word or action.

Trials had no time limit. A trial ended when the infant retrieved the toy or refused to try any longer. Younger infants are more clumsy than older infants and sometimes drop the toy in the process of retrieving it, or have difficulty consolidating their grasp. To avoid penalizing younger infants for this, duration of a trial was timed to the first touch of the toy of the retrieval sequence. If an infant touched the toy, but withdrew his hand without trying to retrieve it, the trial continued. However, if an infant touched the toy, but fumbled with it for several seconds before getting a firm hold on it, timing of the trial stopped at this touch; time spent fumbling was not included in the trial. This is a conservative strategy in that it minimizes the difference in trial duration over age. (Duration of trial was timed from the video tape. It would not have been possible to use this procedure with on-the-spot timing.)

Minimal restrictions were placed on how infants might try to obtain the toy. They could use either or both hands. They could bend down or lean to the side. They were <u>not</u> permitted to pick the box up, lifting it off the toy, or to push the box back off the toy, and they were not permitted to stand up. They were permitted, however, to move the box in a variety of other ways. They might turn the box so that the left or right side faced more toward the front, raise the box so that the front was in the air with the back of the box still on the table, tip the box bringing the back up while the front remained on the table, or move the box forward or back. The experimenter restricted the size of these movements. For example, infants were not permitted to turn the box so far that an opening that had been at the side was now at the front. Similarly, if the infant attempted to raise the box very high, the experimenter exerted downward force to prevent this.

If an infant succeeded in retrieving the toy by moving the box on one or two trials, the experimenter tried to get the infant to retrieve the toy without moving the box in this way on the next trial. Thus, the infant's initial attempts to move the box were now resisted. If, after some time, the infant was unable to succeed with the box in place, he was again allowed to move it.

The experimenter also imposed restrictions on infants' freedom to make a trial more difficult for themselves. Infants could do this, for example on front-open trials, by pulling the box closer to themselves (thus making it more difficult to see or reach through the front) or by turning the box (which brings the left or right side more toward the front, but also moves the front side more toward the back). When an infant tried to do something that increased the difficulty of a trial, the experimenter allowed him to do it once, but subsequent attempts during the same trial were prevented.

Several seconds after an infant had moved the box, the experimenter returned the box to its original position. Typically, the infant paid no attention to this intervention, as the infant was already trying some other way to get the toy. Infants who were in the process of retrieving the toy were not interrupted. For example, on a left-open trial, if the infant turned the box, the box was allowed to remain turned as long as the infant continued to try to retrieve the toy through the left side. If he abandoned the left side, for say, the top, then the box was returned to its original position. The one time infants were interrupted was when they moved the box in a counterproductive way. If, for example, on a front-open trial they pulled the box closer to themselves and persisted in trying to retrieve the toy through the top or the back, the experimenter interrupted them after several seconds and returned the box to its original position.

If an infant became distracted, the experimenter tapped the box or jostled it, rattling the toy, in order to regain the infant's attention. This usually succeeded in eliciting renewed attempts to get the toy, although sometimes these attempts were short-lived.

If, after considerable time, the infant was unable to retrieve the toy, the experimenter intervened to provide a "clue." These included slowly _sliding_ the box off the toy and then back over it again, slowly _trailing_ the toy out of the box and then back in, _raising_ the front of the box using the back as the fulcrum, _tipping_ the back of the box up using the front as the fulcrum, _turning_ the box, _pointing_ in the opening, _squeaking_ the toy by going inside the box, and placing the baby's hand inside the box. These procedures will be discussed more fully in discussing their effects on performance in the sections that follow.

After a trial, the infant was permitted to play with the toy briefly. The box usually remained in reach as well. Younger infants ignored the box, while older infants would place the toy in it, repeating the experiment on their own.

All sessions were recorded on video tape. The camera was operated from behind a one-way mirror. The testing table was placed on a diagonal to the mirror, the diagonal running between the baby's front and left side. Behind the one-way mirror a coder recorded the basic variables for each trial (e.g., orientation of opening, whether the deep or shallow box was used, whether a transparent or opaque box was used). Most variables, however, were coded from the video tape. Extensive training was provided for this. Coders had to learn how to record each action made by the baby. They were trained to be conservative in their judgment and to confine themselves to objective and observable behavior. They were not apprised of the experimental hypotheses. Training required about one month. Subsequently, on over half the sessions, the trainer coded at least one trial with each coder to maintain high reliability. Reliability was checked across the three coders on six randomly selected visits. Intercoder reliability across items averaged .88. Any item with a reliability below .80 was eliminated from analysis.

In the results sections which follow we will present evidence on infants' failure and success, and the character of their behavior under varying conditions of Object Retrieval at different ages. One might wonder if an infant who failed at Object Retrieval did so because the transparent box was invisible to him or because his goal was something other than obtaining the toy. After all, an infant can hardly be blamed for failing to detour around a barrier he does not know is there, or, if all of his actions occur at the box rather than the toy, perhaps it is the box he is really interested in. Infants at all ages tested could perceive the boxes and were oriented toward getting the toy. Because of the importance of establishing this at the outset, we will present evidence below to support these assertions.

1. Evidence that Infants were Able to Perceive the Transparent Boxes

a) When one of the transparent boxes was placed on the table by itself, infants picked it up.

Twice during visit 1 or 2, the experimenter placed one of the transparent boxes on the table in front of each infant studied longitudinally. No toy was in the box or on the table. All infants reached to the box on the first presentation, touching it, grasping it, and/or picking it up. Some banged it on the table; most mouthed it. Interest was usually short-lived and six infants refused to reach to it on the second presentation. However, if they could not see it they should not have reached to it even on the first presentation.

b) All infants were able to retrieve the toy straightaway, under all conditions of orientation of the opening, if any part of the toy extended beyond the boundary of the box. However, many infants failed when the toy was totally inside the box, all other conditions held constant.

The four infants tested below 27 weeks of age often failed to enter the box to retrieve the toy when the front of the box was open and the toy was totally inside the box (34 failures on 42 trials). However, they never failed to retrieve the toy when it extended partly outside of the front opening (18 successes on 18 trials).

Below about 8 months of age, infants were unable to retrieve a toy wholly inside the box when the left or right side was open. Indeed, they did even touch, or look at, the left or right side of the box on these trials. Their success rate on side-open trials with the toy totally inside the box was under 10%. However, when the toy was partly outside the left or right opening, the success rate of these same children on the same visits was 100% (as long as they did not accidentally push the toy back in the box -- with the toy wholly back inside the box they often failed).

Thus, infants, especially those at the youngest ages, acted differently when the toy was totally inside the box from when it was partly outside the box. They reached to different places (e.g., on side-open trials, infants below 8 months did not reach to the side-opening at all unless the toy extended beyond the boundary of the box). Therefore, they must have been able to perceive some difference between these trials.

c) Much tactile information concerning the existence of the box was present to the infants.

Evidence of the existence of the box was available not only visually, but tactually. Infants touched, hit, and scratched it, and grasped the edges of the opening.

2. Evidence that Infants were Reaching for the Toy, and not for the Box

a) When presented with a choice between the toy and the box, infants went directly to the toy.

During the intertrial period the toy and the box were usually left on the table for the infant, with the toy now outside the box. If the infant had succeeded on the preceding trial, he would already be holding the toy, but if he failed, the experimenter removed the box from the toy and placed both in easy reach. Infants virtually always chose the toy. Older infants, as noted previously, often played with the toy and box together. The box was almost never chosen alone or first. Moreover, actions toward the box during the intertrial period differed from those shown during a trial. During a trial infants often hit, scratched, or pointed at the box, as if to get to the toy inside. These actions, with the occasional exception of hitting, were not seen during the intertrial interval.

b) When the box and toy were spatially separated, it was the toy, and not the box, to which infants reached.

Two of the "clues" used by the experimenter were "trailing" the toy slowly out of the box and then back in and "sliding" the box slowly off of the toy and then back over it. During trailing infants reached for the moving toy, following it until it reentered the box. During sliding, infants reached for the stationary toy. The box, whether moving or stationary, was always ignored.

c) When presented with the box alone; infants usually acted on it, but their interest was short-lived.

On visit 1 or 2, when the infant was presented with only the box, all infants acted on it on the first presentation. However, they lost interest quickly. Six children even refused to act on it at all the second time it was presented, even though there was nothing else to do. In contrast, play periods with the toy were usually ended by the intervention of the experimenter; infants usually played with the toy as long as they were allowed to have it.

d) When infants could not retrieve the toy during a trial they often became quite frustrated. This frustration vanished abruptly if the toy was made accessible to the infants. They reached for it immediately.

Most of the actions during a trial occurred on the box rather than the toy. The box was hit, scratched, pulled, and pushed. If the infant were interested in the box itself, these actions should not lead to frustration. Yet, frustration ensued often. Infants fussed, flung themselves back, and occasionally cried. The box was freely accessible, yet this had no mollifying effect. However, as soon as the toy was within reach, the countenance of the infants changed. They perked up and reached for the toy, and happy vocalizations and smiles replaced the frustration of moments earlier.

VISUAL CONTROL OF REACHING

Infants 6 and 7 months of age reach directly toward objects they see. If they see the toy through the front of the box, they try to reach through the front; if they see the toy through the top of the box, they try to reach through the top. The proportion of times that 6-7 month old infants (26 to 31 weeks of age) act on a different side of the box from the one through which they are looking is 13% (sd = .12).[44] Almost all of their actions (87%) are directed at the side through which they see the toy. In contrast, by one year (50-54 weeks), children are able to integrate looking at the toy through one side while reaching through a different side; 84% (sd = .11) of their actions are now directed at a different side of the box from the one through which they see the toy.

So controlled is the reach by line of sight in infants of 6-7 months that the parameters determining the side through which they see the toy also determine the side through which they will attempt to reach, and thus whether they will succeed or fail in retrieving the toy. For front- and top-open trials, the side through which they see the toy is determined by (1) distance of the box from the baby, (2) height of the box, and (3) distance of the toy from the front of the box. (Recall that the baby's height above the tabletop was held constant across visits and children.) The closer the box to the child, the shallower the box, and farther the toy from the front of the box, the more likely the child will see the toy through the top. Conversely, the greater the distance between box and child, the deeper the box, and closer the toy to the front of the box, the more likely the child will see the toy through the front.

Thus, infants should see the toy through the top of the box on trials where

a) the deeper box (4-1/2" x 4-1/2" x 2-1/2") is used, and

  1) the box is within 1-1/2" from the infant, and

  2) the toy is at least 1-1/2" from the front edge of the box, or

b) the shallower box (6" x 6" x 2") is used, and

  1) the box is within 3" from the infant, and

  2) the toy is at least 1-1/2" from the front wall.

We predict that on such trials, if the top of the box is open infants will succeed, while if the front is open they will fail to retrieve the toy.

Similarly, infants should see the toy through the front of the box when

a) the deeper box is used, and

  1) the box is at least 3" from the infant, and

  2) the toy is within 1" from the front wall of the box, or

b) the shallower box is used, and

  1) the box is at least 4-1/2" from the infant, and

  2) the toy is within 3/4" from the front wall of the box.

Thus, on these trials, we predict infants should fail when the box is top-open, but succeed if the front is open.[45]

Table 35 presents the results for these trials for 6-7 month old infants. It contains the percentage of trials on which infants succeeded _without_ the intervention of the experimenter. The average time until

TABLE 35

Percentage of Successful Retrievals when Toy was Visible Through the Opening or Through a Closed Side, for 6-7 Month Old Infants (26-31 weeks of age)

	Line of Sight to Toy					
	Directly Through Opening			Through a Closed Side		
	Top-Open: Condition I[a]	Front-Open: Condition II[b]	Total	Top-Open: Condition I	Front-Open: Condition II	Total
Succeeds in Retrieving Toy without Experimenter's Intervention[c]	92%	86%	88%	64%	10%	29%
Fails to Retrieve Toy Before Experimenter's Intervention	8%	14%	12%	36%	90%	71%
Number of Trials	(102)	(161)	(263)	(53)	(95)	(148)

[a] Condition I= 4-1/2" x 4-1/2" x 2-1/2" box, box within 1-1/2" of child, toy at least 1-1/2" from front edge of box; or, 6" x 6" x 2" box, box within 3" of child, toy at least 1-1/2" from front edge of box.

[b] Condition II= 4-1/2" x 4-1/2" x 2-1/2" box, box at least 3" from child, toy within 1" from front edge of box; or, 6" x 6" x 2" box, box at least 4-1/2" from child, toy within 3/4" from front edge of box.

[c] The average time until the experimenter intervened was 14.5 seconds, while the average duration of trials ending in successful retrieval without assistance was 8.9 seconds. Thus, it does not appear that the experimenter biased the results by intervening too early.

the experimenter intervened was 14.5 seconds, while the average duration of trials ending in successful retrieval without assistance was 8.9 seconds. Thus, it does not appear that the experimenter biased the results by intervening too early. Actions by the experimenter, such as tapping the box to attract the attention of a distracted child, were not considered intervention here, for such actions do not affect the parameters determining line of sight.

When infants, even as young as 6 or 7 months, see the toy directly through the opening, they almost always succeed in retrieving the toy without assistance. However, when they see the toy through a closed side, they are less likely to succeed. For example, the same conditions which lead to failure on 90% of the front-open trials, lead to success on 98% of the top-open trials. Small changes in the dimensions of the box or the distance of the box from the infant have an enormous influence on the probability of success. Because a small change alters the line of sight to the toy. Infants fail, not by reaching randomly, but by reaching to the side through which they see the toy. By one year of age, these same children succeed on 99% of all trials without assistance, regardless of which box is used or where it is placed.[46]

On trials where the infants were unable to retrieve the toy on their own, the experimenter helped them to succeed simply by moving the box so that the infant was able to see it through the opening. On front-open trials, the experimenter accomplished this by moving the box away from the infant or by "raising" the box. ("Raising" the box consists of tilting it so that the back of the box is lowered and the front raised.) On top-open trials, the experimenter accomplished this by moving the box toward the infant or "tipping" the box. (To "tip" the box, the experimenter lifted the back of the box and tipped the box toward the infant with the base of the front as the fulcrum.) All children received assistance on at least 4 front-open and 3 top-open trials between 26-31 weeks of age, because they were unable to retrieve the toy.[47] Of the 95 front-open assisted trials, infants succeeded on 88 (even though they had failed these trials up until the experimenter's intervention). On the top-open trials, 66 of the 69 trials were successful after assistance.

When the experimenter moved the box so that the infant could see the toy through the opening, it had a dramatic, immediate effect on the infant's behavior. Infants who were crying or fussing stopped abruptly. Those reaching to a closed side withdrew their hand. All reached straightaway for the opening.

But success can be turned into failure for a 6-7 month old infant by moving the box so that the infant no longer sees the toy through the opening. This was done by the experimenter raising or tipping the box _and then returning it to its original position before the infant had touched the toy_. This procedure is called "show and return," for the infant is shown the toy through the opening and then the box is returned to its original position. All infants were given at least 2 "show and return" sequences on top-open trials and at least 4 "show and return" sequences on front-open trials between 26 and 31 weeks of age. The 53 instances of show and return sequences on top-open trials produced only 20 successes (38%, as opposed to the 97% success rate when the box was left in the changed position). The 120 instances on front-open trials produced 35 successes (or 29%, as opposed to the 93% success rate when the box was allowed to remain in the changed position).

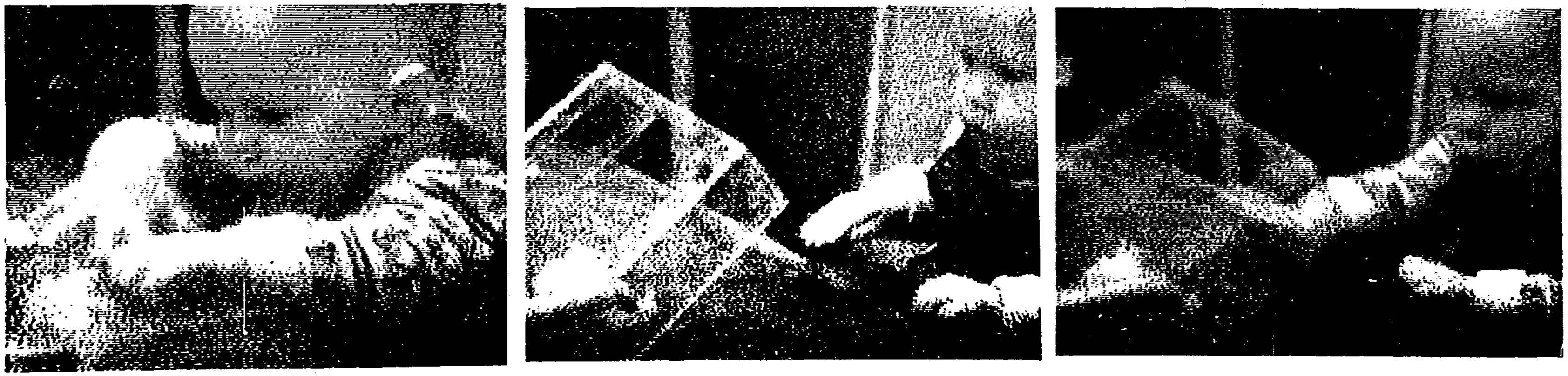
Typically, infants immediately reach into the opening when they see in, but desert the opening just as quickly when their line of sight to the toy is again through a closed side. It is striking to see a child go to the trouble of withdrawing his hand from inside the box, barely an inch from the toy, and return to the closed side on which he was acting before the show and return sequence occurred. An illustration of this behavior is presented in Figure 10.

On most "show and return" sequences, the infant's hand had entered the box at least part of the way by the time the box was returned to position. Instances of successful retrieval following "show and return" only occurred on occasions when the infant's hand had already entered the box before the end of the sequence. However, on most occasions where the infant's hand had entered the box, "show and return" still did not aid the infant. We have not been able to determine any consistent difference between the instances of "show and return" which aided the infant and those which did not -- neither proximity of hand to toy nor whether any finger(s) were caught outside the box when the box was returned to position discriminated the instances of show and return which did help from those which did not.

The interruption of a reach already begun when the box is returned to position during show and return is reminiscent of a similar interruption of a reach, noted by Piaget and Bruner in children 7-8 months of age, when a cloth is dropped over the object for which the infant is reaching:

> At 7 months, for example, we do the following experiment. The child reaches for an object placed on one side of the midline with the ipsilateral hand. As his hand arrives at the object, we drop a light cloth over his hand and the object. He withdraws his hand empty and begins the

Figure 10: "SHOW AND RETURN" SEQUENCE WITH A BABY EARLY IN THE SECOND HALF OF FIRST YEAR



Front open. Brian sees toy thru top & tries to reach thru top.

Exp "raises" box, enabling Brian to see toy thru front opening.

As soon as Brian sees toy thru opening, he reaches into opening.

Exp lowers box to original position. Brian's hand is inside box on an unobstructed line to toy.

However, with box down, Brian sees toy thru top again. So, rather than completing reach, he withdraws hand and...

tries to reach thru top to toy. As soon as his line of sight changes, his hand, too, moves to that line.

> reach again, but it is interrupted by the visual absence of the object.
>
> (Bruner, 1969:229)

> At the third test I place the box 15 centimeters away from [Laurent, age 8 months], and as soon as he extends his hand I cover the object with the same pillow as before; he immediately withdraws his hand.
>
> (Piaget, 1954:45, obs. 34)

The present results may be thought of as extending the observations of Piaget and Bruner to a slightly younger age when even a transparent cover is used.

It was common for an infant to fail to retrieve the toy following a show and return sequence, but then succeed on the same trial when the box was allowed to remain in this changed position. The large differences in success rate between show and return sequences and the instances where the box was left in its changed position show that in 6-7 month old infants successful retrieval depends upon not only seeing the toy through the opening, but on maintaining that line of sight throughout the reach. Even if the reach has already begun, if the baby's line of sight changes so that he sees the toy through a closed side, he will not be able to retrieve the toy.

Infants of 6-7 months persist in hitting and scratching at the side through which they are looking. The kinesthetic information that the surface is solid and will not permit entry does not seem to affect their behavior. The children claw and/or bang at the side through which they are looking, followed by either fussing, finding something else to amuse themselves with (such as a spec on the table or a poster on the wall), or repetition of their act on the box now as an end in itself. The experimenter is able to re-elicit goal-directed behavior simply by tapping the box and pointing to or rattling the toy. The cycle then begins again -- prolonged reaching at the side through which the infant is looking, followed by giving up. No attempt is made to try a different route to the toy.

Infants commonly grasp the open edge of the box upon touching it, but this tactile information specifying an opening is ignored. (See Figure 11.) Indeed, so powerful is the lure of the line of sight that even the tactile information provided by the infant pushing the toy inside the box himself is ignored when the line of sight is through a different side. All children, at all ages, quickly reached directly to the toy if it was partly (even very slightly) outside of the box, regardless of whether the opening was on the top, front, or side. Being a bit clumsy, infants sometimes pushed the toy back inside the box in trying to grasp it. Rather than pursue the toy through the opening (which would have meant simply extending their hand another inch), 6-7 month old infants often desert the opening and try to reach instead through the side of the box through which they are looking. Of the 23 children in the longitudinal sample who were tested by 31 weeks of age, 14 of them pushed the toy back into the box accidentally at least once between the ages of 26 and 31 weeks. In all, we recorded 22 instances. On 10 of these 22 instances the infants deserted the opening, reached to a closed side or fretted, even though they had pushed the toy in the box themselves. Figure 12 illustrates one such instance.

Even more impressive are occasions when the baby was reaching to the partly exposed toy and the experimenter slid the box over the toy, fully covering it. This was tried at least once with 20 of the children between the ages of 26-31 weeks. Although all of these children had already touched the toy by the time the box was moved over it, on 34 of

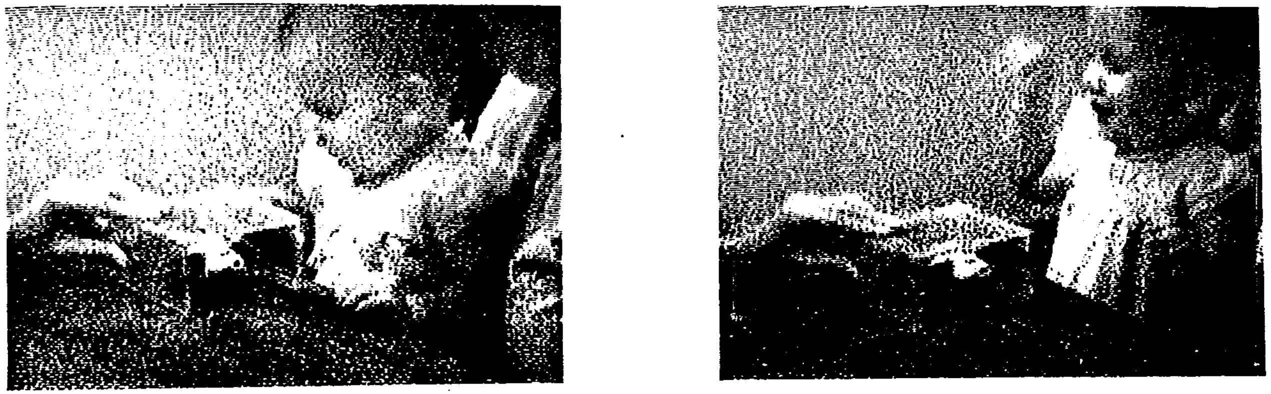
Figure 11: EXAMPLE OF AN INFANT WHOSE HAND IS AT THE OPENING BUT WHO IGNORES THIS TACTILE INFORMATION

Right side open. Erin sees toy thru front and points at toy with left hand on front wall. Her right hand is wrapped around opening. Four fingers are inside box, flush against front wall; thumb is sticking out of opening.

Here, Erin is looking thru top of box. Right hand is again at opening. Four fingers are inside box; thumb is gripping edge from above. Erin, however, is attending to where she is looking. She shows no sign of attending to the information available to her right hand.

Erin again sees toy thru front. She attempts to reach only thru the side thru which she is looking. Here, she points at toy thru front.

Figure 12: EXAMPLE OF INFANT WHO PUSHES TOY INSIDE BOX HERSELF AND THEN IS UNABLE TO RETRIEVE IT



Left side open; transparent box.
Kate sees toy thru front, &
scratches at front with right hand...

and gives up.

Exp moves box so toy is partly
out of opening.

Kate immediately stops fussing &
reaches for toy sticking out of
box. However, in trying to grasp
toy, she accidentally pushes it in.

Once toy is totally inside box again,
Kate is again unable to retrieve it,
even though she herself pushed toy in.

the 47 instances (72%), the infants deserted the toy as soon as the box was moved. Most of those who succeeded had already begun to grasp the toy by the time the box was moved.[48]

The tendency to reach along the line of sight overrides the effect of reinforcement, as it overrides tactile information. We tested this by the following sequence of front-open trials:

Trial 1 -- box placed so that infant cannot see through opening; infant fails to retrieve toy on his own;

Trial 2 -- box placed at least 1" farther from baby and toy placed at least 1" closer to opening; infant succeeds in retrieving the toy without aid from experimenter;

Trials 3 and 4 -- identical to trial 2. Box and toy placed in same position as on trial 2; infant succeeds in retrieving the toy;

Test Trial: Trial 5 -- identical to trial 1. I.e., box and toy placed in same position as on trial 1.

The sequences of trials 1-4 was a precondition for administration of the test trial. For example, if the infant did not succeed on trials 2, 3, <u>and</u> 4, then the test trial was not administered. Instead, the experimenter tried again (on the same visit or a subsequent one) to create the sequence of trials 1-4 as described above. All 23 children had received this sequence by the age of 31 weeks.

Note that the test trial is administered after three consecutive successes. Nineteen of the 23 babies failed to retrieve the toy on this trial without the aid of the experimenter even though they had just succeeded in retrieving the toy from the same side of the same box three times in a row. Table 36 summarizes these results, and Figure 13 provides a photographic illustration of this series of trials during one experimental session.

The dramatic difference in success rate depending on whether the

TABLE 36

Effect of Prior Success on Correct Retrieval, 6-7 Month Old Infants, Front-Open Orientation

	Trial 1: Infant Cannot See Toy Through Opening	Trials 2, 3, & 4 Box at least 1" farther from baby; Toy at least 1" closer to opening	Trial 5: identical to Trial 1
Infant Successfully Retrieves Toy without Experimenter Assistance[A]	0	23	4
Infant Fails to Retrieve Toy without Experimenter Assistance	23	0	19

[B]

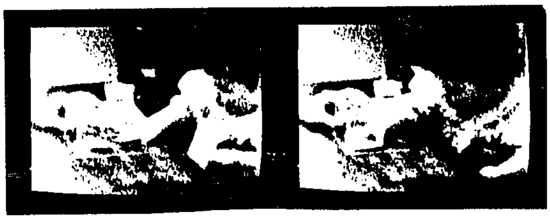
Ns = number of subjects

A: See Table 28, footnote C.

B: Failure on trial 1 and success on trials 2-4 were the preconditions for the administration of the test trial, trial 5.

Performance on trial 5 is significantly worse than on trials 2-4 ($x^2 = 32.37$, p .001), while it is <u>not</u> a significant improvement over performance on trial 1 ($x^2 = 4.38$, ns).

1



Phase 1: FRONT of box is open. Jennine is able to see toy thru OPENING...

& thus she is able to retrieve it.

2

Again, FRONT of box is open. But, box is now lower & slightly closer to her. She sees toy thru the CLOSED TOP, & so attempts to reach thru the top to retrieve toy (even though she reached correctly on the previous trial & was reinforced for doing so). She persists in this, trying no other route to toy...

until she finally gives up.

= Trial 1 of sequence

3

Same box; FRONT still open. But box is back slightly & toy is closer to opening. Jennine can now see the toy thru the opening...

& so is able to reach in and retrieve toy.

= Trials 2, 3, & 4 of sequence

This trial is repeated twice more, with the same effect.

4

Same condition as sequence 2. After several front open trials front open trials, she now starts to repeat the motor m'v't (entering box thru front) she has been doing so often...

but she sees toy thru the top & so WITHDRAWS her hand from inside box...

& tries to reach for toy thru the top (the route along which she sees the toy).

= Trial 5 of sequence

Figure 13

child sees through the opening or not (Table 35) also suggests that, in the face of present visual information to the contrary, the effect of prior reinforcement is weak. Infants who fail to obtain the toy by reaching to a closed side of the box nevertheless continue to attempt to reach along that route. Infants who have successfully obtained the toy through the front of the 4-1/2" x 4-1/2" x 2-1/2" fail when the 6" x 6" x 2" is used (all other variables held constant), and succeed again when the 4-1/2" x 4-1/2" x 2-1/2" is again used.

It would be misleading, however, to suggest that there is no evidence of learning in this situation. On the test trial in the sequence described above, infants often started to reach to the front, repeating the motor movement which had been thrice reinforced. However, the tendency to reach along the line of sight proved the stronger and they pulled their hand away from the opening and reached to the side through which they were looking. Evidence of learning can also be seen in the behavior of the children over a series of trials in which orientation of the opening and line of sight are unchanged. When the infant had been successful and similar trials were again presented (with no intervening trials), time to retrieval of the toy was progressively reduced as the infant became more efficient and confident in his behavior. When the infant had been unable to retrieve the toy and the trial was repeated, the infant usually did not persist as long as he did on the earlier trial(s). Thus, even in the present experimental situation there is some evidence that the responses of the 6-7 month old children were strengthened by success and weakened by failure. But the power of vision is so strong that it overrides whatever learning has occurred.

In short, infants begin the second half of the first year of their lives with a strong tendency to reach along their line of sight. Where an infant of 6-7 months is looking determines, virtually singlehandedly, where he will reach. So powerful is this tendency that when vision and touch provide contradictory information, the infant's reach is dominated by the information from vision, without any indication that the conflicting tactile information is taken into account at all. Vision similarly overrules conflicting information from past experience. This is impressive because we know that infants at this age, and younger, will react to tactile information () and we know that their behavior can be shaped by reinforcements (e.g., Lipsitt et al., 1966; Siqueland and Lipsitt, 1966; Moore et al., 1977).

Evidence corroborating these results has been reported by others. For example, in studies of detour reaching using a transparent wall between the infant and toy, it has been reported that early in the second half year of life infants try only a straight line of sight reach through the barrier (Bruner et al., 1968 Bruner, 1971; Gaiter, 1974; Lockman, 1981).

In agreement with our results on the effect of reinforcements, Bruner et al. (1969), in their study of detour reaching, note the absence of any evidence of learning over repeated trials when the toy is again seen directly behind the barrier.

Failure to use available tactile information when the visual information contradicts it has also been consistently reported. For example, Lockman (1981) reports:

> When confronted with the transparent barrier, the infants would try to reach through it several times and then give up. Sometimes they would even hold onto the edges and shake the barrier as if to move it out of the way. But even the tactual information of the edge was not sufficient to insure success.

Gratch and Landers (1971) report that if a 6 month old infant is holding an object, and the experimenter places a cloth over the hand and object so that hand and object can no longer be seen, the infant acts as if he does not know he is holding anything. Infants can and do get information from their hands, but when their eyes tell them something else, they seem to ignore the tactile information.

It should be noted that Gratch and Landers found that if a _transparent_ cloth was dropped over the hand of a 6 month old child holding a toy, the infant retained the toy. This is similar to our observation that those infants who succeeded when the partly exposed toy became totally covered by our transparent box were those who had already begun to grasp the toy. There thus appears to be some limit to the dominance of vision.

The progress infants make on this task over the first year is dramatic. By 50-54 weeks of age (5 months later), they are able to retrieve the toy straightaway no matter where the box or toy is placed, which side of the box is open, or which box is used. The average duration of a trial, which was 21 seconds when the children were 26-31 weeks old, drops to 5 seconds. This decrease in trial duration is especially dramatic because the average difficulty of the trials presented to infants of one year of age was far greater than the difficulty of the trials given at 6-7 months. Assistance by the experimenter is no longer required. Infants are able to reach along a detour to retrieve the toy while looking through a closed side of the box. (See Figure 14.) Instances of acting at one side of the box while looking through a different side jumps from 13% at 6-7 months to 84% at one year on front-open trials.

One year olds show good use of tactile information, without the need to confirm it visually. If they feel the edge of the opening, they reach in and retrieve the toy, even if their line of sight to the toy is through a closed side. Similarly, if they feel a solid surface, they desert that side and try elsewhere. This can be seen by recorded instances of "touch alone."

The variable "touch alone" was intended to capture instances when the infant was able to tell, by tactile feedback alone (without visual confirmation) that a side was open or closed. An act meeting the following criteria was counted as a "touch alone": 1) The baby feels the solid surface of a closed side of the box with his hand, and without looking in, abandons that side. 2) The baby touches an edge of the opening, and then reaches in and retrieves the toy, without looking in the opening. Infants were not credited with a "touch alone" if they cleared the opening perfectly and simply proceeded in and got the toy. (It is too difficult to distinguish this from a lucky reach.) Therefore, the infant had to first feel the boundary of the opening, and only then reach through it, in order to get credit here. Note that this strict criterion probably underestimates the actual number of instances of touching alone in 11-12 month old infants, for they were often able to reach directly through an opening to the toy. Instances of touch alone were not seen before 9 months, but they were consistently seen by 11 months of age. (See Figures 15 and 16.)

Figure 14: PERFORMANCE OF A YEAR OLD INFANT ON OBJECT RETRIEVAL

RIGHT side open.
No need to look thru
opening. Brian LOOKS
thru TOP & REACHES with
near hand thru RIGHT.

HOORAY

LEFT side open.
Here, as well, Brian
LOOKS thru TOP & reaches
with near hand thru
opening.

FRONT side open.
As in Phase 3, Brian
looks thru top, while
reaching thru front.

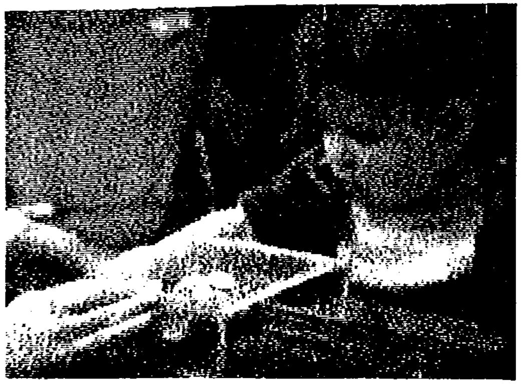
!

Figure 15: EXAMPLES OF "TOUCH ALONE"

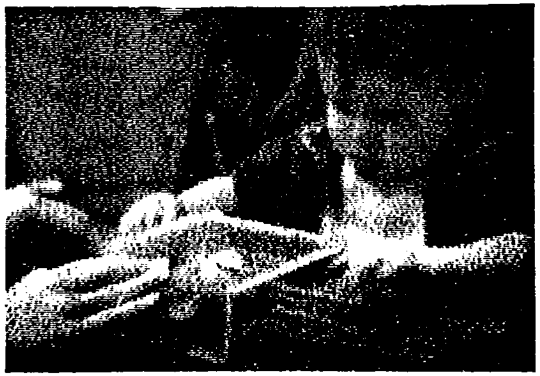
Right side open. A single touch to left tells James left is closed; he tries elsewhere. No persistence at left; no lean & look.

A single touch to right tells James right is open...

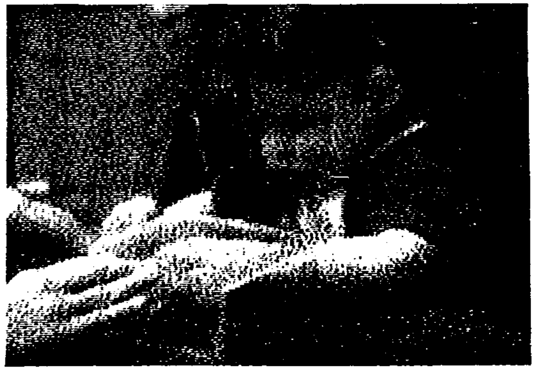
without confirming this w/ his eyes, he reaches in while looking at toy thru closed top.



Left side open. Jamie touches right side. He needn't also look in to discover right side is closed.



Feeling the edge of the opening with his hand...



he proceeds in to retrieve toy without needing to lean & look thru opening.

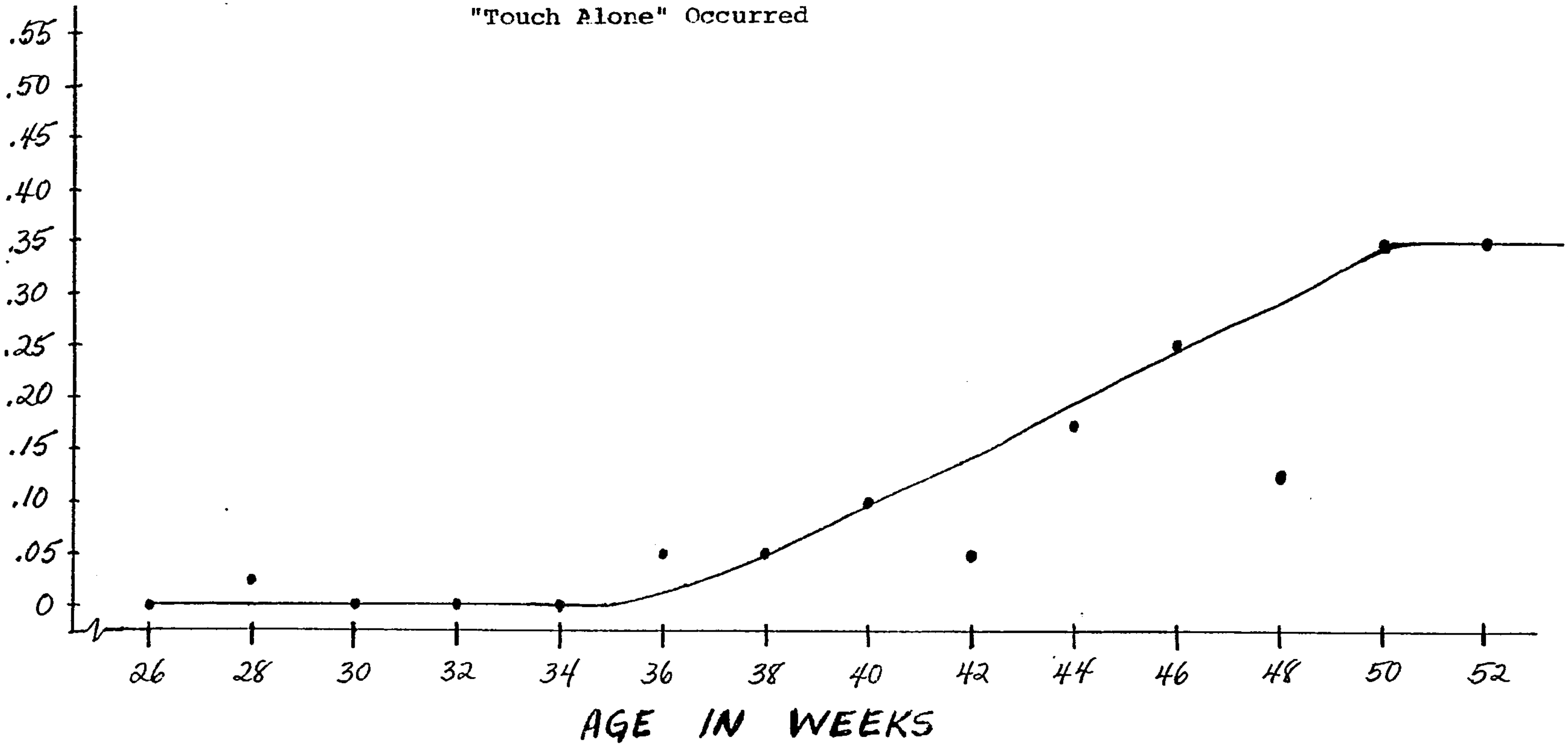
Similarly, by the end of the first year, an infant can look to a side, and without needing to touch it, determine whether it is open or closed. In 6-7 month olds, the hand moves with the eyes. It is very rare to see an infant at this age simply look at a side without going to touch it. Older children can separate reaching from looking, and refrain from reaching if the side is closed.

Instances of "looking alone" were determined by the following criteria: 1) The baby peers into a closed side of the box, and without touching it, abandons that side (that is, by a "look alone," without the aid of tactile information, the infant seems to know that he must try another route to the toy). 2) The baby peers into the opening and then, as a clearly separate act, reaches in. If there were any indication that the hand was moving with the eye initially, the baby was not credited with a "look alone." Again, this is intentionally conservative. Indeed, recorded instances of looking alone to an opening, as opposed to a closed side, were very rare.

No instance of "look alone" was recorded before 10 months, but many infants of 11 or 12 months did display this behavior. In general, however, touching alone is a more frequent occurrence than looking alone. (Figure 17 provides an illustration of "looking alone.")

At 6-7 months and at 11-12 months, there is little variation in performance among infants of the same age. At the younger age, the reach is determined primarily by line of sight: if the toy is seen through a closed side performance is poor. By one year, even the most difficult trials pose no problem. The following pages attempt to chart how the children progress from such poor performance to such superior performance. The similarity among infants is less striking during these

Figure 16: Proportion of Trials on Which at Least One Instance of "Touch Alone" Occurred



intervening months and no single variable, such as line of sight, predicts accurately whether a given trial will end in success or failure. To some extent, each child makes this journey in his own way, at his own pace. Yet, there are commonalities among infants even here.

The first evidence of any ability to separate the line of reach from the line of sight does not appear until about 9 months of age. Although children at this age still need to look along the route their hand will take, their triumph consists in not needing to continue to do so. Having seen the toy through the front opening of the box, they can reach in and retrieve the toy while looking through the closed top. The memory of having looked along the line of reach enables them to coordinate a line of sight with a line of reach coming from a different angle.

When the infant cannot retrieve the toy (because he is looking through a closed side of the box) if the experimenter briefly raises the box or moves it farther away (showing the child the toy through the opening and then returning the box to its original position), the infant is now able to retrieve the toy. The infant can also raise the box himself to the same effect. He looks in, box comes down, and he is able to reach in and retrieve the toy. Similarly, if the infant bends down to peek through the opening, he can then sit up and retrieve the toy while looking through the closed top. (See Figure 18.)

The total number of "show and return" sequences on front-open trials (experimenter or infant produced) which occurred in children in the longitudinal sample while they were 9 months of age, was 95, with an average of 4 per child. Of these, 87% ended in success (i.e., the infant reached in and retrieved the toy directly following the return of the box to its original position).[49] (There was no significant

Figure 17: EXAMPLE OF "LOOK ALONE"

Left side open. Andrew looks in right side. He does not reach or touch side. The look tells him side is closed, & he leaves it.

Andrew looks in left side. He sees that it is open. He does not need to touch side to verify this.

He simply reaches in, sitting up, using the near hand.

Figure 18

ON FRONT OPEN TRIALS, INFANT STILL NEEDS TO SEE TOY THROUGH OPENING, BUT HAVING DONE SO, CAN REACH INTO BOX WHILE LOOKING THROUGH A CLOSED SIDE

FRONT of box is open. Michelle peeks down so as to see toy THRU opening.

Having seen toy along this route, she sits up & REACHES for it thru FRONT while LOOKING at it thru TOP.

SUCCESS

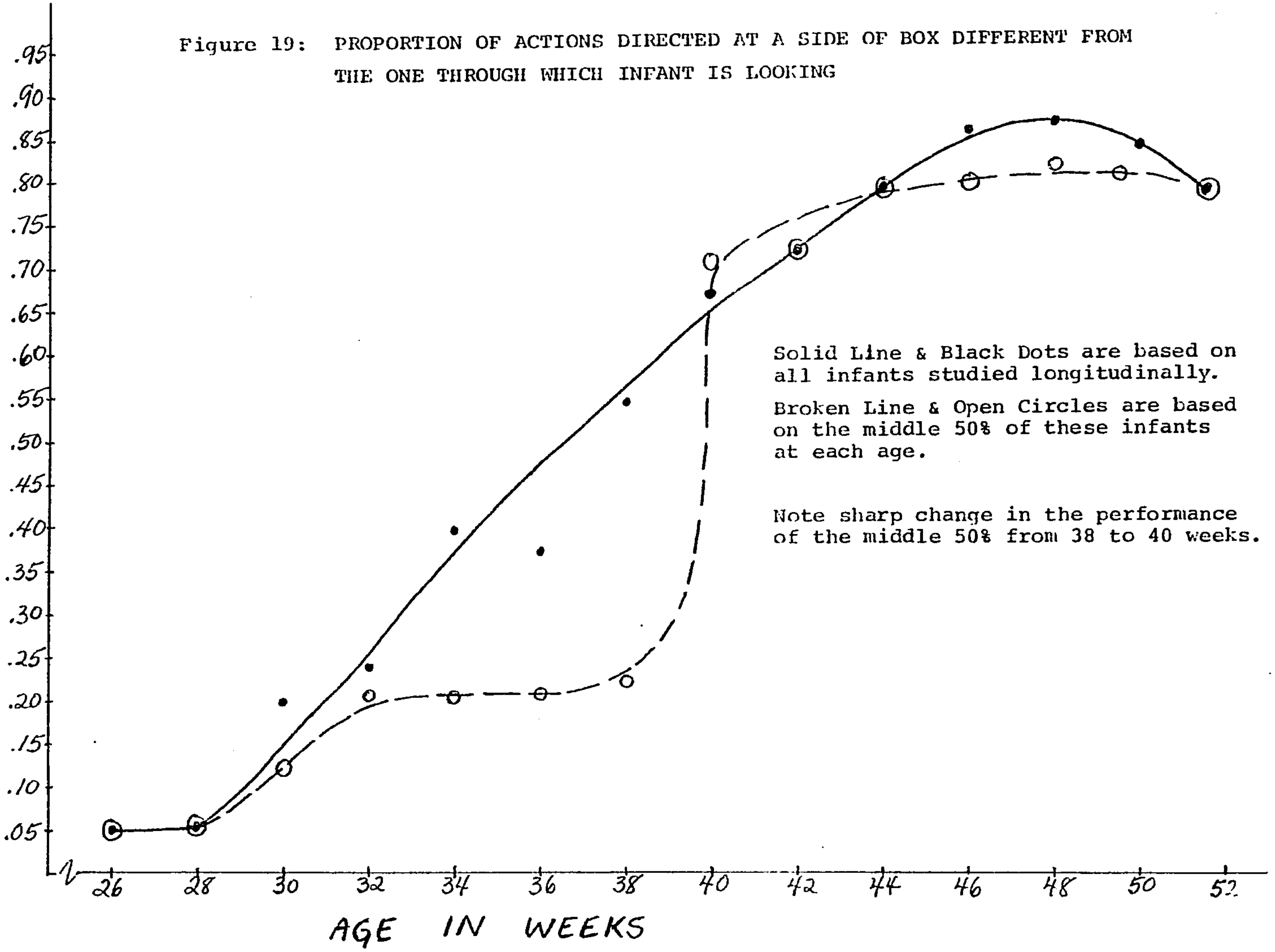
difference in success rate following experimenter produced sequences versus infant produced ones.) Compare this to the 29% success rate following show and return sequences on front-open trials at 27-31 weeks of age.

The percentage of front-open trials on which 6-7 month old infants did not look through the opening as they reached in and retrieved the toy was roughly 5%. It was rare and usually not replicated on the next trial. By the time the infants reached 9 months, however, almost 40% of the acts on front-open trials coded as "reaches in and retrieves toy" (this was typically the last act of the trial) received the following code for eyes, "looking at toy through a different side from the one acting on."

Figure 19 presents the proportion of actions directed at a side of the box different from the one through which the infant was looking, by age. The solid line represents the results based on all the children, while the dotted line represents the results based on the middle 50%. Some children mature especially quickly, others especially slowly. To compute the dotted line, we ignored the highest and lowest scores for each two-week period and took the average of the remaining half. While the solid line shows a rather smooth increase in the proportion of times infants looked through one side while acting through another, the dotted line shows a sharp increase at 9 months of age. Until 9 months, the average child acts at a different side of the box from the one through which he is looking only about 20% of the time. At 9 months, however, this percentage jumps to about 70%.

Because the number of times infants look one place, while acting at another is expressed in percents, and so has an upper bound of 1 and a

Figure 19: PROPORTION OF ACTIONS DIRECTED AT A SIDE OF BOX DIFFERENT FROM THE ONE THROUGH WHICH INFANT IS LOOKING



Solid Line & Black Dots are based on all infants studied longitudinally.

Broken Line & Open Circles are based on the middle 50% of these infants at each age.

Note sharp change in the performance of the middle 50% from 38 to 40 weeks.

lower bound of 0, we have used a logit transformation of the data in doing the regression analysis, thus minimizing the distortion due to ceiling and floor effects. Regressing "looking one place, acting another" against age shows a general linear trend both for total longitudinal, and for the middle 50%. For the middle 50%, it also shows that there is a discontinuity at 9 months of age. That is, a model with two separate discontinuous lines fits the data significantly better than does one continuous line. Thus, at 9 months we see the first major advance in the infant's ability to resist the tendency to reach along his line of sight. Occasionally, one sees a child at this age actually look to and fro between the opening and the toy through a closed side, as if he is trying to relate these two things to one another.

In an important pair of experiments by Millar and Schaffer (1972, 1973), the ability to look one place and reach another was also found to emerge at about 9 months. Millar and Schaffer trained infants to perform the operant response of pushing down on a manipulandum in order to obtain the reward of seeing a display of colored lights. When the lights came from the manipulandum, infants at all ages tested (6, 9, and 12 months) acquired the response. Similarly, when the lights were displaced 5 degrees from the manipulandum, close enough to remain in the same visual field, infants at all ages again showed learning. However, when the lights were displaced 60 degrees from the manipulandum, the 6 month olds failed to show learning. Infants of 9 months succeeded by looking at the lights while simultaneously touching the manipulandum, without looking at their hand or its target. They looked at one place (the lights) while acting at another (the manipulandum). This strategy was not in evidence at 6 months.

Although the achievement of 9 month old infants is impressive, it is limited in two ways. First, these infants do not show evidence of being able to reach through one side of the box while looking through a different side _without_ first looking along the route their hand will take. If they have not looked into the opening on a given trial, they will not reach into it. At this age, there were almost no recorded instances of successful retrieval on front-open trials where the infant had not looking through the opening at all during the trial. (This should not be confused with the 40% figure quoted earlier, which referred to not looking in during the final act of retrieval itself.) In contrast, by the time they were 11-12 months, they did not bother to look into the opening at all on almost one-half of the front-open trials, even though all trials ended in success.

The second limitation to the achievement of the 9 month old infants was that the ability to look along the line of reach, and then reach while looking through a closed side, was not in evidence on side-open trials. Here, the percentage of acts coded as "reaches in and retrieves toy" where the infant was coded as looking through a different side of the box was still only roughly 12%. Indeed, the infants contorted their bodies into very awkward positions in order to look through the side opening as they reached. (For a fuller discussion of this, see the section on the reach with the contralateral hand on side-open trials.)

This phenomenon of the advance being in evidence on front-open trials weeks before it is seen on side-open trials was repeatedly observed. Similarly, top-open trials proved much easier than front- or side-open ones. Achievements were often seen first for the top-open orientation, next for front-open, and only later for the side-open orientation.[50]

The next major advance is in evidence at roughly 10-1/2 months. Now, on front-open trials, the infant does not need to see the toy through the opening at any time during the trial in order to succeed. If the infant sees the front opening and also sees the toy through the closed top, he is able to relate these two pieces of information without looking along the line of reach at all. (See Figure 20.)

When the left or right side of the box is open, an infant of 10-1/2 months typically leans to the side and looks in the opening, sits up, and reaches in while looking at the toy through a closed side. While he still needs to look along the line of reach for the side-open condition, he is freed from the need to continue to do so. The memory of having done so will suffice. (See Figure 21.) This achievement first appeared on front-open trials at 9 months.

Among 10-1/2 month olds, the percentage of acts on side-open trials coded as "reaches in and retrieves toy" on which infants did not look through the opening was 61%. (Recall that at 9 months the percent of such acts was only 12%.) However, most of the infants at 10-1/2 months still needed to look through the side opening before they could reach through it. Among most of the 10-1/2 month old children, instances of reaching to the opening without having looked along that route at some point during the trial were rarely seen in 10-1/2 month olds.

Four of the 25 infants followed longitudinally, however, did not look at the toy through the opening at all on side-open trials during this stage of development. They knew where to go without looking in the opening and they tried to reach in while looking through a closed side. They showed a very sophisticated behavior at an unusually early age. However, they did not succeed in retrieving the toy. Each of them

Figure 20

PERFORMANCE OF AN INFANT IN THE FINAL QUARTER OF THE FIRST YEAR: HE NO LONGER NEEDS TO LOOK THROUGH OPENING

FRONT open.
Brian does not look at toy thru opening at all.

He REACHES directly thru FRONT as he LOOKS at toy thru the TOP.

Figure 21

EXAMPLE OF PHASE 3 BEHAVIOR:

ON SIDE OPEN TRIALS, INFANT STILL NEEDS TO SEE TOY THROUGH OPENING, BUT HAVING DONE SO, HE CAN REACH INTO BOX WHILE LOOKING THROUGH A CLOSED SIDE

RIGHT side open. Brian leans & looks at toy thru opening.

He then sits up, REACHING with his RIGHT hand thru the RIGHT side, all the time LOOKING at the toy thru the TOP.

LEFT side open. Brian leans & looks at toy thru opening.

He attempts to awkwardly reach in the LEFT with his RIGHT hand, but that hand is unable to reach the toy.

Brian sits up & switches hands...

now using his left hand to reach thru the left, all the while looking at toy thru the top.

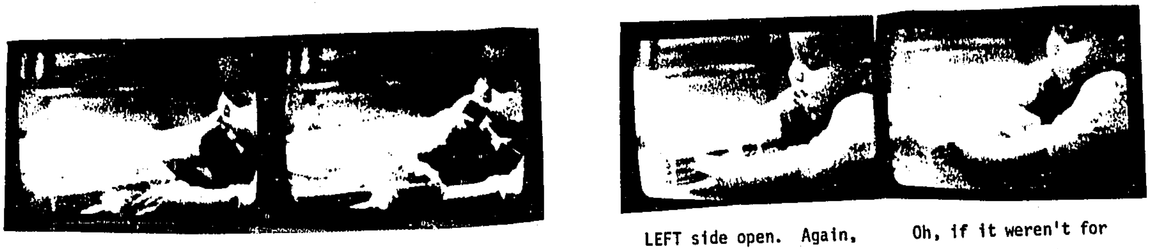
failed to adjust the orientation of their fingers or the angle of their reach adequately to clear the opening and obtain the toy. Typically, the upright thumb, poised to grasp the toy, was stopped by the edge of the opening. Try as they might to uncatch it, the thumb remained blocked by the box. (See Figure 22.) Another common error was to calibrate incorrectly (i.e., to miss the opening by reaching too high, too far forward, or too far back). Sometimes, for example, they reached too high and only the last two fingers entered the opening, or the entire hand went over the top of the box. On other occasions, while feeling for the edge of the opening, they touched the back edge and reached behind the box, as if they thought they had found the opening.

These four infants provide an important lesson. The development we are witnessing is not simply the ability to resist the lure of the line of sight, but also involves the ability to aim and adjust one's movements correctly. During the second half of the first year, infants look along the line they must reach in order to be able to properly direct their arms and hands. They fail to properly calibrate the movements of their hands for the spatial requirements of the task if they lack this visual information. The four infants who did not first look into the side opening before reaching had much more difficulty clearing the opening with their hand than did the infants who looked in first. The ability to direct their hands into an opening on the side of the box appeared to go astray even as late as 10-1/2 months when vision had not directly established the correct line of reach.

By one year, infants have gained sufficient sophistication in maneuvering their hands through a spatial configuration and in attending to various sources of information that Object Retrieval becomes a very

Figure 22

An Example of a Problem in Adjusting the Hand
to Clear Opening and Obtain Toy
When Infant Does Not Look Along the Line of Reach



Example of exception to the general rule: RIGHT side open. Erin looks at toy thru top & reaches with her right hand to the right side - BUT her thumb gets caught on top edge of opening...

& it remains caught despite Erin's persistent efforts to free it.

LEFT side open. Again, Erin LOOKS thru TOP & REACHES with LEFT hand at LEFT side - but her thumb gets caught on top edge of opening.

Oh, if it weren't for that thumb! Erin never leans & looks in opening, either before her reach or in her efforts to free the thumb.

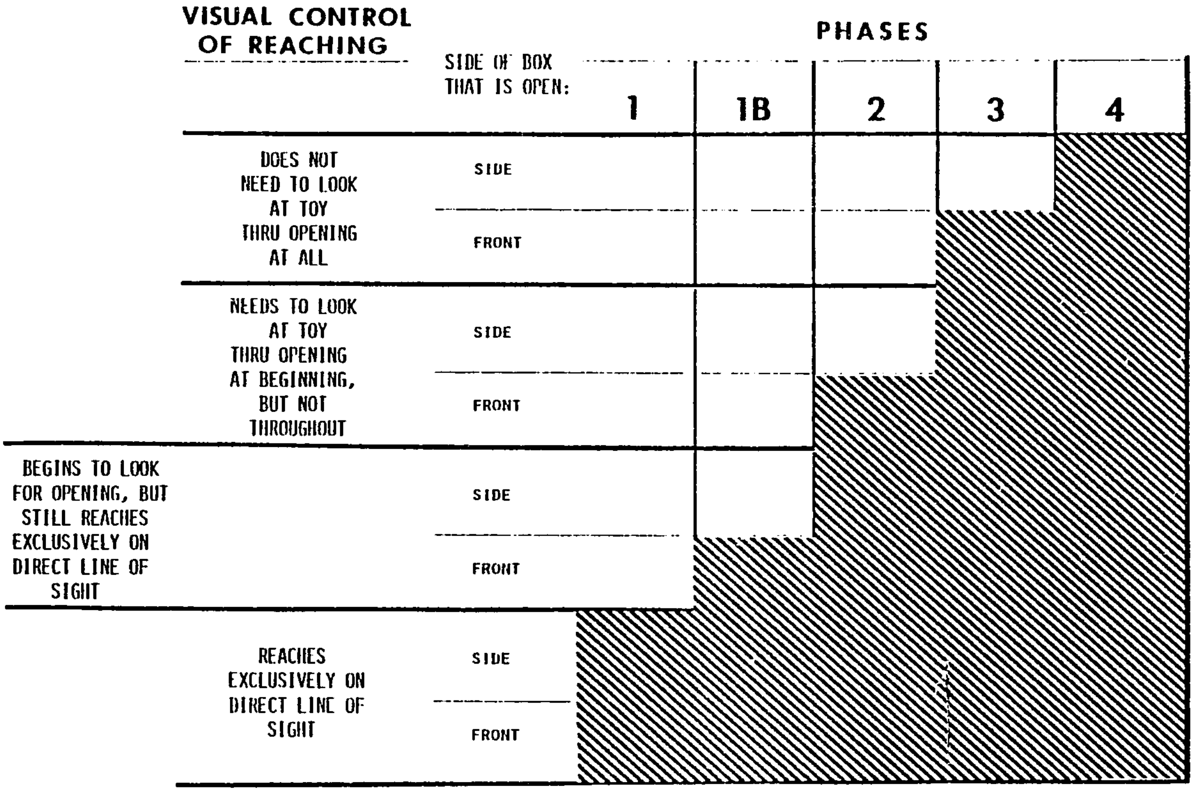
Enlarged view.

easy task. Even on side-open trials, they no longer need to look into the opening at any time during a trial in order to succeed. Figure 23 presents the average percent of left- and right-open trials at each age on which the infant never looked through the opening at all and yet still succeeded in retrieving the toy. For infants one year of age, this is roughly 80%, while even as late as 10-1/2 months it is still only about 40%. Among the children in the middle 50%, the success rate on side-open trials, where the infant has never looked in the opening, is 80% at one year and 15% at 10-1/2 months of age.

Figure 24 outlines the four stages of increasing independence of the reach from visual control which have been described in the preceding pages. This development can be understood as a linear progression in the coordination of the eyes and the hands, both in the sense of integrating visual and tactile information and in the sense of the eye needing to instruct the hand (younger infants appear to be unable to adjust their hand movements to the spatial configuration of the task unless they look directly long the correct line of reach). In Phase 1 and 1B, infants reach exclusively along the line of sight. No clue, no coaxing, no amount of failure will persuade them to try anything else. When there is a conflict between vision and touch, tactile information appears to be ignored. The conflict is resolved by attending exclusively to the visual information. In Phase 4, infants do not need to look along the line of reach, and when a conflict between vision and touch arises, they are able to attend to both the tactile and visual information, and to relate these two sources of information to one another. In Phases 2 and 3, one sees the beginning and gradual development of the integration of information from the eyes with information

THE DEVELOPMENT OF OBJECT RETRIEVAL UNDER CONDITIONS OF VISUAL CONFLICT

Figure 24



THIS SEQUENCE OF DEVELOPMENT FITS A GUTTMAN SCALE WITH A COEFFICIENT OF REPRODUCIBILITY OF .93 FOR THE BABIES IN THE LONGITUDINAL SAMPLE. THAT IS, THE BABIES DEVIATED SO RARELY FROM THE SEQUENCE OF BEHAVIOR OUTLINED ABOVE THAT BY KNOWING SIMPLY WHETHER A BABY WAS AT LEVEL 1, 1B, 2, 3, OR 4 ONE COULD ACCURATELY PREDICT WHICH OF THE BEHAVIORS ON THE VERTICAL AXIS HE WOULD, AND WOULD NOT, DISPLAY 93% OF THE TIME.

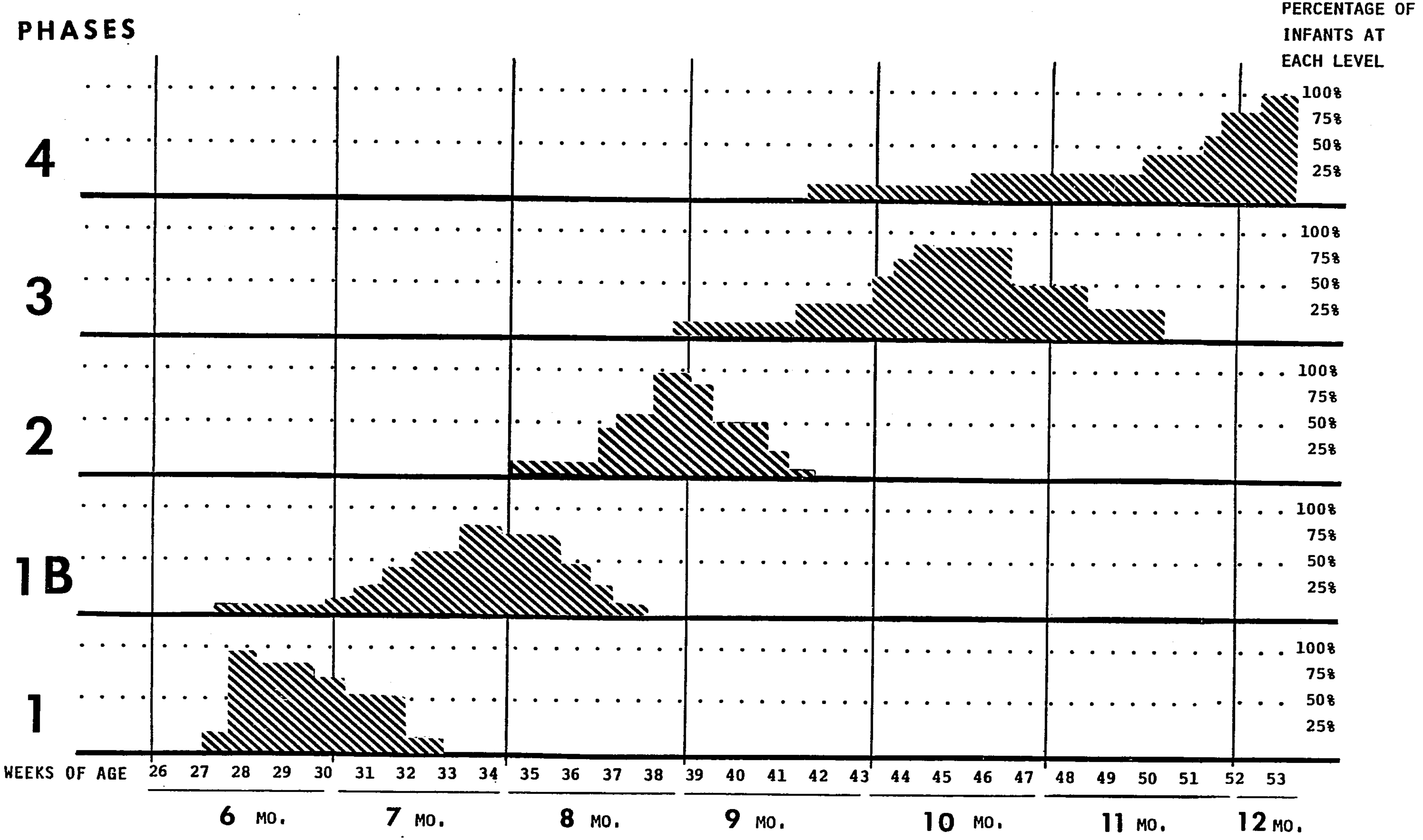
from, and actions of, the hands.

Phase 2 marks the first time that infants do not need to simultaneously look and reach along the same line; they can do this sequentially. If they have looked through the opening, they can then reach through it while looking through a closed side. However, this ability has not yet generalized to all orientations of the box (infants are not yet able to do this when the opening is on the left or right), and this ability is still limited by the need to look along the line of reach; the new-found freedom consists only in not having to continue to do this. Phase 3 marks (1) the first time that infants do not need to look along the line of reach at all on front-open trials and (2) the first time they can sequentially look, then reach, along the route through the opening on side-open trials.

(Phase 1B is not an advance in freedom from visual control. Rather, it marks the beginning of the end of passive acceptance of the task as given. Reaching during Phase 1B is still exclusively along the line of sight, as in Phase 1, but during Phase 1B infants begin to move themselves or the box to change their line of sight. Phase 1B will be discussed in greater detail in the section outlining the development of the infant's more active participation in the world.)

Figure 25 presents the age distributions for these phases of development. The phase of development characterizing an infant's behavior on each visit was determined by the most mature behavior displayed on at least three front-open trials and similarly on at least three side-open trials. (Additionally, on side-open, this behavior had to be in evidence on at least one left-open trial and at least one right-open trial.) Less mature behaviors rarely disappeared entirely.

HISTOGRAMS OF AGE DISTRIBUTIONS FOR THE PHASES



based solely on babies seen longitudinally; does not include control subjects. (N=25)
based on transparent boxes only; ages for all levels are younger for the opaque box, except for Phase 1.

In particular, when the difficulty of the trials increased, infants often reverted back to behaviors which they had stopped displaying on the easier trials. However, very sophisticated behaviors did not appear before less sophisticated ones. The order in which the infants progressed in their ability to retrieve a toy from a transparent box differed very, very little among the children. Thus, for example, the oldest children might, on occasion, insist on leaning to look through the opening throughout an entire trial. But the youngest children were never able to retrieve the toy without having looked through the opening at all.

THE OPAQUE BOX

Object Retrieval was much easier with an opaque box, for infants passed through the same sequence of phases more quickly when an opaque box was used. Most infants showed the behaviors typical of Phases 2, 3, and 4 at earlier ages with the opaque box than with the transparent boxes. No infant reached any of these phases earlier for the transparent than for the opaque box. (Use of an opaque box with younger infants, in Phases 1 & 1B, is complicated by the fact that infants who cannot yet find a hidden object will not search at all in the opaque box if they do not see the toy through the opening.)

Table 37 summarizes these results. Each child at each visit was classified as being at a particular phase based on his performance with the transparent boxes. (The criteria used here are summarized in Figure 24.) On each visit where the opaque box was used (it was only used on about 70% of the visits), the child's level of performance with the opaque box was also evaluated. The first column in Table 37 refers to the first visit, for each phase, when a child was rated as being at that level based on performance with the transparent boxes, <u>and</u> the opaque box was used. It addresses the question, "At what level were the children performing on the opaque box during this visit -- at a lower Phase than with the transparent boxes, at the same Phase, or at a more advanced phase?" One might have thought that Object Retrieval would be more difficult with the opaque box for there is less visual information available. Column 1 shows, however, that early in a child's attainment

TABLE 37

Comparison of Performance on Opaque Box with Performance on Transparent Boxes

	Earliest Visit at each Phase where Opaque Box was used			Last Visit at each Phase where Opaque Box was used			TOTAL		
	ahead on opaque	equal	behind on opaque	ahead on opaque	equal	behind on opaque	ahead on opaque	equal	behind on opaque
Phase 1B	11	9	4	19	4	2	30	14	6
Phase 2	15	10	0	21	4	0	36	14	0
Phase 3	12	13	0	20	5	0	32	18	0
TOTAL	38	34	4	60	13	2	98	46	6

Infants were rated as being at a given phase based on their performance on the transparent boxes. "Ahead on opaque" means that their performance on trials where the opaque box was used met the criteria for the next higher phase. "Behind on opaque" means that their performance with the opaque box met only the criteria for the next lower phase.

of a particular level of performance on the transparent boxes, he is doing at least as well or better on the opaque box. These scores can be transformed into z scores to test the difference between advanced versus behind (38 vs. 4), giving each a 50% probability, or this transformation can be used to test the difference between advanced-or-equal versus behind (71 vs. 4), giving the first a 67% probability (as it combines 2 out of 3 categories). Both of these tests show that performance on the opaque box is at least as good as performance on the transparent box at levels well beyond what one might expect by chance.

Column 2 of Table 37 examines the last visit, for each phase, when a child was still rated as being at that level based on performance with the transparent boxes, <u>and</u> the opaque box was used. By this time, most children have moved ahead on the opaque box. Using a z transformation, and testing the difference between the number of children at each Phase who were a Phase ahead on the opaque box (60) versus the number who were at the same level or behind on the opaque box as compared to the transparent boxes (15) is significant at the .01 level.

Children were never observed to be two phases ahead on the opaque box compared to the transparent boxes, but they were rarely behind on the opaque. Typically, they were one phase ahead on the opaque box, especially toward the end of a particular phase on the transparent boxes. Figure 26 provides three illustrations of advanced performance on comparable trials with the opaque versus the transparent box. Each set of comparison trials is within a single visit.

Experience with the opaque box often aided performance when the transparent box was again used. Infants at the boundary between Phases 2 and 3, for example, often progressed to Phase 3 on the transparent

Figure 26: THREE ILLUSTRATIONS OF PERFORMANCE ON OPAQUE BOX SUPERIOR TO THAT ON TRANSPARENT BOX, WITHIN THE SAME TESTING SESSION

Front open, transparent box.
Tom tries to reach thru top.

After prolonged attempt to reach thru top, he looks away.

Upset, he refuses to try any longer.

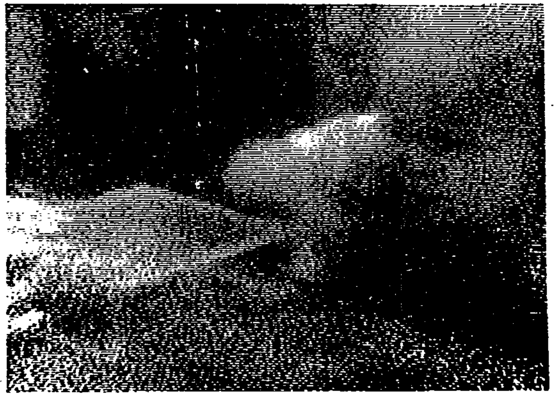
THIS IS CHARACTERISTIC OF PHASE 1.

Front open, opaque box.
Tom raises box & looks in opening.

Box is down, but Tom can still see thru opening.

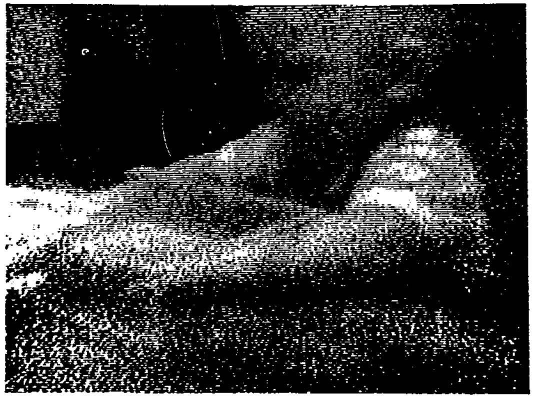
Looking into the opening, he reaches in with both hands & retrieves toy.

THIS IS CHARACTERISTIC OF PHASE 1B.



Left side open, transparent box.
Brian leans & looks in opening,
right arm raised.

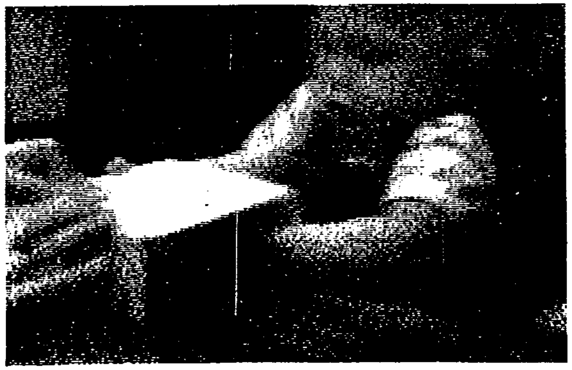
After looking in opening, he
sits up...



and reaches in with the near hand
(left) as he looks thru top of box.

THIS IS PHASE 3 BEHAVIOR.

Left side open, opaque box.
Using his sense of touch,
Brian finds the opening.



He reaches in & retrieves toy without
ever leaning & looking in opening.

THIS IS PHASE 4 BEHAVIOR.

Left side open, opaque box.
Kate leans & looks in opening.

She reaches in awkwardly with the far hand (right)
as she continues to look thru opening.

THIS IS TYPICAL OF PHASE 2 BEHAVIOR.

COMPARE TO FIGURE 12. WHICH ILLUSTRATES A TRIAL FROM SAME VISIT, ALSO LEFT SIDE OPEN, BUT TRANSPARENT BOX. KATE'S BEHAVIOR HERE IS TYPICAL OF PHASE 1 OR 1B; SHE MAKES NO ATTEMPT TO LOOK OR REACH THRU SIDE OPENING.

boxes after a few trials with the opaque box. However, children who had just reached a phase, or who would yet remain in that phase for weeks to come, were rarely able to duplicate the high level of performance they had shown on the opaque box when a transparent box was again introduced. It was as if experience with the opaque box could aid them in making a transition if they were on the verge of making it on their own. But such experience did not help them if they were not already at this level of preparedness. The salutary effects of experience with the opaque box for children at the upper boundary of a phase means that if the order of testing had always been transparent boxes first and then opaque, the results in Table 37 would probably have been more dramatic. Because we systematically varied the order of the presentation of the boxes the opaque box was presented before the transparent box on several visits. Some children, at the upper boundary of a phase, were helped by the opaque box to advance to the next phase. These children thus appear in column 1 under "equal," instead of in column 2 under "ahead on the opaque box."

Phases 1 and 4 have been omitted from Table 37 because of ceiling and floor effects. It is not possible to be ahead of Phase 4, because it is the highest level. Similarly, it is not possible to be behind Phase 1, because that is the lowest level. Including these phases in the table would have distorted the overall picture. The results for these two levels are:

	Earliest Visit at that Phase Where Opaque Box is Used			Last Visit at that Phase Where Opaque Box is Used		
	ahead on opaque	equal	behind on opaque	ahead on opaque	equal	behind on opaque
Phase 1	0	23	-	8	15	-
Phase 4	-	25	0	-	25	0

(Only 23 infants were tested at Phase 1 on the opaque box.) It should be noted that children could not progress to Phases 1B and 2 on the opaque box until they could find a hidden object. Thus, the difference in performance on the opaque and transparent boxes becomes more apparent once the ability to find a hidden object has been attained.

Other work with barriers corroborates the finding that performance is superior at earlier ages with opaque versus transparent barriers. Bruner, Kaye, and Lyons (1968) report superior performance (more trials ending in success) with an opaque wall barrier versus a transparent wall for infants 6-9 months of age. Lockman (1981) reports that most of the 8-12 month old infants he tested successfully retrieved a toy from behind an opaque wall barrier at an earlier age than they did with a transparent wall. None solved the transparent detour problem earlier than the opaque. Finally, Church (1971), using a barrier even more similar to the present one -- a top-open, wide, shallow cup -- found that 8-10 month olds who failed when the container was transparent could succeed on identical trials when the container was opaque.

Even though it is clear in the present experiment that infants could perceive the transparent box, the opaque box must have served to make the presence of the barrier more salient, and thus the need to circumvent the barrier (instead of trying to reach through it) must have been more salient as well. Also, younger infants, for whom looking along the route they are reaching is so important, receive more incentive to look through the opening with the opaque versus the transparent box, for with the opaque box it is <u>only</u> through the opening that one can see the toy.

The counterintuitive finding that a retrieval task is easier when one cannot see the goal can be understood if one realizes that when an infant under one year can see the goal, his tendency to reach on a straight line to where he is looking exerts a strong pull on his behavior. With the transparent boxes, this perception must compete with the other information available (the sight of the opening, and the tactile information specifying a solid surface and the edge of an opening). By contrast, this competition is eliminated with the opaque box, where there is less visual information available. That infants perform better with the opaque box suggests that the information which has been omitted must have impeded their performance. More information is not always better.

TOP-OPEN, TOY INSIDE BOX, BORDERING FRONT WALL

Even as early as 7-8 months, infants are proficient at retrieving the toy in the top-open condition. Typically, they do this by pulling the box toward themselves, leaning and looking at the toy through the top, and then reaching in to retrieve the toy. They do this quickly and easily. However, if the toy is placed directly behind the front wall of the box, many infants do not retrieve it. That is, moving the toy but one or two inches, without covering or transforming it in anyway dramatically affects the likelihood that infants will retrieve it. Infants do not fail because they do not try; they do attempt to reach for the toy. Nor do they fail because of insufficient manual dexterity to grasp the toy when it is against the wall; those who fail never touch the toy. Instead, the infants act as if they cannot find it.

This chapter reports an exploration into this phenomenon. Because the top-open orientation proved so easy even for young children, several months into the study we attempted to increase the difficulty of top-open trials by placing the toy against the front wall of the box, instead of in the center. Because this manipulation was not part of the original experimental design, infants in the longitudinal sample were first tested on this at different ages. Fifty full-term infants (25 male, 25 female) tested only once received this manipulation as well. Ten of these children were 7 months of age at the time of testing, and ten were 8, 9, 10, and 11 months of age.

Method

Testing on the top-open orientation under the revised procedure consisted of:

trial 1 -- a toy in center of 4-1/2" x 4-1/2" x 2" transparent Plexiglas box;[51]

trial 2 -- Lego building block (2-1/2" x 1-1/4" x 3/4") flush against front wall of the box;

trial 3 -- Lego block in the center of the box;

trial 4 -- Lego block again flush against front wall of the box.

If an infant gave up without retrieving the toy on any trial, the trial was again presented again and the infant again encouraged to try. On trial 4, if the infant gave up a second time, the experimenter intervened by either "trailing the toy" or "tipping the box."[52]

To "trail the toy" the experimenter grasped the Lego block and slowly raised it in a vertical line above the box and then slowly returned it to its original position. The infant always watched attentively and usually tried to reach for the toy, following the movement of the experimenter's hand and the toy with his or her own hand. If the infant still failed to retrieve the toy, trailing was repeated one more time. Figure 27 illustrates what "trailing the toy" actually looked like.

To "tip the box" the experimenter picked up the back of the box and tipped the box toward the infant with the base of the front as a fulcrum. The box was maintained in this position as the infant reached.

On trial 5, half the infants were presented with an opaque box

Figure 27

Example of a Trailing Sequence

Exp slowly raises toy out of box.

The infant watches toy's progress attentively.

Infant reaches eagerly for toy

and the reach continues as the Exp slowly lowers the toy into its original position.

equal in size to the transparent one with the Lego block inside, bordering the front wall, and half the infants were presented with the transparent box again, but this time with the Lego block outside, bordering the front wall.

On trial 6, every child again faced the Lego block, inside the transparent box, against the front wall.

Thus, all children received the condition: toy inside box, bordering front wall, transparent box, three times (on trials 2, 4, and 6). Table 38 provides an outline of the testing sequence, and Figure 28 illustrates how the box and toy appeared to the infant at the outset of each trial in this sequence.

Infants were permitted to pull the box toward themselves and to lean and look in the box. If in pulling the box toward themselves the toy moved accidentally, the trial was presented to the infant again. Similarly, if the infant reached out and grasped the box and toy in one fell swoop, the trial was presented again as a check on whether this had been a lucky accident.

Results

Of the 75 children tested, 38 were unable to retrieve the toy on trials 2 and 4, trials where the toy was against the inside front wall of the transparent box.[53] No child, however, failed when it was in the center of the box, against the front wall of the opaque box, or when it was outside against the front wall of the transparent box.[54]

For the 38 infants who failed on trial 4, the experimenter "trailed the toy" for 19 of them, and "tipped the box" for the other 19. Only 2

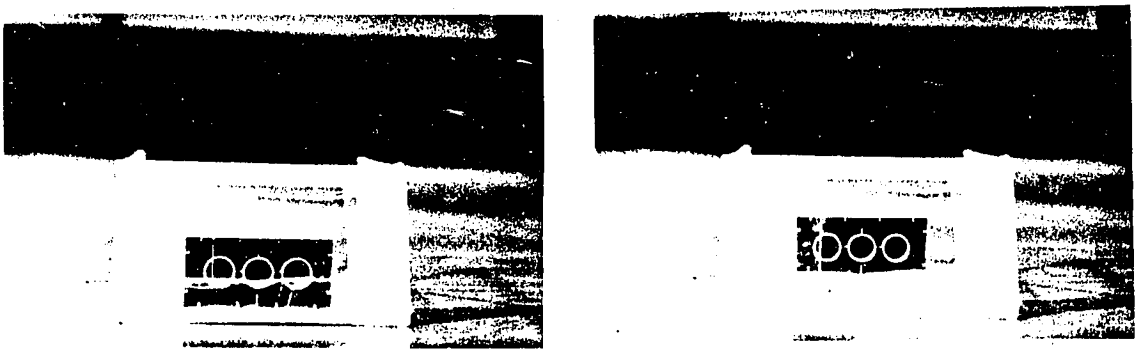
Table 38

THE TESTING CONDITIONS AND SEQUENCE

Conditions:	Toy Inside Box, Bordering Front Wall Transparent Box	Toy Inside Box, in Center, Transparent Box	Experimenter Trails Toy	Experimenter Tips Box	Toy Inside Box, Bordering Front Wall Opaque Box	Toy Inside Box, Bordering Front Wall Transparent Box
TRIALS						
1		all children; toy other than Lego				
2	all children					
3		all children				
4	all children		half the children who failed trial 4 twice	half the children who failed trial 4 twice		
5					half the children	half the children
6	all children					

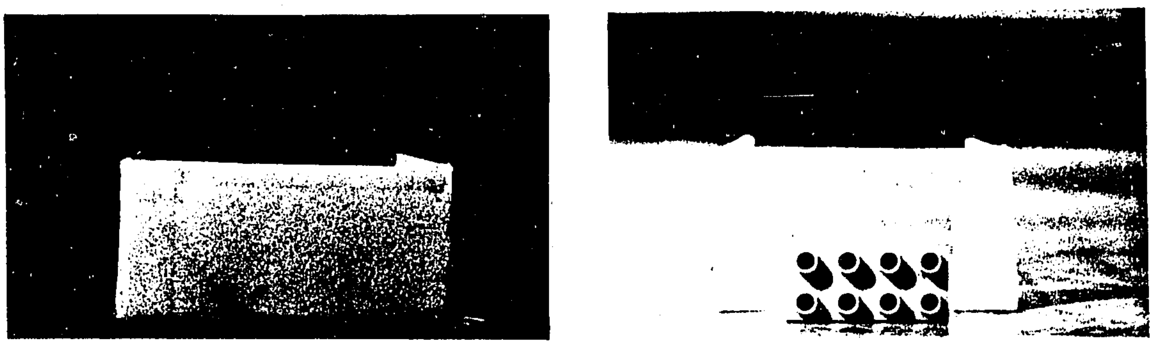
Figure 28

The Appearance of the Box and Toy at the Outset of Various Conditions



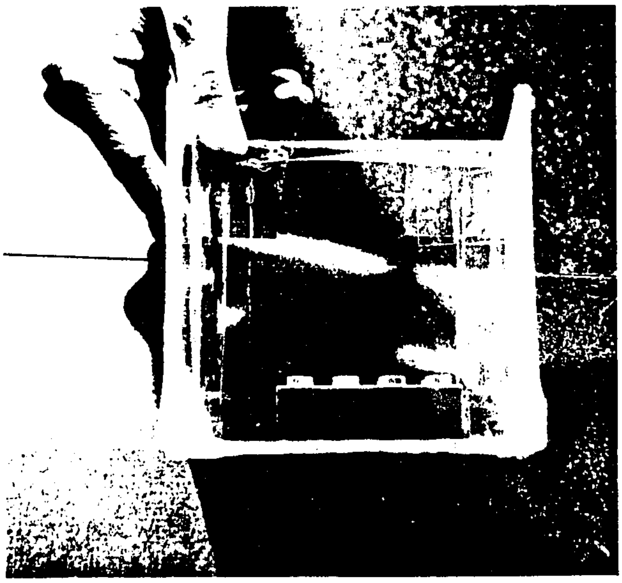
Toy Inside Transparent Box, Bordering Front Wall

Toy Inside Transparent Box, in Center of Box



Toy Inside Opaque Box, Bordering Front Wall

Toy Outside Transparent Box, Bordering Front Wall



Toy Inside Transparent Box
Bordering Front Wall,
Box Tipped

of the children were able to retrieve the toy after it had been "trailed," even though most of these children had followed the toy with their hand as it descended back into the box, and even though the trailing was repeated a second time for all infants who were still unable to retrieve the toy after the first trailing.

Of the 19 children for whom the box was tipped forward, all 19 succeeded in retrieving the toy with the box in this position. It was never necessary to present the tipped box a second time.

There was no sex difference in the results. The results across age are presented in Table 39. At 7 months of age, virtually all infants failed to retrieve the toy on trials 2 and 4. Virtually all 11 month olds succeeded on these trials. (The results for each of these ages are significantly different from chance at less than .01 using the cumulative binomial distribution.) At 8, 9, and 10 months, the performance of infants was intermediate between the almost 0% success rate of the 7 month old infants and the almost 100% rate of the 11 month old infants; the percentage of infants succeeding on trials 2 and 4 did not differ significantly from 50% for ages 8, 9, and 10 months. Controlling for age, there is no difference between the children tested longitudinally and the children who were seen only once.

No child failed because of not attempting to retrieve the toy. All infants made at least some attempt to get the toy. Typical behaviors of the infants who failed were: (a) trying to reach for the Lego block through the front of the box; and (b) pulling the box toward themselves, leaning over, and looking in through the open top of the box. This look might be accompanied by no reach, by a reach which stopped before completion, or by a reach too far back in the box, missing the toy

Table 39

PERCENT OF INFANTS SUCCESSFULLY RETRIEVING THE TOY IN THE CONDITION:

TOY INSIDE BOX
TOY FLUSH AGAINST FRONT WALL OF BOX
TRANSPARENT BOX

BY MONTHS OF AGE

	Months of Age				
	7	8	9	10	11
Longitudinal Sample	0% (1)	33% (3)	64% (11)	57% (7)	100% (3)
Cross-Sectional Sample	10% (10)	40% (10)	70% (10)	60% (10)	90% (10)
Total	9% (11)	38% (13)	67% (21)	59% (17)	92% (13)

entirely. A common sequence was: tries to reach for toy through front of box, pulls box toward self, leans and looks inside box, pushes box away, looks at toy through front of box, pulls box again, leans and looks, gives up. Figure 29 presents photographs of a few behavioral sequences from actual trials.

Infants who successfully retrieved the toy on these trials typically: (a) pulled the box toward themselves, leaned and looked in the top of the box, and then reached in and grasped the toy; or (b) reached over the front wall of the box and grasped the toy without any attempt to lean and look at the toy through the top of the box. See Figure 30. Sometimes these children showed some of the behaviors seen in the infants who failed (such as trying to reach for the toy through the front of the box) before they succeeded in getting the toy.

When the opaque box was used, infants pulled the box toward themselves, leaned and looked in, and retrieved the toy. There were almost no instances of reaching over the front wall without first leaning and looking on the opaque box trial. Figure 31 illustrates the sequence of behavior on these trials.

When the box was tipped forward or the toy was placed outside the box, infants simply reached straightaway for the toy. Figures 32 and 33 illustrate this.

When the toy was placed in the center of the box, infants typically pulled the box toward themselves, looked in through the top, and retrieved the toy. Sometimes they scratched at the front of the box first. See Figure 34. On a number of these trials, infants, in attempting to retrieve the toy, accidentally pushed it against the front wall of the box. No infant who pushed the toy against the front wall

Figure 29

Examples of Trials where Toy was
Inside Transparent Box, Against Front Wall,
and Infant Failed to Retrieve Toy

(Children pictured here will also be pictured with the opaque box, box tipped, toy outside box, toy in center of box, and toy trailed. The reader may want to compare a child's behavior here with that seen in the other conditions.)

Kate looks at toy thru Front of box.

Pokes Front of box.

Starts to reach for toy.

Stops her reach at edge of box opening.

Again looks at toy thru Front.

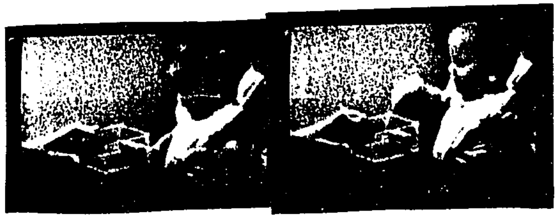
"Get me out of here."

Tries to reach for toy thru Front.

Begins reach for toy thru Top (aiming past toy)

Stops her reach at edge of box opening.

Kate looks in Top of of box for toy.



Looks at toy briefly thru Front.

And gives up.

Rachel pulls box to herself and begins to reach

The reach appears to be headed too far for the toy.

In any case, the reach stops, & Rachel looks in further.

She removes her hand and looks at toy thru Front of box.

Rachel looks thru Top.

She reaches into box past toy.

Withdraws her hand and looks at toy.

Tries Front of box

Gives up.

Looks at toy thru Front.

Looks at toy thru Top.

Leans further and looks at toy thru Top.

Pushes box away in great frustration.

Another trial.

Rachel pulls box to herself and looks in.

Looks at toy thru Front, pointing.

Reaches, again past toy.

Gives up.

Erica is held by her mother as box and toy are set in place

She scratches Front of box.

She pulls box to herself.

Looks in at toy over Front wall.

Looks in further.

Gives up.

Tries reaching thru Front again.

She looks in thru Top of box as she pulls box toward herself.

Gives up.

Figure 30

Examples of Trials where Toy was
Inside Transparent Box, Against Front Wall,
and Infant Succeeded in Getting Toy

Graham reaches for box...

and pulls it toward himself.

He looks down.

Looks in further

and retrieves toy.

Emily reaches over Front wall without pulling box or leaning and looking...

and retrieves toy.

Similarly, Jane reaches around the Front wall,

and so does Rachel (at a later age than she is pictured in in Figure 4).

Figure 31

Examples of Trials where Toy was
Inside, Against Front Wall, of the Opaque Box

Kate pulls the box toward herself.

Looks thru top and begins to reach.

Stops reach at box edge and looks in further

Retrieves toy.

Joe pulls the box toward himself.

Looks in.

Retrieves toy.

Beginning of trial.

Erica pulls box to herself and looks in Top.

Starts to reach for toy,

Stops at edge of box opening.

Reaches in,

and retrieves it.

Figure 32

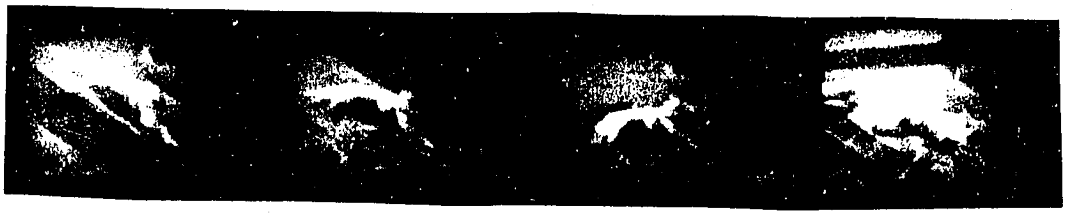
Examples of Trials where Toy was
Inside Transparent Box, Against Front Wall
and Box was Tipped

Exp tips the box toward Rachel.

Immediately, Rachel descends on the toy.

Grasps it...

and retrieves it.



James begins to reach as soon as box is tipped.

He grasps toy...

and retrieves it.

Figure 33

Examples of Trials where Toy was
Outside Transparent Box, Against Front Wall

Outset of trial. Jamie reaches for toy. Grasps it And retrieves it.

When the toy is behind the Front wall, Tyler cannot retrieve it.

But he has no trouble
when the toy is in
front of the wall.

Figure 34

Examples of Trials where Toy was
in the Center of the Transparent Box

Joe reaches for box.

Reach starts as he pulls box (looking thru Top).

Palm lands on edge of box.

However, reach continues to toy...

and toy is retrieved.

Beginning of trial.

Erica reaches for toy.

Grasps it

and retrieves it.

himself ever failed to retrieve the toy, even though when presented with trials where the toy was placed in this position many of these infants did fail.

Finally, Figure 35 illustrates a "trailing" sequence, including infants' responses to this event. Recall that the experimenter first trailed the toy after an infant had given up for the second time on trial 4. All infants ceased fretting when the experimenter began to trail the toy. Occasionally, the infant simply observed the trailing, without trying to reach for the toy in the air. On these occasions, the infant always resumed his attempt to retrieve the toy once the trailing was completed, but this never led to success. Usually, infants tracked the toy's movement with their hands. However, this "following" almost alway as stopped at the boundary of the box. Most commonly, the infants stopped after touching the box; occasionally they stopped before ever touching it. Regardless of when or where they stopped, they typically reverted back to looking at, or reaching for, the toy through the front of the box once the toy was back in place.

Recall that infants were given another opportunity to attempt to retrieve the Lego toy in the "inside box, against front wall, transparent box" condition after they had retrieved this toy from the center of the transparent box (trial 4), and after they had retrieved it from the opaque box or from outside of the transparent box (trial 6). Also, if an infant grasped the toy and box as one unit at the outset of a trial, or if in grasping the top edge of the front wall of the box the infant accidentally touched and moved the Lego away from the wall, the trial was repeated. In all these instances the infant was given an opportunity to attempt the task after a success experience. Did any of these

Figure 35

Examples of the Reaching Behavior of Infants
During and Following a Trailing Sequence

As soon as Exp begins to move toy, Joe begins to reach.

His reach follows the toy's slow progress up and back down.

However, he stops at the edge of the box...

and looks at toy thru Front of box.

Tries to reach thru Front.

Begins a reach thru Top.

Stops.

Starts another reach.

Reach stops at edge of box.

Joe refuses to try any longer.

Exp begins to raise toy out of box.

Kate watches toy's progress...

and starts to reach for toy as it is returned to box.

However, she stops at boundary of box

and reverts to trying to reach thru the Front.

Exp begins to trail toy while Erica is upset.

Erica stops fussing and tracks the toy's movements with her eyes.

She begins to reach for the toy as it is returned to place.

But she is reaching at the Front, not the Top.

She remains at Front after Exp's hand has left.

Looks in Top.

Gives up.

experiences aid the infant on his next attempt at retrieving the toy from inside the transparent box along the front wall? Table 40 summarizes the results here.

Experience with the toy in the center of the box and experience with the toy outside the box did _not_ aid performance when the toy was once again presented bordering the inside front wall. On the other hand, success rate improved after experience with the opaque box and after experience grasping the toy when it was in place against the front of the transparent box. Whether it can be asserted that the opaque box or grasping experience can be given credit for this improved performance will be addressed in the discussion section below.

_No_ previous experience (even with the opaque box or grasping the toy and box as one) aided a child below the age of 8 months. That is, following these experiences, 7 month old infants remained unable to retrieve the Lego toy from the inside front wall of the transparent box.

All results reported thus far pertain to the first presentation of this task. The infants tested longitudinally, however, were given this task again at two-week intervals until their first birthday. Of the 10 infants in the longitudinal sample who failed trials 2 and 4 on their first testing, seven did so again two weeks later, and three infants were still doing so at least six weeks later. Had testing begun at an earlier age with these children, even more of them might have evidenced difficulty for periods of several weeks.

Summary and Discussion

Many children could not retrieve the rectangular toy when it was placed directly behind the front wall of a transparent box. This is particularly striking because these children retrieved the same toy when the box was tipped forward with the toy in this position, when an opaque box was used with the toy in this position, when the toy was in the center of the transparent box, and when the toy was outside, directly in front of the front wall of the transparent box. (Trailing the toy did not aid the children.) This is the principal set of findings to be presented in this chapter and possible explanations for why this was found will be discussed below, after the other findings are outlined.

1. Age Differences

An age trend was found. Seven month old infants could not retrieve the toy from directly behind the transparent wall; 11 month old infants could. The number of babies at intermediate ages who could retrieve the toy did not differ significantly from 50%. No experience provided in the present experiment provided any indication of helping infants of 7 months to master this task. However, about three-fourths of the 8, 9, and 10 month old children tested with the opaque box were then able to retrieve the toy in the transparent box. Many of them also performed better after they had accidentally grasped the toy when it was in place behind the transparent wall. Thus, there was also an age difference in the infants' ability to profit from experience in order to retrieve the toy in this situation -- only after 7 months was there any gain from experience.

That analysis of the data by age yields roughly three levels (almost no infants succeed at 7 months, approximately 50% succeed at 8, 9, and 10 months, and virtually all succeed at 11 months) suggests either that two competences are emerging here (one between 7-8 months and the other between 10-11 months) or that a single competence, or set of competences, is emerging, the beginnings of which we see at 8, 9, and 10 months, but which does not fully appear until the eleventh month of life. I favor the second interpretation, for abilities more typically appear gradually, rather than being all or none.

When the present results are analyzed, not by age, but by the Phases which infants seem to go through generally in the Object Retrieval experiment, one finds:

Percent of Infants Successfully Retrieving Toy from Inside Transparent Box, Against Front Wall

Phase 1B	7%	(N = 14)
Phase 2	58%	(N = 19)
Phase 3	33%	(N = 24)
Phase 4	94%	(N = 19)

During Phases 1 and 1B, the success rate is virtually zero; Phases 2 and 3 see a success rate not significantly different from 50%; Phase 4 sees a success rate close to 100%.

2. The Effect of Experience

There is no indication that experience with the toy in the center of the box, the box tipped, the toy trailed, the toy bordering the outside of the front wall of the box, or accidentally moving the toy away from the front wall, aided subsequent performance when the toy was directly behind the front wall of the transparent box. However, it is possible that these experiences combined with those which did immediately precede increased success and so were helpful in some summative way. Alternately, it is possible that had these experiences been provided more than once, a salutary effect would have emerged. Repeated exposure to the "inside transparent box, bordering front wall" condition does not seem to lead to improved performance either. (While these trials were not given consecutively, they were always presented a second time if an infant failed to retrieve the toy on the first presentation.)

On the other hand, success rate did improve after experience with the opaque box and experience grasping the toy when it placed against the front of the transparent box. Of the 19 children tested with the opaque box, 13 succeeded on the next trial with the transparent box. This is significant at the .05 level using the cumulative binomial distribution. It is unlikely that these successes were simply due to the substantial experience infants had had with the Lego block in the box (this was trial 6) because of the 19 infants tested with the toy outside the box on trial 5 only one succeeded on trial 6. These children had an equal number of trials, but they did not seem to profit from them.

It is possible that grasping the toy and box as soon as the trial began, rather than being a fortuitous accident, was indicative instead of sophisticated mastery of the task (the infant knew where to reach without ever looking over the wall). This seems unlikely, however. It was common for infants who were successful (especially older ones) to simply reach over the front wall and grasp the toy as soon as the trial began. However, they rarely grasped both the box and toy, as is true here; rather, their grasp was more localized. Second, of the 13 infants who grasped the toy and box as one, none ever repeated this performance, and only 2 ever reached over the wall and grasped the toy in the more

Table 40

THE RETRIEVAL PERFORMANCE OF INFANTS IN THE CONDITION:

TOY INSIDE BOX
TOY FLUSH AGAINST FRONT WALL OF BOX
TRANSPARENT BOX

FOLLOWING VARIOUS EXPERIENCES

	Previous Trial							
	No Previous Trials With Lego (Trial 2)		Lego in Center of Box, Transparent Box[a] (Trial 4)		Opaque Box, Lego Inside, Against Front Wall[b] (Trial 6)		Lego Outside Box, Against Front Wall, Transparent Box[b] (Trial 6)	
Performance on Present Trial. . . .	Succeed	Fail	Succeed	Fail	Succeed	Fail	Succeed	Fail
Present Trial								
No Preceding Experience on This Trial	17	37	1	32	11	4	0	18
Grasped Toy and Box "Accidently"	5	1	4	2	0	0	1	0
Touched and Moved Toy "Accidently"	9	6	1	4	2	2	0	0
TOTAL	31	44	6	38	13	6	1	18

[a] Only infants who failed trial 2 are included in this column. That is, we are looking at, of those infants who were unable to retrieve the toy before the experience with the Lego in the center of the box, how many were able to do so after experience with the Lego in the center?

[b] Only infants who failed both trials 2 and 4 are included in this column. That is, we are looking at, of those infants who thus far have been unable to retrieve the toy under the present condition, how many are now able to do so after experience with the opaque box or the toy outside of the box?

precise way. Instead, 8 of the 10 children who subsequently were able to retrieve the toy did so after leaning over and looking in the top of the box, often having considerable difficulty before succeeding. Thus, it seemed that grasping the box and toy was an accident which helped children to locate the toy or encouraged them to persist in the face of initial failure.

One element common to the opaque box trials and to grasping the toy and box as one (an element not found in the trials which did not aid performance) is the experience of retrieving the toy from the very place it occupies in the "inside transparent box, directly behind front wall" condition (with the box, also, in the same position).

The fact that many 8-10 month old infants were aided by experience with the opaque box or with grasping the toy and box together, and the fact that half these infants were able to succeed even before such experience, suggest that this task is difficult, but not impossible, for 8-10 month olds. It is likely that with appropriate training all of these infants would have become able to succeed.

3. Opaque Box versus Transparent Box

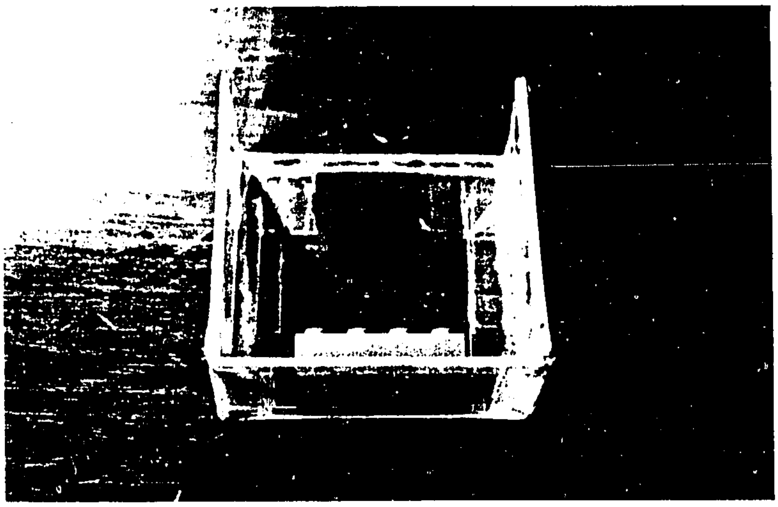
All infants succeeded with the opaque box even though many failed with the transparent box. There is more information available with the transparent box. Indeed, at the outset of a trial with the opaque box the toy is not visible at all. Why should infants perform more poorly when they have more information? With the transparent box, infants see the toy through the front. They also see the opening at the top of the box and may even see part of the toy through the top, but this information must compete with the sight of the toy through the front. If an infant looks over the front wall to see the toy when the box is transparent, he or she is likely to see part of the toy exposed through the top and part of the toy still behind the front (see Figure 36). If an infant looks over the front wall of the opaque box, he or she will see the toy only through the top (see Figure 36). With the transparent box there is the confusing perception of the toy simultaneously through the top and through the front.

Infants often appeared bewildered or unsure when the Lego block was directly behind the front wall of the transparent box. It is as if with the opaque box they were more "confident" that the route to the toy was through the top (they had no information to the contrary). Certainly, minor difficulties (such as brushing the edge of the opening instead of clearing it cleanly) appeared to bring the reach to a halt when the box was transparent, while the reach was more likely to continue to completion when the box was opaque.

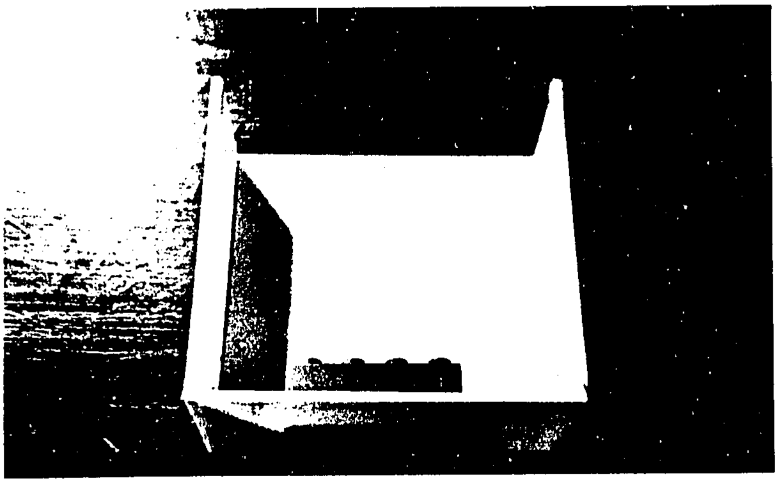
On the other hand, additional information available with the transparent box might have made infants more certain of the toy's location, rather than more confused. Infants, seeing the toy through the front, may have thought they knew exactly where the toy was. If they were wrong (and they often look and reach too deeply in the box, well beyond the toy), they may have been less inclined to abandon this strategy or to try something else. On the other hand, when the opaque box was used infants could not know where the toy was, and so may have been more inclined to search the box until they found it. It is true that if an initial look or reach did not produce the toy in the opaque box, infants were more likely to continue that look or reach until they produced the toy than they were with the transparent box.

Figure 36

The View of the Toy seen from Looking Over the Front Wall of the Box



When the transparent box is used,
the toy is seen both through the opening
and behind the front wall.



When the opaque box is used,
the toy is visible only through the top opening.

4. Possible Explanations for the Principal Finding: Poor Performance When the Toy is Directly Behind the Front Wall of the Transparent Box, in the Face of Otherwise Excellent Performance

Infants did not fail simply because they did not want the toy. This motivational explanation can be ruled out because (1) on all other trials with the same toy these same infants did reach and retrieve it, (2) as soon as trailing began and the toy was outside of the box, most of these infants reached for it immediately, (3) no infant failed by not trying to retrieve the toy, (4) infants often became very upset at their failure to get the toy (as can be seen in Figure 29), and (5) if the infant was permitted to have the toy, this fussing and crying stopped abruptly.

On the other hand, success rate (particularly at the intermediate ages of 8-10 months) may have been higher if a more desired object had been used. The Lego block was not a greatly favored toy. Other objects, such as keys, rubber squeak toys, and rattles, were pursued with more vigor and played with for longer periods than the Lego block. Indeed, there was some difficulty in sustaining children's interest in the Lego over 6 trials.

Piaget (1954) and Bower (1974, 1977) suggest the problem for infants is that they do not understand the spatial relationship of contiguity. They do not understand that an object continues to exist independently when it shares a boundary with another object.

> . . . There is general difficulty in conceiving of the relations of objects among themselves (in contrast to the relations of objects with the subject himself). It is this general difficulty which prevents the child from realizing that two objects can be independent of each other when the first is placed upon the second.
>
> (Piaget, 1954:177)[55]

> Furthermore, if infants are presented with an object that lacks a boundary of its own -- whether top, bottom, front, or back -- they will not attempt to grasp the object until they are nine or ten months of age (Piaget, 1937). One can make an object seemingly 'disappear' by placing it in such a way that one of its boundaries becomes invisible.
> (Bower, 1974:117)

> [The infant] doesn't seem to realize that one object can be on top of another . . . . The same thing happens with the concept behind [sic] . . . . It seems that what the baby doesn't understand is that two objects can be in a spatial relationship to one another, so that they share a common boundary. Evidently it is the common boundary that is critical.
> (Bower, 1977:116-117)

This explanation cannot account for the data in the present experiment, however. All infants who failed to retrieve the toy when it was behind the front wall of the transparent box succeeded when the box was tipped, when the toy was behind the opaque wall, and when the toy was in front of the transparent wall. Yet, in each of these conditions, the toy still bordered the wall. Therefore, sharing a common boundary is not a sufficient condition for failure to retrieve. Indeed, it may not even be a necessary condition. I predict (1) if the same toy were placed close behind the front wall, although not in contact with it, infants would still have difficulty here, (2) if an object such as keys was placed directly behind the front wall (an object which cannot hug the wall as closely as can a rectangular object, but which is relatively narrow and so would not extend too far into the box), infants would still have difficulty here, and (3) objects can be placed farther away from the wall the higher the wall, the narrower the toy, or the lower the infant relative to the box (the toy must remain well within the shadow of the wall) and the error will still remain (this is within narrow limits; too high a wall will cause infants to stand and thus be able to retrieve the toy).

A second possibility is that infants do not understand that an object viewed from different perspectives is the same object. Perhaps infants do not understand that the toy they saw through the front of the box is the same toy they see when they look over the front wall, through the top. Certainly, the toy looks different from the two angles. However, the toy also looks different when viewed over the opaque wall and when viewed in the center of the box than it appeared when the experimenter showed the toy to the infant before placing it in the box. (At the beginning of each trial, the toy was always shown to the infant with the surface with the raised knobs facing the infant.) Yet, the change in appearance of the toy is most abrupt when it is against the front wall of the box. Similarly, one little boy who succeeded with the block behind the transparent wall did so by standing up. From this greater height, he would have had a clearer view of the front of the toy.

Work by Uzgiris and Hunt (1970) suggests that infants are able to recognize a three-dimensional object when seen from different perspectives by 9 months of age. One way to test this hypothesis in the present experimental situation would be to use a cube with identical surfaces on all sides. If infants were still unable to retrieve this toy, then the hypothesis that infants do not understand that an object's identity remains invariant across changes in perspective could be eliminated as an explanation for the present results.

Perhaps infants cannot use information gained from seeing the toy through the front of the transparent box to correctly locate the toy within the box. They look or reach to the wrong place because they incorrectly represent the object's location. One variant of this position is that the problem is one of the depth perception: when infants see the toy through the front, they are not able to determine accurately how far behind the wall the toy actually is. They err by thinking it is deeper in the box than it really is. Two observations, made repeatedly, support this interpretation. One, on leaning and looking over the front wall of the box infants often appear to be looking well beyond where the toy is, in fact, located. Two, on reaching for the toy infants often reached well past the toy. Examples of this can be seen in Figure 37. This dramatic behavior was often observed, but there were also instances when infants appeared to be looking straight down at the toy and still failed to retrieve it. (See Figure 38.)

Much research has been done on depth perception in infancy, but it is not clear when the ability to make the rather precise judgments required in the present experiment first appears. The ability of infants to perceive differences in the distance between objects emerges dramatically between 16 and 21 weeks of life and is quite sophisticated by the time the infant is 5 months old according to Held (1981) or 7 months according to Granrud et al. (1982). However, as Yonas (1979:92) correctly points out:

> [On the one hand, there is] clear evidence that by 5-1/2 months, infants are responsive to binocular information for depth. On the other hand, we can conclude very little about the precision of the depth information provided the infants by the binocular stimulation.

One observation from the present study casts serious doubt on the depth perception hypothesis. Almost one-half the infants who failed on earlier trial(s) with the toy bordering the inside front wall of the transparent box reacted with distress when this trial was again presented to them later. This distress was observed as soon as the trial was presented, <u>before the infant made any attempt to retrieve the</u>

Figure 37

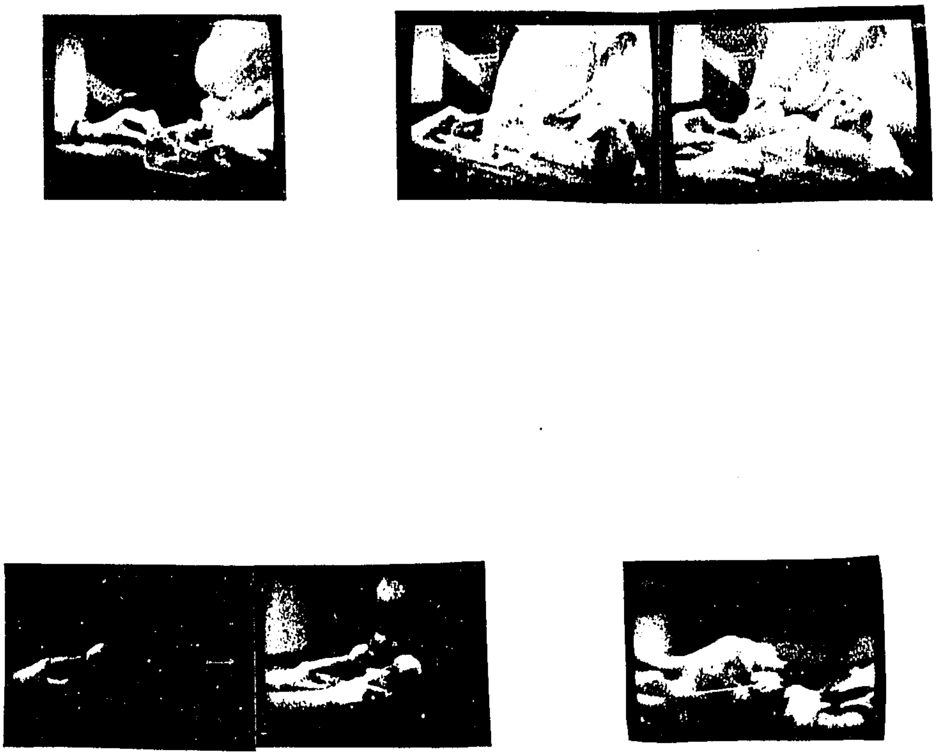
Examples of Looks and Reaches
which appear to be "Too Long"

LOOKS:

REACHES:

Figure 38

Examples of Infants who Appear to be
Looking Directly at the Toy through the Top of the Box
and Yet Failed to Retrieve the Toy



toy, and this distress was not observed on trial 3 (when the toy was placed in the center of the box). That is, infants seemed to perceive a difference between the toy right behind the front wall and the toy farther back in the box, and they seemed to remember that they did not like the former condition.

It may be that infants have difficulty using the information gained from the front view to locate the toy when reaching over the top because when looking over a wall one generally looks on a diagonal. As mentioned, oftentimes the infants seemed to be doing this and thus seemed to be looking well beyond the toy. Infants begin to reach as they begin to look over the wall. Reaches deep in the box would then be reaches to where the infant was looking. Perhaps those who did not complete their reaches did not because when they got a good look over the front wall they did not see the toy.

A third variant of the interpretation that the infants are having trouble correctly representing the toy's location emphasizes the fact that when the toy is against the front wall and the box is transparent infants see only about half of the toy exposed through the top. The other half is still seen through the front. The top edge of the front wall thus cuts across the middle of the toy. (Refer back to Figure 36.) In no condition where infants succeeded (toy in center, opaque box, toy outside, box tipped) is the toy seen to be divided in this way. Thus, this perception of the toy as simultaneously behind the front wall and also freely exposed is a distinguishing characteristic of the one condition which infants failed. This perception may well confuse infants as to the toy's location. Note, that the little boy who stood up would thereby see the toy wholly exposed; no part of it would be seen through the front. He was able to retrieve it. With one little girl we tried a seventh trial. Here a Lego bridge, which is a larger, wider toy was placed against the front wall. Viewed from over the front wall, about 3/4 of this toy appears to be freely exposed. Although this child had failed trials 2, 4, and 6 (all earlier trials with the toy against the front wall), she succeeded here.

A fourth interpretation suggests that the infants have difficulty translating the visual information into the appropriate action, i.e., into the proper route along which to reach. That is, the infants fail because of a lack of sophistication in using visual information to guide the movements appropriate to particular spatial requirements. When the toy is in the center of the box, the infant can reach on a straight diagonal:  ; when the toy is outside the box a straight diagonal reach will also lead to success: , as it will when the box is tipped:  . However, when the toy is against the inside of the front wall a "two directional" reach is necessary:  . First the infant must clear the wall and only, secondly, can the infant then reach for the toy. This reach involves a somewhat indirect route to the toy, not unlike means-end behavior. The infant cannot avoid the barrier and reach directly for the toy all at once; he or she must go around the barrier first; only then is access to the toy direct. Older children, who successfully retrieved the toy without looking over the front wall, usually simplified this reach thusly: .

Four observations should be mentioned here. First, instead of trailing the toy in a vertical line out of the box and back in place: , the experimenter, on one occasion, returned the toy to the box along the following route: . That is, the toy was brought down to the center of the box and then forward to the front wall. Although trailing rarely aided an infant, on this occasion the infant was then able to reach in and get the toy. Perhaps, by following a route similar to the one the infant would have to take, this version of trailing provides more helpful information to the infant. Or perhaps this version of trailing is helpful because it emphasizes that the toy is forward in the box. It would be interesting to see if further investigation demonstrates that this version of trailing is, in fact, more helpful (one instance hardly makes a case), and, if so, why.

Second, infants who successfully retrieved the toy occasionally reached deep inside the box, but rather than stopping there and withdrawing their hand as the children who failed did, they moved their hand forward until they reached the toy. These infants thus showed a clear two-part reach: .

Third, one aspect of the phases through which infants progress in the Object Retrieval experiment is that when the right or left side of the box is open, younger infants lean and look in, usually then reaching on a straight line:  . Older infants, however, did not need to lean and reached in a rounded movement similar to the one illustrated earlier:  . (See Figure 39.)

Fourth, there is independent evidence that when infants younger than 11 months do not look directly along the line of reach they have difficulty calibrating their arm movements for the spatial requirements. Recall the four infants in Phase 3 who did not look at the toy through the opening before or during their reach. They were usually unable to get their hand inside the opening, despite repeated attempts. They reached to the correct place; their hand was at the opening, trying to

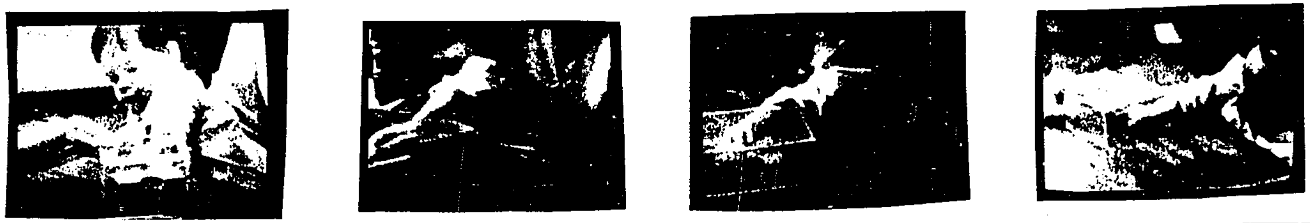
Figure 39

Comparison of Reaches over Front Wall
with Reaches to Opening on Left or Right

Reaching over front wall of box, without first leaning and looking:

involves a similar arced movement to that needed to reach around to a side opening if the infant looks through the top while doing so:

Infants who lean and look in the side opening, often reach on more of a straight line:



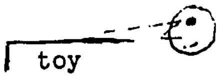
although this is not always the case:

get in -- but they were not able to adjust the angle of their reach or orientation of their fingers so as to clear the opening and get the toy.

Regardless of whether infants fail because they have difficulty making sense of two pieces of information (the sight of the toy simultaneously through the top and the front, or the sight of the toy through the front and the sight of the opening at the top) or because they have difficulty integrating two movements, especially when the second involves reversing the direction of the first, the problem presented by an object directly behind a transparent wall appears to be a problem in relating two things to one another. When infants need only attend to one piece of information (such as when the toy is seen only through the opening) or when they can make a one-part reach, instead of combining two opposing movements, they succeed. By the end of the first year, infants are able to integrate this diverse information quickly and accurately; without even the need to lean and look over the top, they reach in and retrieve the toy. Here, again, is the kind of behavior first noted by Millar and Schaffer (1973): while looking through one place (the front), the older infants act at another place (i.e., reach through the top).

MEANS-END BEHAVIOR

The Object Retrieval task also enables one to observe the increasing facility of infants to act on the box to retrieve the toy. The development of means-end behavior is seen in the ability to pull the box toward themselves on top-open trials and the ability to turn the box so that the opening is more frontal on side-open trials, but it is most clearly seen in the ability to raise the box on front-open trials:

(Outset of trial: 

raise: 

.)

The first of these behaviors to appear is pulling the box. This is in evidence in all children by 7 months of age, and in most cases was seen at 6 months. One can see why this should appear first. Infants reach for the toy, ready to grasp it and to bring it to themselves. In doing this on top-open trials, their palm is certain to touch the top of the front wall at some point. If they then reflexively grasp this edge, or, having touched something, execute the action pattern with which they had begun the reach, they will end up pulling the box toward themselves.

Instances of pulling the box at this early age lack the characteristics that would permit an inference of planfulness. They look unintentional, fortuitous. Infants below 8 or 9 months do not usually pull the box with one hand and retrieve the toy with the other. Even when this does happen, there is rarely an overlap between the two acts. First the box is pulled and only then is the reach made. When one hand is primed to reach as the other pulls, and the reach begins so that the free hand is at the toy as the box is pulled close, the action sequence appears more planned from the start. Coders consistently commented that at this age infants appeared to be reaching for the toy and only accidentally touched the box. These sequences lack the smooth, efficient quality which will be in evidence in a month or two.

Raising the box first appears a few weeks after pulling. From about 7 to 8 months of age, infants often raise the box, but very rarely does this aid them in retrieving the toy. Neither while the box is raised nor after it has been lowered, does the infant reach in and get the toy. This strategy can take a variety of forms.

Often, an infant will raise the box with both hands, but then there is no third hand with which to get the toy. One can appreciate the infant's frustration when the box is raised high and he leans forward, his head within inches of the toy, yet the toy remains beyond his reach. Bruner, Lyons, and Watkins (1969) and Bruner (1971), who noticed this behavior with a slightly different task, believed that the child did not realize that in raising the box he has made the toy accessible. (Bruner's task consisted of a box with a transparent lid mounted on sliding ball bushings. To retrieve the toy, the child had to slide the lid up its track, which was tilted 30 degrees from the horizontal, and hold it open. This sliding is equivalent to raising in the present experiment.) We are inclined to think that the child does appreciate that he has free access to the toy when the box is raised, but he does not know how to make use of this information as both hands are occupied with holding the box up. Certainly, when the experimenter raises the box, children this age are able to reach in and retrieve the toy. They often shoot in the moment the box goes up.

Infants 7-8 months also raise the box with one hand fairly often.

Here, the other hand should be free to get the toy, but it does not. It doesn't move. Bruner's interpretation, offered earlier, could account for this behavior. Our sense of what is happening here, however, is that the infant seems to have forgotten about the other hand for the moment. His attention is focused elsewhere.

At this age, instances of raising the box often begin as attempts to push the box away, off the toy. (Recall that on front- and side-open trials the box has no bottom. If it is pushed back on a front-open trial, it would move off of the stationary toy.) As the experimenter holds the box in place from the back edge, the infant is not able to succeed in pushing the box back, but the result is often that the front of the box is raised.

The first advance in the ability to use raising the box as an aid in retrieval of the toy consists in the following behavioral sequence:

1) raises box with both hands
2) removes one hand from box and attempts to reach for toy
3) but box comes down, halting reach.

Whereas earlier the raise was attempted with no reach whatsoever, now there is the beginnings of a reach. However, the infant encounters two difficulties. One, he is still tied to reaching along his line of sight. Therefore, once the box is down and he no longer sees the toy through the front, he withdraws his hand and once again tries to reach through the closed top. The other problem is that when he lowers one hand to reach for the toy, <u>not</u> lowering the other hand as well is very difficult. The hand remaining on the box does not stay raised, but comes down as well. One can observe repeated attempts to raise the box and reach, but the hand left to hold up the box consistently fails to fulfill its role. It is evidently very difficult for infants at this age to do one thing with one hand, but not the other. With both hands in a raised position, when one is lowered, the other hand tends to come down, too.

Bruner noticed very similar behavior in the experiment which required sliding open a lid:

> A seven months old has great difficulty holding the panel with one hand while reaching underneath with the other. Indeed, the first compromise solutions to the problem consist of pushing the panel up with both hands, then attempting to free one hand in order to slip it under the panel. One notes how often the infant fails because the two hands operate in concert. (Bruner, 1969b:222)

The next advance results in retrieval of the toy. The infant raises the box, and then reaches in and retrieves it after the box is down. Having seen the toy through the opening, he is able to reach in while looking through a closed side. Bruner et al. (1969) noticed that the raise and retrieval tended to be done with the same hand. However, we noticed no such consistent tendency.

Note that here the infant has found a sequential solution to his problem -- first raise, then reach. Indeed, many infants try to solve this task by pushing the box off the toy, thus disposing of the box first, and then going for the toy. (The experimenter's grip on the box prevents this from happening).

Finally, beginning around 8-10 months, infants are able to raise the box with one hand and reach in and retrieve the toy with the other. (A variant of this is to raise the box with both hands and then remove one hand and reach in and retrieve the toy -- with box still raised.) At about the same time, infants begin pulling the box toward themselves with one hand and retrieving the toy with the other. Now it is rare to see the same hand perform both roles. As the pull begins, the other hand is raised in readiness to reach, and the reach is timed to meet the toy as the box draws near. Performance as efficient and swift. Figure 40 presents histograms of the first appearance of (1) reaching in with one hand while the other hand maintains the box in raised position on at least two trials within a single visit, and (2) pulling the box with one hand and retrieving it with the other on at least 75% of the top-open trials where the box is pulled.

Again, we see another indication that at roughly 9 months of age infants become able to do two different things simultaneously. Earlier we saw that at this age they can look one place and act another, and we related this to the work of Millar & Schaffer (1972; 1973). Now we see that they are able to exercise a division of labor between the hands at this age as well. One hand does the reaching; the other holds the box out of the way or maneuvers the box and toy into position. For example, while one hand raises the box, the other is able to go in and retrieve the toy. In an early study of means-end behavior during infancy, Richardson (1934) found that infants' ability to rotate a lever arm in order to obtain a toy showed a marked improvement between 40 and 44 weeks of age (i.e., at 9 months). At 40 weeks, only 20% of the infants successfully rotated the lever, even once, to bring the toy within reach; by 44 weeks, 67% of the infants were doing so.

In discussing the phases outlining the loosening of visual control of reaching, we mentioned that more mature behaviors are almost never seen at early ages, but less mature behaviors rarely disappear entirely. They can be seen at times at even quite late ages. This observation is equally true here. For example, we have noted that pulling the box

Figure 40A

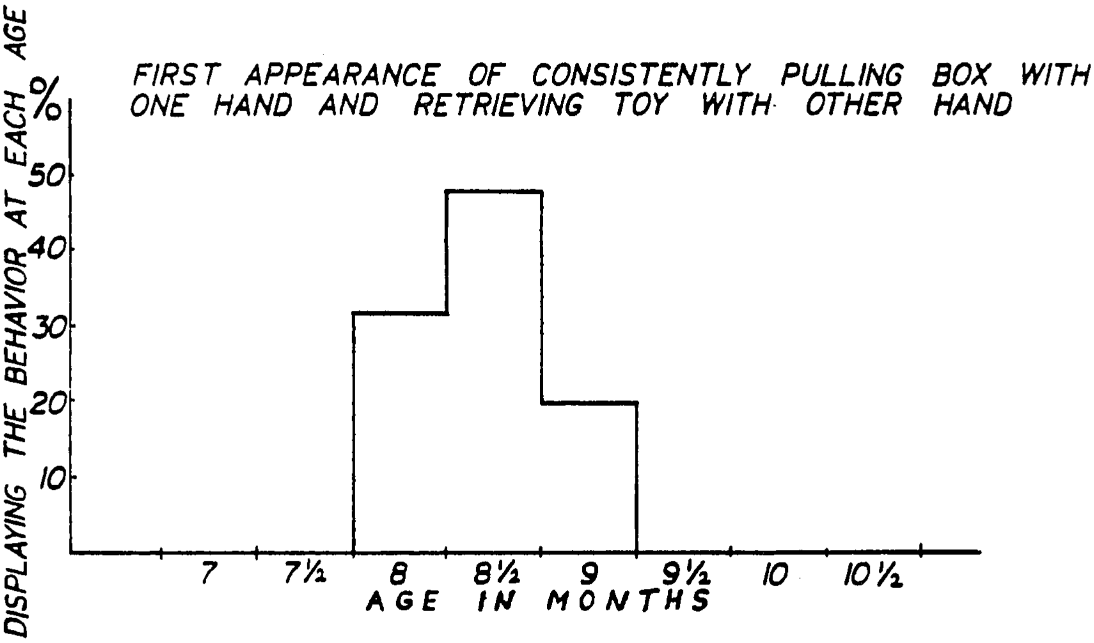
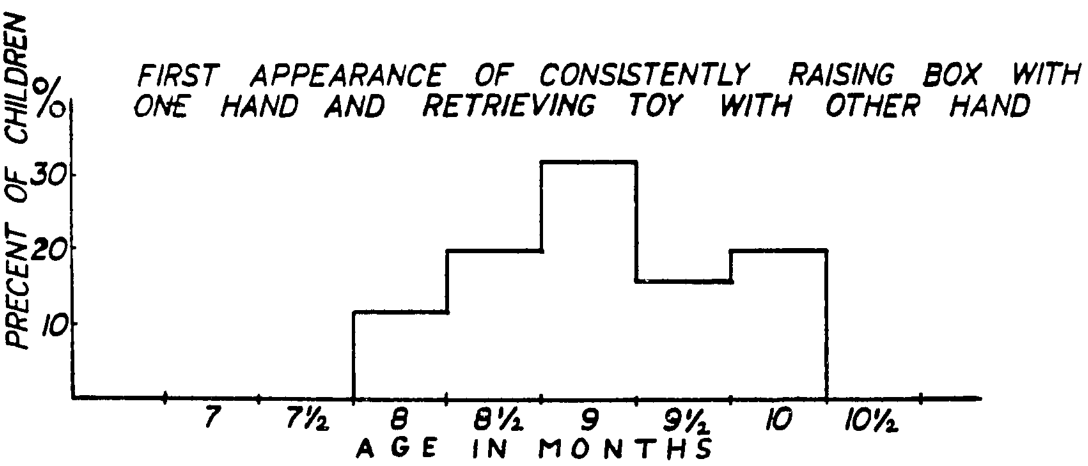


Figure 40B



toward themselves was in every child's behavioral repertoire by 7 months. However, even at 9 months, if the toy were placed so that it was just at the border of being barely reachable/just beyond reach, infants often tried to reach directly for the toy -- even though the less strenuous thing to do would have been to pull the box closer and then retrieve the toy. These same children would straightaway pull the box toward themselves if the toy were well beyond reach.

RELATING TWO THINGS TO ONE ANOTHER

The development of the ability to relate two things to one another is a common theme of the last four chapters. This ability would seem to be fundamental for success on Object Retrieval. At about 9 months of age infants appear to take the first major step toward this competence.

One may view the gradual acquisition of mastery of Object Retrieval, in large part, as the development of the ability to process and relate two sources of information. Initially, the sight of the toy is not integrated with the tactile information specifying a closed side or an opening, nor with the experience of previous trials. Early in the second half of the first year, infants reach exclusively along a direct line of sight to the toy. Contradictory tactile information and history of past reinforcements appear to be ignored or suppressed.

Even within the visual modality, infants initially appear to attend to only one datum. Infants can see the box as well as the toy. But the sight of the toy so captures their attention that they show no evidence of integrating this with the sight of the box. The box is ignored. To use Piaget's terminology, they are "centered" on the toy.

We have also seen that increasing proficiency on Object Retrieval appears to be attributable, in part, to the gradually emerging ability to map one "line" to the toy (the line of sight) onto another "line" to the toy (the line of reach). Early in the second half of the first year, infants insist on reaching along the line of sight. Over the months, they become able to look at the toy through one side of the box as they reach at a different side. Eventually, their hand is able to navigate through the opening and reach the toy without their eyes ever having looked along this route.

When infants reach on a straight line of sight for the toy, even if the reach is through the opening, their hand can reach the toy with a single, straight movement. Often, however, when the infant is sitting up and looking through a closed side, a successful reach for the toy has to first clear the opening and then change direction to go for the toy. Young infants may have difficulty combining these two requirements.

It is not yet clear why the top-open orientation becomes so difficult for infants when the toy is placed inside the box, bordering the front wall. However, the most plausible hypotheses concern (1) problems in integrating two pieces of information -- young infants may be confused by seeing the toy partially through the front of the box and partially through the top, and (2) problems in executing a two-part reach -- to obtain the toy from behind the front wall, the infant must first reach away from the toy (in order to clear the front wall) and then reverse direction (in order to come back in and retrieve the toy). Even 7 month old infants can succeed when they see the toy exclusively through the top or when they can reach on a single, straight line to the toy.

In the development of the ability to act on the box in order to obtain the toy, we see the infants acquire skill in doing two things simultaneously. Instead of looking one place and acting another, they must act one place, or execute a particular action, with one hand and another place/another action with the other hand. One hand pulls, raises, or turns the box and the other hand reaches for the toy. When the infant raises the box with both hands, a special problem arises: one hand must go down to retrieve the toy but the other hand must remain raised to keep the box out of the way.

The first major advance on most of these variants of the ability to relate two things to one another comes around 9 months of age. Phase 2 begins at this age, marking the first evidence of separation of the line of reach from the line of sight. Nine month old infants look through the front opening of the box, and then, while looking through the closed top, reach in an retrieve the toy. Instances of looking through one side of the box while acting at a different side increase markedly at this time.

Rate of success in retrieving the Lego toy from against the front wall also increases dramatically around this time. Only 9% and 38% of the 7 and 8 month old infants respectively succeeded, but by 9 months, 67% of the infants were retrieving the toy in this condition.

The ability to coordinate pulling the box and reaching in to retrieve the toy, or raising the box and reaching in with one hand while the other hand holds the box up, first appears around 9 months as well. They are absent before 8 months, but by 9-1/2 months most infants are displaying these behaviors.

Results from other experiments also point to an advance in the ability to relate two things to one another at 9 months of age. We have already mentioned the work of Millar & Schaffer (1972; 1973), who found that 9 month olds, but not 6 month olds, can look one place to see a reward while acting with their hands at a different place, outside the visual field, to produce that reward.

Kagan and his colleagues (Fenson et al., 1976; Szpak, 1977; Fox,

1979) report that infants begin to relate two objects in play at around 9 months of age. They scored the play of infants as "simple relational" if it involved putting together two ordinarily unrelated objects (such as placing a saucer on top of a teapot) and as "accommodative relational" if the play involved an appropriate association between two objects (such as placing a cup on a saucer). Fifty percent of their subjects showed simple relational play by 8 months, and 100% were displaying it by 9 months. The more sophisticated accommodative relational play came later, at about one year of age.

We have evidence from the present study as well that the beginnings of reaching for two objects at the same time, and even of relating them in play, comes at around 9 months, although we did not set out to study this. One piece of evidence comes from the procedure we used to assess hand and side preferences. Here, an infant was presented five pairs of identical objects. For each pair, we noted the hand with which the infant reached and the object chosen. On each trial, an infant could chose the object to the left, to the right, both objects simultaneously, or neither object. This series of five trials was administered to all infants on their first and last visit and on two visits in between.

As Table 41 shows, infants below 9 months almost never reach for both objects at once. (This is not to say that they do not use two hands. It is not uncommon for them to reach for one object with both hands, however they do not extend one hand for one toy as the other hand goes for the other toy.) Finally, at 9 months, a couple of sessions occur where infants reached for both toys on the majority of the trials. This behavior does not become the rule, however, until about one year of age.

Table 41

Number of Times Infants Reached for Both Objects (Based on Side Preference Task; Five Trials per Testing)

Age in months:	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
Jack					1					1		0			0
Lyndsey				1						1	0				2
Tyler				0					0		0				2
Jamie					0		0				3				5
Emily					1			1			2		3		
Rachel				0					0			0			2
Brian	0				0						0				3
Ryan				0				0				3			3
James	0					0				4					5
Erin			0						3		5				5
Sarah				0					0			0		5	
Julia		0					2					3			3
Marianna					0					1			3		3
Kate				0				0				0			4
Rusty					1						1		1		2
Todd			0			0				0				1	
Nina			1				2					2			4
Isabel				0			0			0				2	
Jennine	0					1			1						4
Jane				0					0			1			2
Bobby					0					0			1		2
Graham					0						1		5		4
Blair					0				4				1		4
Michael			0					2					0		0
Chrissy				0				1			3			2	

5 mo.: 0 out of 20 trials 0%

6 mo.: 2 out of 65 trials 3%

7 mo.: 4 out of 60 trials 7%

8 mo.: 8 out of 45 trials 18%

9 mo.: 15 out of 70 trials 21%

10 mo.: 24 out of 85 trials 28%

11 mo.: 24 out of 55 trials 44%

12 mo.: 61 out of 100 trials 61%

In the Object Retrieval experiment, we often noticed infants take the box and toy between trials and perform the experiment themselves, as both experimenter and subject. They would place the toy in the box (often deep inside the box), withdraw their hand and sit up straight (as one sees at the start of a trial), and then reach in and retrieve the toy. The infant often had difficulty retrieving the toy he, himself, had placed in the box. Sometimes, he reached first to a closed side, and often his aim needed correction in order to enter the box. Such imitation of our experiment was not seen before 8 months, although most children (17 out of 25) were displaying it by 9-1/2 months. The earliest instances of these imitative attempts to relate toy and box were rather brief. Often, the infant simply placed the toy in the box, and that was the end. Or, he might extend his hand into the box holding the toy and withdraw his hand, still holding the toy. Not infrequently, the infant placed the toy on top of the box, or tried to put the toy inside the opening, but could not quite succeed. It was not until about 10-1/2 to 11 months that these sequences began to receive their fullest elaboration, with the infant turning the box over in various ways and experimenting with different toy placements and multiple retrievals, i.e., performing what Piaget would term "experiments in order to see."

In the AB̄ experiment, too, infants sometimes undertook to perform the experiment themselves, placing the toy back inside a well, covering the well, sitting back, and then retrieving the toy. Such imitation was less common on AB̄ than on Object Retrieval. It was not seen in all children and did not first appear until about 9-1/2 to 10 months of age. Here, too, however, infants often had trouble getting the order of the sequence, and the placement of the objects, quite right. The most common "error" was to first cover the well and then place the toy on top of the cover. Sometimes an infant would look at this with a confused expression and try again, but the second attempt usually ended in the same result. As with Object Retrieval, during many of the earliest instances the infant never relinquished the toy, extending hand and toy into a well and then removing the hand still with the toy. We might also note that many infants were satisfied to have placed the toy in the well and covered it. They sat back with a big smile on their faces, content to leave the toy hidden.

One of the questions addressed in the AB̄ experiment was whether infants reach to the same absolute or same relative position. We found that infants below 9 months of age tended to reach to the same absolute position, while from 9 months on above reached to relative position and half to absolute. Infants below 9 months, thus, showed a special absence of a reaching style based on relating the locations of the two hiding wells to one another. Note that the use of a landmark, which enables one to find the toy by attending to only one piece of information (in this case, the location of the blue cover) aided infants at all ages. Even infants of 7 or 8 months performed at very high levels if they could rely on one thing only, the landmark.

Considerable evidence thus exists from Object Retrieval, AB̄, and other experimental paradigms that the ability to relate two things to one another shows its first advance at approximately 9 months of age.

BEHAVIOR CHANGES AT 7-1/2 MONTHS

Phase 1B

At approximately 7-1/2 months of age, infants progress from Phase 1 to Phase 1B on the Object Retrieval task. This is marked by a single, very important, change in their behavior -- they begin to actively change their line of sight so that they can see through different sides of the box. Infants in Phase 1 and 1B will only reach through the side they are looking, but infants in Phase 1B will take active steps to change the side through which they see the toy, whereas younger infants do not.

Beginning at about 7-1/2 months of age, infants shift their bodily position (e.g., bend down and peek in the front) or move the box (e.g., raise the front of the box). Thus, they are no longer restricted to acting on only one side of the box; on their own initiative they try both the top and the front of the box on a single trial. (Figure 41 illustrates both the achievements and the limitations of this phase of development.)

Onset of the $A\bar{B}$ Error

The beginning of the Phase 1B coincides with the first appearance of the ability to find a totally hidden object. The mean age at which each of these behaviors appears is 33 weeks. Eleven of the 25 infants tested longitudinally showed Phase 1B behavior for the first time on the same visit on which they first committed the $A\bar{B}$ error. In addition, recall that 6 children could find a totally hidden object at a single

Figure 41

EXAMPLE OF PHASE 1B BEHAVIOR:

INFANT MOVES BOX TO CHANGE LINE OF SIGHT THROUGH WHICH TOY IS SEEN, BUT REACH IS STILL EXCLUSIVELY ALONG LINE OF SIGHT

Phase 1B: FRONT of box is open. Nina raises box, establishing a direct line of sight to toy thru OPENING. (E is holding back of box, exerting downward pressure on it.)

Nina starts to reach for toy thru opening. Box comes down. Now her line of sight to toy is thru the top...

& so she withdraws her hand from inside box & tries to reach for toy thru the top.

hiding place before they began to make the $A\bar{B}$ error. (On the first visit where they could find a hidden object, their behavior was too random when two hiding places were present for it to be termed the $A\bar{B}$ error.) All of these 6 children first showed Phase 1B behavior on the visit where they could first find a fully hidden object when one hiding place was used. Thus, 17 of the 25 children tested entered Phase 1B at exactly the same age at which they could first find a hidden object. (See Table 42.) Of the remaining 8 children, 5 showed Phase 1B behavior one visit (two weeks) ahead of being able to retrieve a hidden object, and 3 showed Phase 1B behavior one visit after first being able to retrieve a hidden object.

We have come to view the onset of Phase 1B on Object Retrieval and Stage IV Object Permanence as indicative of the beginning of a change in the way infants interact with the world around them. Until this point, babies act more in response to environmental cues than on the basis of their own intentions. If they see an object, they reach. If they feel an edge, they grasp. Their behavior seems more automatic and directed by the outside world than directed by internal plans. The infants make no effort to alter what is presented to them. They make no effort to remove or circumvent a barrier.

Other behaviors, too, appear to mark this same transition and we mention a few of them below.

Table 42

Age (in weeks) of First Appearance of:	Phase 1B, Object Retrieval		Able to Find Totally Hidden Object, One Hiding Place	$A\bar{B}$ Error
Jack	35 (3)	=	35 (3)	37 (5)
Lyndsey	33 (2)	=		33 (2)
Tyler	36 (2)			38 (4)
Jamie	34	=		34
Emily	34 (2)	=		34 (2)
Rachel	32 (4)			30 (6)
Brian	28 (3)	=		28 (3)
Ryan	33 (1)	=		33 (1)
James	28 (5)	=	28 (5)	30 (5)
Erin	30 (3)			32 (4)
Sarah	34 (6)	=		34 (6)
Julia	33 (2)	=		33 (2)
Marianna	34			36 (3)
Kate	31 (6)			33 (5)
Rusty	35 (6)			33 (5)
Todd	39 (4)	=	30 (4)	35 (1)
Nina	31			29
Isabel	32 (5)	=		32 (5)
Jennine	31 (4)	=	31 (4)	33 (2)
Jane	34 (5)	=		34 (5)
Bobby	33 (2)	=		33 (2)
Graham	34 (2)	=		34 (2)
Blair	35 (4)	=	35 (4)	37 (3)
Michael	34			36 (4)
Chrissy	32 (6)	=	32 (6)	34 (4)

Onset of Protest or Distress

Infants 5, 6, or 7 months rarely protest when a toy is taken away from them. After this period, however, protests are the rule. Older infants must be cajoled to relinquish a favorite toy, or distracted by something new, but not younger infants. An experimenter can remove the toy they are holding (after the intertrial play period, for example) without eliciting a reaction. In place of the fits or cries of a 9 month old, three is flat affect. One is tempted to use terms such as complacency, equanimity, or passivity. Nor is it a case of "out of sight, out of mind," for often the removed toy is still visible. The infant simply allows the experimenter to take the toy. The infant does not offer it, but neither does he try to cling to it, as is common in babies just a few months older.

Another investigation in the Harvard Infant Study required that heart rate be monitored, and 3 electrodes were placed on the infant's chest. Infants ranging in age from 7-8 months to 14 months were studied. The investigators noted that 7-8 month olds never protested the placing of the electrodes, although older infants sometimes resisted the intrusiveness of the experimenter with such strange wires.

Young infants will cry loudly in the face of pain or a strong physical need, or if startled by a sudden, loud noise. They may even cry out of boredom. However, they rarely cry, complain or show surprise to events that take place calmly in the world around them.

Avoidance of the visual cliff, separation anxiety, stranger distress, and "fear" of a variety of assorted stimuli do not appear until about 7-1/2 to 8 months of age. We believe these behaviors are further evidence of a transition from flat affect in response to events in the world to a more active, willful orientation.

Although by at least 5 months infants have sufficient depth perception to discriminate the deep side of the visual cliff from the shallow side (Campos et al., 1970; Held, 1982), 5, 6, and 7 month old infants show no distress at being placed atop, or wheeled across, the apparent chasm (Campos et al., 1970; Schwartz et al., 1973; Rader, 1982). By 8-9 months, they are greatly distressed by the visual cliff and refuse to cross it. The 5 month old will cry if he falls; the 8-9 month old will cry if he thinks he might fall.

In studies performed in America (Tennes & Lampl, 1964; Bronson, 1972; Ricciuti & Poresky, 1973; Kearsley et al., 1975; Emde et al., 1976), Guatemala (Kagan, 1976), Scotland (Schaffer and Emerson, 1964), Israel (Kagan, 1976), and the Kalahari Desert (Kagan, 1976), distress at the departure of the mother or another adult to whom the infant is "attached" has been found to begin between 7-9 months of age. This is so despite the fact that the Israeli infants lived in an infant house on a kibbutz and saw their parents only a few hours each day, and even though half of the infants in the Kearsley et al. study and all of the infants in the Ricciuti and Poresky study attended day care.

Similarly, one rarely sees an infant protest the approach of an unfamiliar adult before 7 or 8 months of age. This has been corroborated by studies conducted all over the world. (In the U.S.: Freedman, 1961; Polak et al., 1964; Scarr & Salapatek, 1970; Ricciuti & Poresky, 1973; Campos et al., 1973; Gaensbauer et al., 1976. In Greece: Stevens, 1971. In Scotland: Emerson & Schaffer, 1964; Schaffer, 1966.)

Bayley (1932) reported that the incidence of crying during standard physical and psychological examinations was twice as great at 9-12 months as it was at 5-6 months. Scarr and Salapatek (1970), in a study of the development of fear during the first two years of life to a variety of non-painful stimuli (such as a mask or a jack-in-the-box, as well as to the visual cliff or an unfamiliar adult), found almost no evidence of fear or distress before 7 months of age.

In short, infants younger than 7 or 8 months are remarkably imperturbable in the face of a variety of events. They do not protest and they do not take an active role in altering their situation.

Reduced Distractibility

Infants of 5, 6, or 7 months are more easily distracted than older infants. After a brief attempt to reach for the toy during an Object Retrieval trial, they are inclined to start picking at the tape on the box or a spec on the table, to look elsewhere in the room, or even to desert the toy for the fun of hitting the box. They start to reach for the toy but then they get sidetracked. Their attention can be readily regained by the experimenter tapping the box or jingling the toy, but each time it is short-lived.

Table 43 presents the number of times during Object Retrieval testing that infants were distracted by something else in the room or became focused on the box itself (instead of trying to get the toy). Instances of this behavior drop off during the 7th month of life. The youngest infants often appear to be headed for the toy, but upon touching the box, their attention seems to be diverted from the toy to the box. With older infants, one action rarely turns into another in this way.

TABLE 43

Number of Times Infant is Distracted from Goal of Retrieving Toy

Age in months:	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
Brian	20	22	5	7	2	3	2	8	3	1	0	0	0	0	0
James	19	14	10	19	2	4	7	5	1	0	2	3	1	0	0
Jennine	15	18	9	4	7	2	6	5	0	5	0	2	0	1	0
Julia		8	14	11	33	3	4	7	1	4	9	5	1	0	1
Nina			8	3	1	0	0	2	10	0	0	0	0	0	0
Todd			10	12	4	4	1	3	2	0	0	2	0	0	
Michael			22	15	11	12	7	1	4	1	2	1	0	1	1

$\bar{x} = 11.68$

$\bar{x} = 1.74$

During AB testing, infants of 6 or 7 months often start to reach, pick up the cloth, but get interested in the cloth do not continue looking for the toy. They desert the cloth immediately, however, once they are shown the toy. Similarly, they sometimes start a reach and then stop it before completion, as if they forgot why they started. In both cases, the infants appear to have difficulty keeping their goal in mind. They get distracted.

Recall that the one difference we found in the character of the AB error over age was that the youngest infants do not continue searching once they have reached incorrectly. Infants rarely corrected themselves after a wrong reach on the first visit where the AB error appeared. In contrast, on later visits, they rarely failed to do so. (Refer back to Table 41.) Gratch (1976) and Szpak (1977) have also observed this in their longitudinal studies of performance on the AB task. Again, it appears that the youngest infants give up easily or fail to sustain their goal.

We coded where an infant looked throughout each AB trial from hiding to reaching from the videotape records, and the length of time each look lasted. Infants of 5, 6, and 7 months had many more looks coded "looks away," (i.e., looks not directed at any of the hiding wells or at the experimenter) than did older infants, and most of these looks were momentary. The youngest babies appeared to have trouble holding their attention on any single thing. Their eyes would go from one thing to the next.

In summary, the behaviors of infants below about 7-1/2 months include:

-- failure to move themselves or the box to change their line of sight during Object Retrieval;

-- failure to retrieve a totally hidden object;

-- reflexive reactions such as grasping or withdrawal upon contact;

-- lack of protest or distress to a variety of events and stimuli which are distressing to older infants; and

-- high distractibility.

These children react to the world in an unreflective, automatic way. They do not take steps to shape or make sense of the events around them. They are pulled this way and that by stimuli which catch their attention. Adults come and go, move the infants one place and then another, give them things and take them away -- and to most of these events the infants submit without complaint. In just a month or two, these infants begin to show evidence of plans, anticipations, and fear. They become more active, aggressive actors in the world.

INHIBITION OF PREPOTENT TENDENCIES

In some respects, mastery of Object Retrieval tasks involve the gradual suppression of reflexive reactions that interfere with performance, rather than the acquisition of new sophisticated behaviors. Many of the behaviors older infants use to retrieve the toy are present earlier, but in younger infants other reactions override these behaviors or intervene before they can be brought to their successful conclusion. In a sense, what is developing is the ability to inhibit "primitive" mechanisms; the ability to stop an action, rather than the ability to do something new.

Grasping Upon Contact

One behavior that impedes performance is reflexive grasping of the box. The infant is headed for the toy, but en route his palm or the inside of his finger(s) happen to brush the edge of the box. Upon contact, the hand reflexively grasps the box. For 5, 6, and sometimes even 7 month old infants, this problem is particularly severe when the front of the box is open. They rarely clear the front opening without grazing it, and each time they touch it they automatically grasp it. The next step is to withdraw their hand and try the reach again. They do not release their grasp and proceed inside the box. The hand retreats first and begins the reach from the start. It is as if the reach is all or none. It cannot be modified once begun. It cannot be continued from the midpoint once interrupted. Many times, the infant can get one or two fingers on the toy while he is grasping the box. He may even strain so hard to get the toy that the fingers remaining on the edge turn shades of red and white. But he does not release the fingers and proceed inside the box. Eventually, he draws back his arm to try again.

By 7 months, it is more common for the infant's fingers to remain straight when they touch the edge of the box (they grasp much less often) and to continue in to retrieve the toy (instead of backing up to begin again). Table 44 and Figure 42A present the number of recorded instances of "reflexive grasping of the box" at ever age, for the 7 children for whom testing began by 6 months of age. By 7 months, infants are exhibiting this response much less often. They are able to inhibit the reflexive reaction to grasp upon contact.

Twitchell (1965, 1970), who has carefully outlined the character of reflexes during infancy, notes that the grasp reflex or reaction is not fully formed by 4 months, and that "it becomes capricious and difficult to elicit during the latter months of the first year of life" (1970:30). This is fully consistent with the data just presented.

The AB̄ error does not occur until about 7-1/2 months of age. By this age, reflexive grasping of the box during Object Retrieval testing has already begun to disappear. However, we have observed a behavior in the AB experiment that might be interpreted as "reflexively grasps." It was not seen often, and it showed no age trend. We mention it here as a reminder to the reader that the behaviors of younger infants rarely disappear entirely from the repertoires of older infants.

An example of this phenomenon during AB̄ would be: Infant is reaching to the left well. His eyes are focused there and his left hand is headed there. As he is reaching, his right hand accidentally touches

FIGURE 42

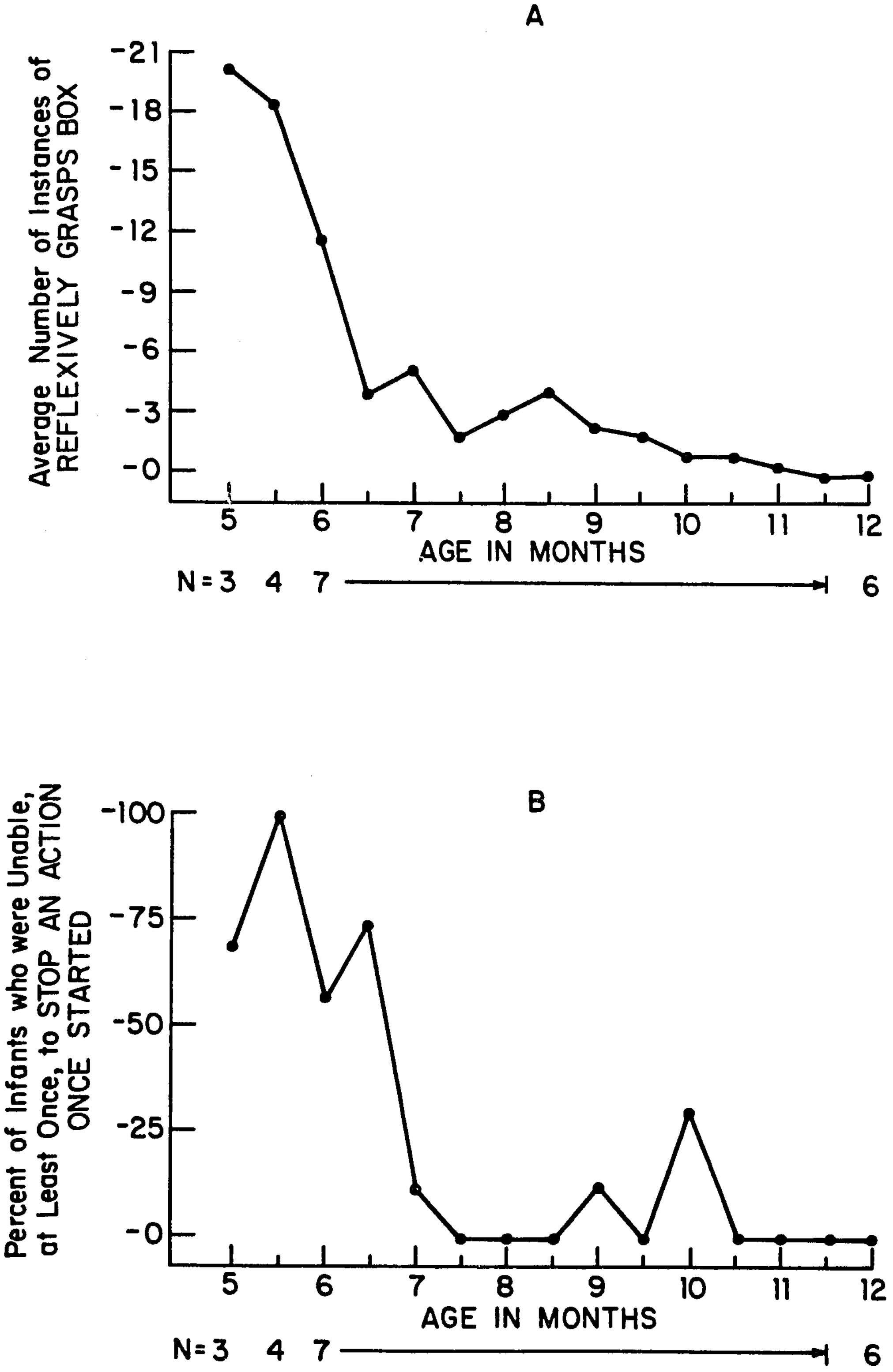

A
Average Number of Instances of REFLEXIVELY GRASPS BOX
-21
-18
-15
-12
-9
-6
-3
-0
5
6
7
8
9
10
11
12
AGE IN MONTHS
N=3 4 7
6
B
Percent of Infants who were Unable, at Least Once, to STOP AN ACTION ONCE STARTED
-100
-75
-50
-25
-0
5
6
7
8
9
10
11
12
AGE IN MONTHS
N=3 4 7
6

TABLE 44

Number of Recorded Instances of Reflexively Grasping the Box

Age in months:	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
Brian	14	12	5	6	0	1	2	0	2	1	0	1	0	0	0
James	24	21	7	1	4	2	4	4	1	2	1	0	0	0	0
Jennine	21	16	10	2	5	1	4	6	2	1	0	1	1	0	0
Julia		25	18	1	1	1	2	4	1	1	2	0	2	0	0
Nina			8	1	3	1	0	3	1	2	2	2	0	0	0
Todd			14	12	8	2	4	3	4	1	1	0	1	0	
Michael			18	5	14	3	5	8	3	3	0	1	0	0	0

TABLE 45

Number of Recorded Instances of Failure to Inhibit an Action already underway

Brian	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
James	1	3	1	1	0	0	0	0	1	0	0	0	0	0	0
Jennine	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Julia		6	4	0	0	0	0	0	0	0	1	0	0	0	0
Nina			1	1	2	0	0	0	0	0	0	0	0	0	0
Todd			2	1	0	0	0	0	0	0	1	0	0	0	
Michael			2	1	0	0	0	0	0	0	0	0	0	0	0

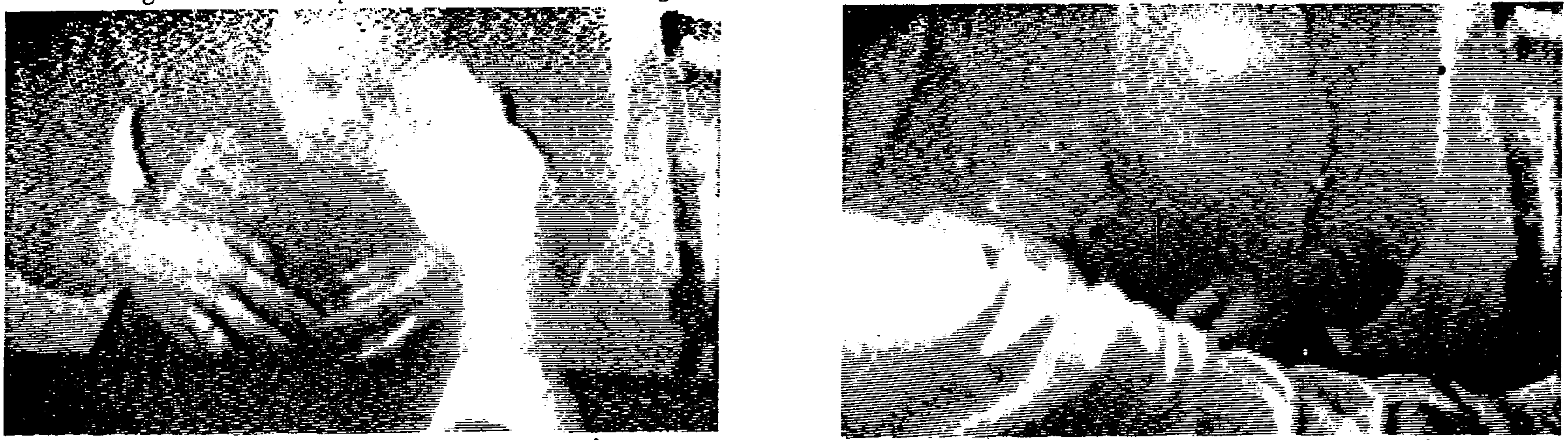
the cover of the center well. Upon contact, he grasps the center cover and removes it. Again we see tactile contact with the palm or fingers resulting in an automatic grasp. It is as if the infant begins the reach set to grasp and uncover; as soon as the infant's hand touches something, this "program" is released.

Another variant of this behavior is: Infant is reaching to left well, based on the orientation of his body and the direction of his gaze. He reaches with both hands. One touches the center cover as the other touches the left cover. Both covers are grasped and removed simultaneously. This is reminiscent of the problem encountered on raising the box with both hands -- one hand must go on to the next step (go down and enter opening or grasp and uncover well), while this must be inhibited in the other hand. It is difficult to stop both hands from doing the same thing when they are in the presence of similar stimuli.

Szuman (1927), Piaget (1954) and Bower (1977) report instances where infants fail to retrieve a smaller object placed on a larger object. Instead, the infant grasps the larger object or both objects together.

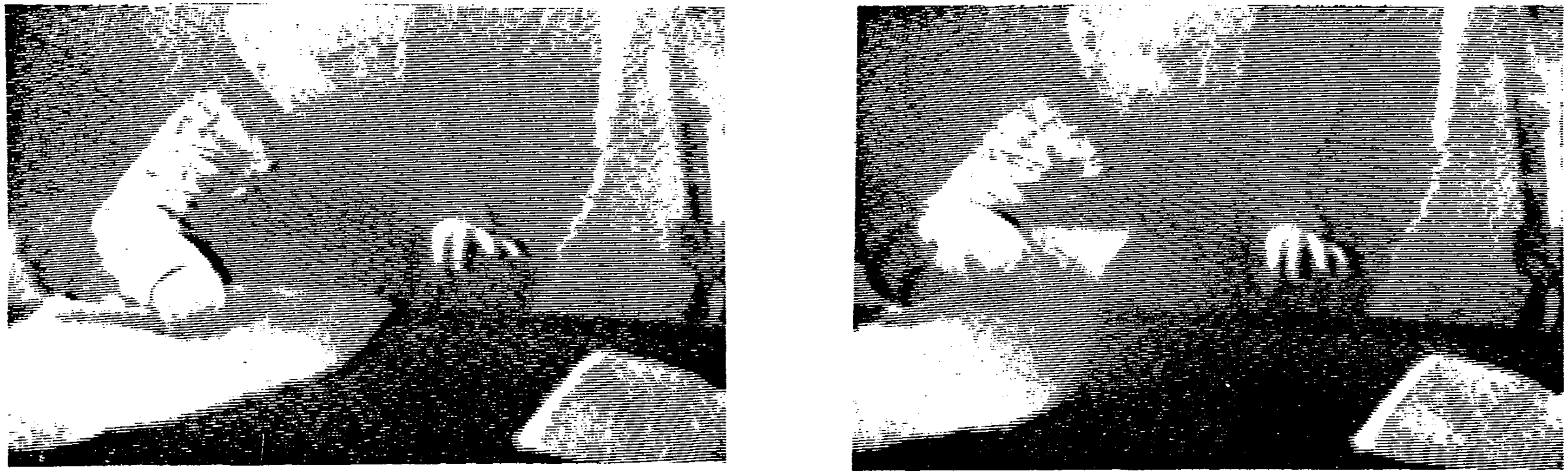
> OBS. 101. At 0;6 (22) Laurent tries to grasp a box of matches. When he is at the point of reaching it I place it on a book; he immediately withdraws his hand, then grasps the book itself. He remains puzzled until the box slides and thanks to this accident he dissociates it from its support.
>
> Same reactions with a pencil, a penknife, etc. On the other hand, when I place upon the book a narrow and deep goblet which stands out from its support, Laurent takes possession of it directly. But this experiment does not teach him anything about the general problem and when I place the matchbox on the book again he still does not try to grasp it.
>
> At 0;6 (27) I resume the experiment by placing the object (a matchbox, an eraser, a watch, etc.) sometimes n a notebook, sometimes on the palm of my hand. Laurent does not once try to grasp the object directly even when his

Figure 43: Example of an Infant Looking at the Correct Well Even as He Uncovers the Incorrect Well



Experimenter holds toy up to catch infant's attention. Parent restrains infant's hands.

Experimenter places toy in well to infant's left. Infant clearly sees where toy is placed.



Infant's hands are released. He stares at correct well (well to his left). Indeed, the left hand is extended to grasp that cover. However, the right hand touches the right cover first, and on touching it, infant grasps it without attending to what he is doing.

Infant uncovers incorrect well, but as he does so, he continues to attend to the correct well throughout.

> hand is already outstretched and touches it almost at the very moment I slide the support under it. Moreover, when Laurent grasps the support and I hold it, he does not return to the object but immediately strikes the whole thing without trying to dissociate the two objects.
>
> At 0;7 (1) same reactions. I place the object sometimes on the back of my hand, sometimes on a small pillow; Laurent stretches out his hand to grasp the object (a little rubber lamb, a plush bear 10 centimeters long, etc.) as long as it is simply offered with my fingertips, but as soon as I put it on the support Laurent strikes the support and gives up the object. (Piaget, 1954:177-178)

These are instances where the infant is capable of grasping an object, such as a matchbox, and appears to be reaching for that object, but if it is placed on a support, such as a book, the infant ends up grasping the edge of the book rather than the matchbox. This is most prevalent at 6 and 7 months, but it can still occasionally be observed as late as 10 months. If the object for which the infant is reaching stands out clearly from its support, as does a deep, narrow goblet, the infant is able to retrieve it. Similarly, if the support is substantially larger than the object (e.g., a matchbox on a tabletop, or a watch/chain on a big cushion) the infant is also able to retrieve the object.

Piaget and Bower interpret this behavior as indicating that infants somehow fail to understand that independent objects, not greatly different in size, still continue to exist when they are contiguous with one another. (See the chapter "Top-Open Orientation Toy Inside Box, Touching Front Wall" for a more extended discussion of this.) ". . . We have concluded that there is a general difficulty in conceiving of the relations of objects among themselves (in contrast to the relations of objects with the subject himself). It is this general difficulty which prevents the child from realizing that two objects can be independent of each other when the first is placed upon the second. (Piaget, 1954:177)

An alternative interpretation is the one offered above: infants of 6 or 7 months cannot inhibit grasping what their hand contacts, and their motor control is not sufficiently refined to permit them to aim directly for something like a matchbox without grazing the book on which it is resting. This behavior is similar to aiming for the toy, brushing the opening of the box, and grasping the edge, or grasping both the box and toy. A goblet is retrieved because it stands out sufficiently that the hand does not touch the support below. A large support produces no problem because the edge of the support is sufficiently distant from the object for which the infant is aiming that the infant's fingers do not touch the edge of the support.

Halting an Action Once Started

Another seemingly involuntary behavior that impedes performance on Object Retrieval is an inability to release the grasp once initiated, to let go of the box in order to grasp the toy. For example, on trials where the top of the box is open, the infant grasps the top edge of the front wall and pulls the box toward himself. The next step is to reach for the toy, but when the infant cannot let go of the box, this step goes awry. In reaching for the toy, still holding the box, the infant pushes the box and toy away. He tries again, pulls box close, but again in reaching for the toy the box goes with him. Finally, the sequence is repeated to its successful conclusion. In a slightly different variant of this, on reaching for the toy the front of the box comes up with the infant's hand so that the box is tilted thusly:  infant. Whether the infant's attempt to reach results in pushing or tilting the box depends solely on the angle of the infant's attempted reach, and a sequence ending in a push may be followed by a sequence ending in a tilt. This problem is not insurmountable. Infants do release their grasp and retrieve the toy. However, infants 7 months or younger occasionally do not release the grasp, whereas we have never seen an instance of this in infants 8 months or older. When the younger infant is set to grasp the toy, it may be difficult to un-grasp the box.

Difficulty in releasing a grasp was also observed during A$\bar{B}$ testing. As in Object Retrieval, this response disappeared after a couple of months. Recall that in A$\bar{B}$ the infant must grasp a cover and remove it in order to retrieve a toy. In the early months, infants sometimes have trouble dropping the cloth. They shake their hand and head for the toy, but the cloth remains with them. This makes it difficult to get the toy and they shake their hand again to release the cloth. It may take three or four shakes before the cloth falls down. It looks almost as if the cloth were sticky, although of course it is not. The problem may be that the infants are preparing to grasp the toy, so it may be difficult to do the opposite with the cloth. This behavior was seen in eight different children at 8 months (36 weeks) or younger, and in only one child after 8 months, although there were many more testing sessions after 8 months than before, especially since most children did not begin to make the A$\bar{B}$ until 7-1/2 months.

Halting a grasp once initiated was not the only behavior young infants found difficult. For example, in Object Retrieval an infant might grasp the toy and begin withdrawing hand and toy, but accidentally drop the toy. Occasionally, young infants, but never older infants, continue withdrawing their hand anyway; only after having completed the withdrawal do they return to get the toy. When an older infant dropped the toy, he stopped the withdrawal of his hand, and picked the toy up again. Younger infants seemed unable, on occasion, to halt the withdrawal. Again, we see a behavior which appears to be all or none; it cannot be changed in mid-course.

One variable coded from the videotape recordings of Object Retrieval sessions was any instance where the infant showed an inability to stop an action once initiated. This might be a grasp, a withdrawal, or some other action. Instances of this variable were not recorded often, probably due in part to our efforts to be conservative and to resist the temptation to read things into the infant's behavior. Table 45 presents the number of instances of this variable noted at every age for the seven infants who began testing by 6 months. For Figure 42B, we have dichotomized this variable and present the percentage of infants displaying this behavior at least once at each age. The ability to halt a behavior once initiated, as with the ability to inhibit a grasp upon contact, is more firmly established by 7 months than it is earlier.

Withdrawing Upon Contact with the Box

We have also noticed that often the slightest touch of the box will cause 5-7 month old infants to withdraw their hands. They reach for the toy, their hand grazes the box ever so slightly and they back up. The infant may even succeed in getting his hand inside the box, but if the outside surface of his fingers brushes the box, he withdraws his hand straightaway, without the toy. While this was most often seen at 5, 6, and 7 months, we also noted it during "trailing" sequences with infants as old as 10 months. A 10-month-old might follow the experimenter's hand and the toy back to the box, but as the experimenter's hand and toy re-enter the box, the infant's hand brushes the box's edge, and the reach stops, the hand withdraws.

The contact with the box is often so minimal that we were surprised that the infants did not simply ignore it and proceed in for the toy. We began to hypothesize that the 5-7 month old infants perceived the boundary of the box and were afraid to cross it. Indeed, the infants often seemed "afraid" to enter the box. They could retrieve a toy that extended just outside the box, but they would not venture in the box in order to get the toy, even if they were looking directly through the opening. We now believe that nothing so mysterious as an innate knowledge of boundaries or a fear of crossing boundaries is involved, but before we offer our present understanding of the meaning of this behavior, we would like to describe similar observations made by Bayley (1932, cited in Piaget, 1954) and by Piaget (1954).

> [S]zuman has shown that seven-month-old children do not know how to grasp a small object placed on a support; when they try to put this object in the mouth they seize the support and try to swallow the object along with it. Following this interesting discovery, Bayley resumed these experiments with children, monkeys, and baboons and observed an equally interesting reaction which he has called the "negative reaction" in comparison to Szuman's "positive reaction": some children give up grasping the desired object as soon as it is placed on a support. Mr. Baley discovered this negative reaction in the lower monkeys and baboons such as the mangabeys and the mandrills. . . . In the case of the negative reaction the animal often presents curious behavior, "as though he were afraid." (Piaget, 1954:176-177)

The reader might also recall that Laurent's initial reaction to an object placed on a support (in observation 101 quoted earlier) was to withdraw his hand. Only then did he reach again and grasp the support.

Piaget interpreted this phenomenon, as he did the earlier grasping of the support, to indicate that the infant lacks a proper understanding of relations between objects. However, a much less sophisticated ability may be involved. The interpretation we find most persuasive is that this is another instance of an instinctive behavior which infants, particularly at 5 to 7 months, fail to inhibit and which therefore interrupts their reach. The instinctive reaction involved is the avoidance response (Twitchell, 1965, 1970). This reaction is fully developed by 24-40 weeks and it involves withdrawal, the springing back of the hand and fingers in response to contact. A touch too slight to trigger the grasp reflex is often sufficient to trigger the avoidance reaction (Twitchell, 1970).

There may be other factors operating as well: 1) the young infant may not be able to modify his reach, even slightly, once it is launched -- upon touching the box, rather than adjusting his aim and proceeding, the infant may have to withdraw his arm and start again; 2) touching the box may distract the infant so that he forgets why he began the reach; 3) the infant may be so unsure of himself that the slightest resistance is sufficient to discourage him; and 4) finally, an important element, particularly in accounting for the extreme difficulties here of infants 5 and 6 months of age, is the imprecision of the reach at this age. This factor will be discussed more fully in the chapter on motor control. Certainly, the instinctive avoidance reaction alone would not be sufficient to produce withdrawal if the infant were able to reach precisely on target without touching any neighboring objects.

Piaget (1952, 1954) has suggested that the reflexes of the infant are the building blocks of sensorimotor intelligence. These are the first behaviors with which the child comes into the world, and it is from these that the more sophisticated, intentional behaviors become elaborated. There may be less continuity here than Piaget has supposed. Automatic grasping may not gradually become intentional grasping. Instead, the early automatisms may need to be inhibited in order for the more mature behaviors to be exhibited. Reflexive grasping, continued grasping, and reflexive withdrawal impede the performance of infants early in the second half of the first year. Often these infants appear to be reaching straight for the toy -- it is not that they need to acquire this behavior; however, en route one of these instinctive reactions is triggered and it interrupts the reach.

Inhibition of Response Tendencies

In a general sense, mastery of Object Retrieval, and of $A\bar{B}$, may be largely a matter of inhibiting prepotent tendencies, of resisting the initial impulse. In Object Retrieval, the strong tendency is to reach along the line of sight. To retrieve a toy when it is inside a box an infant must suppress this automatic reach in response to the sight of the toy. First the barrier must be circumvented; only then is there direct access to the toy.

In $A\bar{B}$, the strong tendency is to reach where one has been rewarded in the past. Decades of work on conditioning have shown that a strong response tendency can be built up after a single success experience (see, for example, Spence, 1956). This tendency must be suppressed in order for the infant to be able to act in accord with the information specifying the toy's new location.

Indeed, babies sometimes stare at the correct well as they reach to the wrong place, the place where they were previously reinforced. They look at where the toy really is, as if at some level they know the correct choice, but their hands nevertheless go to the old location. (See Figure 43.) They seem unable to stop themselves from reaching to the former site of the reward, even though more recent evidence of the toy's whereabouts is available to them.

At other times, they reach to a well, do not bother to check if the reward is there, and then immediately reach to the other well. Again, it is as if the children know their initial choice is wrong, but reach there anyway.

A typical sequence of trials here might be:

1) toy hidden in center well -- infant reaches correctly to center;
2) toy hidden in right well -- infant reaches to center;
3) " " " " " -- " " " " ;
4) " " " " " -- " " " "
but without even looking in the
center well, reaches next to
the right well immediately;
5) " " " " " -- infant reaches to right.

One can almost see the competing response tendencies "doing battle." However, reaching to one well, not looking in and reaching immediately to the other well is sometimes repeated over many trials. On these occasions, it seems almost as though the infant has gotten into a rhythm and has transformed our experiment into a new game. Piaget (1954:51), noticing the same behavior, called it an "automatism."

Thus, AB̄ and Object Retrieval present the infant with the problem of resisting a prepotent tendency. The ability of infants to do this appears to improve during the second half of the first year.

Evidence from the work of others also suggests that the ability to inhibit one's actions develops during this time. Using a conditioning paradigm, Fagen (1979) tried to condition 3 month old infants to kick their feet in order to move a mobile overhead. He found that the response rate increased from a baseline rate when the kicks were reinforced, but when the kicks were not followed by a reward the rate of response did not decline. This failure to show extinction may have been due to a problem in inhibiting the previously reinforced motor response.

In a series of experiments by Schaffer and Parry (1969), and Schaffer, Greenwood, and Parry (1972), babies were familiarized with a plastic "nonsense" object over 7 trials and then were presented with an object of the same shape but different color on the 8th trial. Although the first study involved only 6 and 12 month olds, the second study was longitudinal, following infants from 6 to 12 months of age. All subjects (ages 6 through 12 months) were consistently able to discriminate the two objects. Children at all ages fixated longest on the objects presented on trials 1 and 8 (the unfamiliar objects) and gradually showed less and less visual attention over the familiarization trials as they habituated. However, 6, 7 and 8 months olds reached impulsively for whatever object was presented, independent of their degree of familiarity with it. Their latency to reach was roughly equal on all trials, that is to say, _very_ short. It was not until 9 months that infants were able check this tendency to reach immediately for a seen object. Although response latencies on all trials were very brief even at 8 months, at 9 months the latency to reach for objects on trials 1 and 8 increased dramatically. Hesitation to touch unfamiliar objects first appeared.

> [W]hat matters primarily is not whether the organism decides to investigate or to withdraw, but the fact that it is able to <u>select</u> the appropriate response instead of being <u>dominated</u> by a primary, indiscriminately elicited approach tendency.
>
> (Schaffer et al., 1972:174-175)

The younger infants looked longest at the unfamiliar objects, in a sense they "knew" they had not been shown these objects before, but this knowledge did not get translated into their reaching behavior. This is reminiscent of the infant looking at the correct well during the $A\bar{B}$ Experiment but nevertheless continuing to reach back to the incorrect well.

Replicating these results using dot patterns as the stimuli, Parry (1973) found that infants of 6 months reached almost immediately for the stimulus regardless of its relative familiarity; 12 month old infants, however, showed a longer latency to reach the more unfamiliar the stimulus. To some extent, this emerging ability is probably responsible for the steady improvement in performance on Object Retrieval and $A\bar{B}$ during these months.

The ability to resist reflexes of the hands seems to come in around 7 months, while the ability to inhibit more general response tendencies appears more gradually over these months.

SKILL IN REACHING: THE DEVELOPMENT OF MOTOR CONTROL AND THE CHILD'S REPRESENTATION OF SPACE

The ways infants adjust, or fail to adjust, their movements to the spatial requirements of the Object Retrieval task provides insights into the development of motor control and the understanding of space during infancy. In order to succeed at Object Retrieval, infants must be able to figure out where they should reach and be able to direct their movements so that their hands get there.

Phase 0

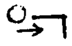
Phase 1 does not characterize the earliest behavior to appear during Object Retrieval. Between the time when infants can first reach for and grasp a free-standing object and the time when Phase 1 behavior first appears even the sight of the toy directly through the opening is not sufficient to enable an infant to retrieve the toy.

Infants during this period, Phase 0, can retrieve a toy that is partly, even very slightly, out of the box, but if the entire toy is inside the box they are often unable to retrieve it. This is reminiscent of the inability to remove a cover to obtain a hidden object; but here the toy is visible and the box is open.

Often, the infants reach to the edge of the box and stop or withdraw their hands, or grasp the edge and look in, but do not enter. Other times, the infants do not try to reach along the line of sight at all. They may see the toy through the front but try to reach through the side.

The primary problem for the infants during Phase 0 is motor control. They cannot aim their hand so that it clears the opening and enters the box. Once they touch the box, they automatically grasp it or withdraw. They cannot modify the reach in order to compensate for small errors in aim. If they do not clear the box, they begin the entire reach over again. Their hand keeps trying to zoom in the opening, like an airplane trying to land, but it fails. Their movements are agitated, spastic, and occur in jerky bursts.

When the front of the box is open, and the experimenter raises the box to make it easier, the aim of these infants is so poor that they often hit the raised box and push it down. This may happen two or three times in a row and is very frustrating for the baby.

The front-open orientation is particularly difficult for the babies because their natural reach is an overarm arc (), or a two-handed sidearm reach (). Neither of these kinds of reaches is well adapted to enter the front opening, where a straight forward reach () is most appropriate. When the box is raised high enough it aids the infants because it allows them to reach on a diagonal rather than on a horizontal line.

Halverson (1931), in a detailed study of reaching and grasping during infancy, also noted that the line of reach becomes straighter and begins from a lower height after the middle of the first year. Richardson (1934), commenting on the accuracy of the reach at 6-1/2 months, notes that while at this age infants can grasp a free-standing object, they often cannot do so if they must reach through a grill in order to get to the object.

The other contributing factor to the behavior seen during this period is that the infant sometimes ignores the box altogether. Recorded instances of "looks through one side while reaches at a different side" are quite high until about 6-1/2 months, after which time they drop quite low and do not begin to become numerous again until about 9 months. The "look here, reach there" behavior of the 5 or 6 month old, however, means something very different from what it means in a 9, 10, 11, or 12 month old. At 5 or 6 months, the infant is sometimes so "centered" on the toy that he ignores the box. Thus, although he may see the toy through the front opening, he tries to reach for it with a two-handed sidearm swipe which ends up hitting the right and left sides of the box -- even though we know he is capable of seeing the box.

Phase 0 behavior did not predominate in any infant by 28 weeks, whereas no infant showed Phase 1 behavior prior to 26 weeks. Recall that each new phase marks the appearance of more mature behavior, but not the full disappearance of earlier behavior, which can remain, to some extent, for a long time. Below are the ages at which infants tested longitudinally were scored as being in Phase 0:

AGE IN WEEKS

	Phase 0	Enters Phase 1
Brian	22(2), 24(4)	26(4)
James	23(0), 24(5), 26(5)	28(5)
Jennine	23(2), 25(1)	27(1)
Julia	24(2), 26(2)	28(1)
Nina	27(0)	29(0)
Todd	27(2)	29(0)
Michael	27(1)	29(4)

Aim Problems at Later Ages

The most common, and most dramatic, error which infants 8-12 months made in attempting to reach in the front-opening of the box was to miss the opening entirely and reach under the table. This happened most commonly when the box was at the very edge of the table or extended an inch or so over the table's front edge. This error is particularly dramatic because, by this age, infants are usually very accurate in their reaching. (See Figure 44.)

This error occurs rarely, even in younger infants, when the box is in the center of the table. Apparently infants use the surface of the table as a guide in halting the downward descent of their arms. Without this lower boundary extending in front of the opening, infants extend their arms too far down.

Sometimes, one sees a sequence of behavior as follows (front of box is open):

Figure 44: EXAMPLE OF AN ERROR IN AIM FOR FRONT OPENING, BOX AT OR BEYOND FRONT EDGE OF TABLE

Front open. Todd starts to reach.

His misses box opening. It goes under front of table.

Todd's hand goes even farther underneath the table.

1) aims for front opening -- arm goes under table (i.e., aim was too low);

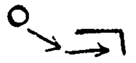
2) tries to correct aim -- top of hand hits the underside of top of box (i.e., aim was slightly too high);

3) tries to correct aim -- arm goes under table again (i.e., aim was too low);

4) tries to correct aim -- thumb enters box, other four fingers go over top of box (i.e., aim was too high) -- the hand is now at the front-top edge and it grasps the edge;

5) as the hand of the previous act continues grasping the top edge of the opening, the other hand reaches in and retrieves toy.

In this sequence, one can see the infant's attempt to adjust the height of the reach. He over-corrects and keeps overshooting his target. Finally, with one hand holding onto the box, and thus serving to mark the opening, the infant is able to direct the reach properly.

It should be noted that a reach into the front of the box usually requires a change of direction. First, the reach must be a downward pointing diagonal and then it must be horizontal:  . When infants reach under the table, they are not switching the direction of the reach early enough.

The most dramatic behavior displayed in reaching to the left or right side of the box is the use of the hand contralateral to the opening. This behavior will be discussed at length in the next chapter. Even the more mature behavior of reaching with the ipsilateral hand, however, is marked by certain problems in aim.

One common error on the side is for the infant to reach too far to that side. For example, if the infant is trying to reach into the box's left side, he may reach to the left, missing the box altogether. The most remarkable feature of these reaches is that sometimes they continue -- as the infant looks at the toy through the top of the box, his hand reaches farther to the left, away from the box. (See Figure 45.)

The reach in the side, while the infant is sitting up straight, looking through the top of the box, is a two-part reach. First, the infant must reach to the side in order to clear the barrier of the box and then he must come back in to get the toy:  . This error, like going under the table, is an error in continuing the first part of the reach for too long.

An even more common error when the left or right side is open, is for the infant to reach around the back of the box instead of reaching in the opening. The infant explores the box tactilely, feeling for the opening. Upon touching the left-back or right-back edge, he bends his arm around the edge as if it marked where the opening began instead of where it ended.

Indeed, infants make much use of boundaries and edges to guide their reaching. In some ways, their behavior is reminiscent of how a person without sight judges space. A blind man cannot see the box in front of him, so he must feel for an edge in order to discover the opening. Feeling the back edge and thinking it the front edge would not be an unreasonable guess if one were blind. Given the visual information available to the babies, however, it is quite remarkable.

One may recall the curious behavior of four babies during Phase 3. They did not need to look through the side opening in order to know where to reach, but they had great difficulty clearing the opening. In

Figure 45: EXAMPLES OF ERRORS IN AIM FOR SIDE OPENING

Left side open. Reach starts (with right hand).

Instead of going in opening, Julia's hand veers away to left.

Vigorously, Julia is reaching into thin air.

As Julia's reach is in progress, Exp's hand goes to box opening.

Julia sees Exp's hand. The reach halts.

Julia brings herself back to box. She reaches to opening w/ left hand.

Left side open. Brian begins reach with left hand for opening.

His hand starts to veer off to the left, instead of entering box. Brian is still looking at toy in box.

Brian's hand continues on its trajectory, away from box. Brian's attention is still focused on toy in box.

Brian cries. He wants toy, but he has been unable to aim his arm into opening to retrieve toy.

particular, the thumb, primed to grasp the toy, was often halted by the edge of the box. When the infant was unable to correct this error on his own, the experimenter occasionally raised the side of the box to increase the size of the opening. (This is exactly like raising the front of the the box, except that here the right or left side serves as the fulcrum, instead of the back.) This did not always aid the infants, however, although the opening was made quite large. For some infants still felt for the edge and their thumb was still stopped by the top edge.

Thus, infants use the limits, the borders, of spatial pathways in order to locate the pathways. Holding the edge of the opening with one hand seems to help the other hand to navigate correctly through the opening. When infants do not look along the line of reach, their reach often misses the mark. It is either too high, too low, too far right, left, forward, or back. It is hard to tell whether infants are misjudging distance and so aiming incorrectly, or whether their aim is correct but their execution is off. Part of the problem is undoubtedly the need to aim for the toy and also to aim to clear the box. Reaches which are two-part in the sense that they require a change in direction pose particular problems. Infants sometimes continue along one course for too long, failing to alter the direction of their movement.

SIDE OPEN, "AWKWARD REACH" WITH HAND CONTRALATERAL TO OPENING

When the left or right side of the box is open, a 9 month old baby leans to the side, looks in the opening, and reaches with the far hand, the hand contralateral to the opening. To perform this reach, the infant must contort his arm into a very awkward position. Yet, this is the most common mode of reaching among infants in Phase 2 when the opening is on the side. Indeed, Bruner, Kaye, and Lyons (1968) and Gaiter (1974) have commented on this "awkward reach" as well. The aim of this chapter is to try to understand why this reach occurs.

The awkward reach is not seen prior to Phase 2. If the toy is placed wholly inside the box and the box is placed so that the opening cannot be seen without leaning, infants younger than Phase 2 will try the top and/or front of the box, but they will not reach to the side at all. They do not lean and look. They reach with neither the awkward hand or the hand on the same side as the opening. By Phase 3 (10-1/2 months of age) the awkward reach has already largely disappeared, replaced by the physically simpler movement of reaching with the hand ipsilateral to the opening. Thus, the phenomenon to be explained lasts only a month or two, although it is seen in most children during this brief period.

Three possible explanations for this behavior will be considered. The simplest explanation is that this behavior occurs because of a hand preference. Infants reach to the left side with their right hand because they do most of their reaching, in general, with the right hand.

Conversely, those infants who reach to the right side with the left hand do so because they favor their left hand.

Bruner, Kaye, and Lyons (1968) and Bruner (1971) offer the explanation that infants at this age reach for a toy with the hand on the same side of their midline as the toy (e.g., a toy to their right will reached for with the right hand) and, once a hand is activated, infants tend to keep using it rather than switching hands. For example, infants reach to the opening on the left with their right hand because the toy is to their right, and it is the hand ipsilateral to the toy, not to the opening, that will be pressed into action.

> The initial option for infants under a year of age is to operate with the hand on the same side of the midline as the object. This phenomenon is commonly observed in infants reaching in an unobstructed space. We now know that the further from the midline the object is, the more likely it is to activate the hand on that side, irrespective of the fact that an obstructing screen makes the contralateral hand [i.e., the hand on the side opposite to the <u>toy</u>, which is the hand <u>ipsilateral</u> to the opening] more and more appropriate from the point of view of efficiency. (p. 13)
>
> One [factor working against the development of skill in reaching around barriers] is the continued activation of the ipsilateral - near hand.... A second retarding factor is the effect of initial action, once underway, upon the serial response pattern that follows it.... Given initial activation of the obstructed hand, it may remain activated and grope round the edge of the barrier to effect a "backhand reach" (Bruner et al., 1968:14). [By "backhand reach," Bruner et al. are referring to what is here called "awkward reach."]

A third possible explanation is that the infants will not reach into the opening unless they see into the opening. To see into the left or right side of the box, they must lean over. In this position, several factors mitigate against the use of the hand ipsilateral to the opening. (These factors will be discussed shortly.) Suffice it to say here that we suggest it is the need to look through the opening which is responsible for the infant's leaning and for the awkward reach.

Different predictions follow from these three explanations. Let us turn now to the observed behavior and see which explanation best fits the data.

1) Within a single visit, an infant will reach into the left opening with the right hand and the right opening with the left hand.

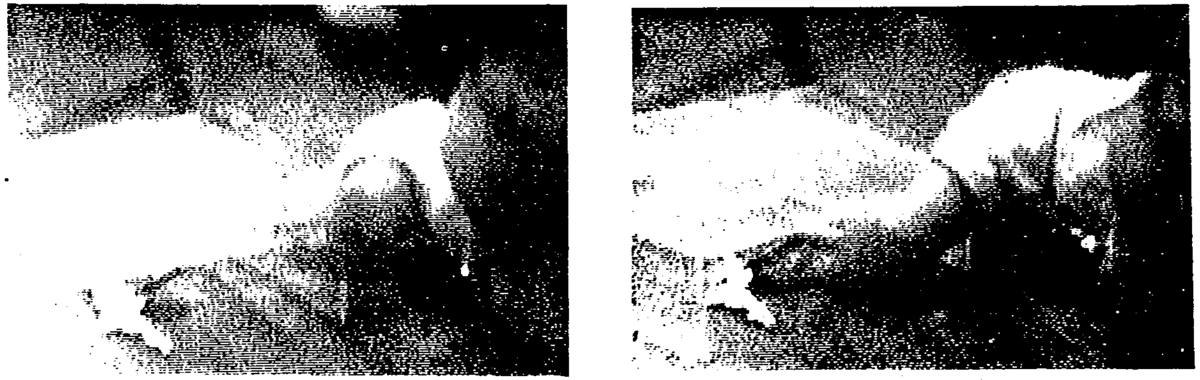
If the awkward hand phenomenon were due to a hand preference it should be observed on one side of the box only. An infant preferring one hand should reach with that hand at both sides of the box. The fact that infants go to the trouble of using the awkward hand at the right and at the left is strong evidence against the hand preference explanation. This finding is consistent with the other two explanations.

Figure 46 provides two examples of this behavior. Note that the hand contralateral to the opening is used on both sides of the box.

Table 46 presents the number of times each infant in the longitudinal sample retrieved the toy with each hand on each side of the box. This is based on trials where the toy was totally inside the box. These trials are from the first visit on which the infant was able to retrieve a toy from the side opening with the box placed squarely at the midline (i.e., the first visit on which Phase 2 behavior was observed) _and_ from the first subsequent visit. There is a clear tendency to use the right hand to reach into the left opening, and the left hand to reach right. (For Left Opening: t-test of observed value compared to an expectation of equal use of both hands yielded $t = 2.05$, $p = .05$. For Right Opening: $t = 4.06$, $p = .0005$).

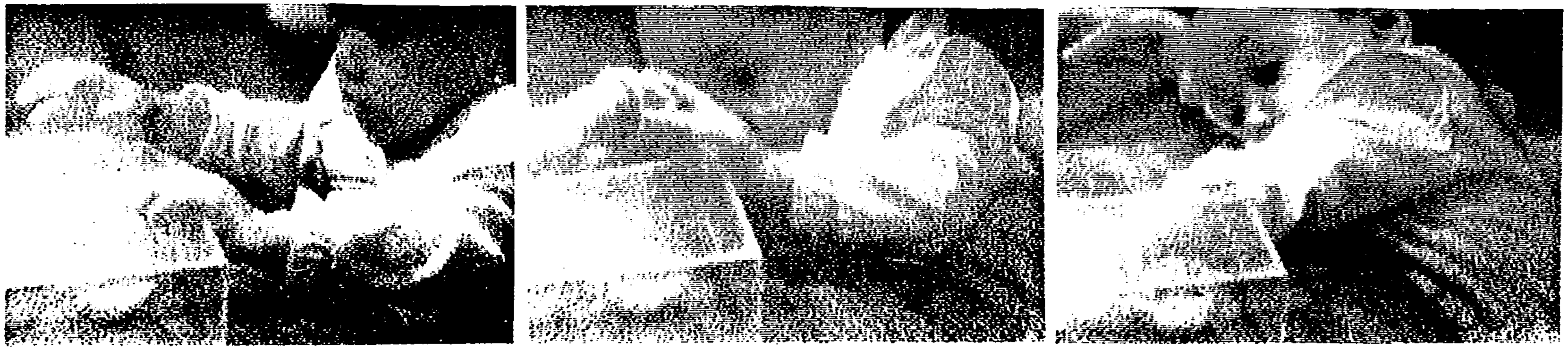
It should be noted, however, that although a hand preference cannot

Figure 46: EXAMPLE OF AN "AWKWARD REACH" ON BOTH SIDES OF BOX (SAME INFANT, SAME SESSION)



Left side open. Mariama leans over & looks at toy thru opening.

She reaches in awkwardly with far hand. (In this way, she can continue to look in opening and keep her hand in view.)



Right side open. Mariama begins w/ her RIGHT hand primed to reach.

She leans down & looks in the right side...

& reaches in awkwardly w/ her LEFT hand, keeping her eye on her hand & toy thru opening.

Table 46

Hand Used to Retrieve Toy by Orientation of Opening

	LEFT OPENING			RIGHT OPENING		
	Retrieves with...		% of Retrievals with Right	Retrieves with...		% of Retrievals with Right
	Left	Right		Left	Right	
Jack	4	3	43%	9	0	0
Lyndsey	6	2	25%	8	2	20%
Tyler	1	5	83%	8	2	20%
Jamie	2	5	71%	4	2	33%
Emily	4	6	60%	8	2	20%
Rachel	3	5	63%	8	2	20%
Brian	6	6	50%	4	2	33%
Ryan	2	8	80%	5	3	38%
James	0	8	100%	3	4	57%
Erin	5	2	29%	2	5	71%
Sarah	6	4	40%	8	4	50%
Julia	4	8	67%	4	3	43%
Mariama	0	9	100%	10	0	0
Kate	1	5	83%	5	3	38%
Rusty	4	8	67%	5	5	50%
Todd	3	5	63%	9	0	0
Nina	5	5	50%	6	4	40%
Isabel	2	5	71%	8	2	20%
Jennine	2	5	71%	6	4	40%
Jane	0	6	100%	2	6	75%
Bobby	4	6	60%	6	2	25%
Graham	5	5	50%	3	3	50%
Blair	4	8	67%	2	2	50%
Michael	3	5	63%	6	1	14%
Chrissy	2	8	80%	5	5	50%
			Mean = 64%			Mean = 34%

account for these data, some children had such a strong preference for one hand that this tendency overrode whatever it is that causes the awkward reach. That is, some children did use the same hand on both sides of the box.

2) When the toy extends partly out of the box, infants reach with hand nearest the opening.

On the same visits when the awkward reach is seen with the toy totally inside the box, infants reach with the hand ipsilateral to the opening when the toy is partly outside of the box. They do this whether the opening is to the left or to the right. Bruner et al. (1968) have made the same observation: "When the toy is in the open, virtually nine in ten initial moves are with the hand on the open side" (p. 9-10).

Looking again at the first visit of Phase 2 and the visit immediately following, we find that 84% of the retrievals were with the right hand when the toy extended outside the right opening (42 out of 50 trials, 2 trials per child) and 78% of the retrievals were with the left hand when the toy extended outside the left opening (39 out of 50 trials).

Finding #2, like the first, is not consistent with a hand preference explanation, although it is consistent with the other two explanations. It should be noted that on all 19 partly-out trials where the far hand was used the infant leaned and looked at the opening. On only 8 of the 81 partly-out trials where the hand nearest the opening was used did the infant lean to look in the opening. (Please remember that a toy partly outside the left opening is to the left of the midline, and one might argue that the infant leans in order to use the far hand, as opposed to using the far hand because he has leaned.)

3) The hand nearest the toy is uncorrelated with the hand used to retrieve the toy.

Even if the toy is to the left of the midline, infants use the right hand to reach to the left opening. The converse holds true for the right. Indeed, if the position of the toy remains constant, but the box is displaced farther to the left on left-open trials, infants are more likely to insist on retrieving the toy with their right hand, although this is extremely awkward. Similarly, the probability of using the left hand on the right side can be increased by moving the box toward the right, although the toy is not thereby closer to the left hand.

Table 47 is based on the same trials as those used for Table 46 (left- and right-open trials, toy totally inside box, first visit of Phase 2 and first subsequent visit). Whereas Table 46 presented the results by side of opening, Table 47 presents the results by side of toy. There is no significant tendency for infants to retrieve the toy with the hand on the same side of the midline as the toy. (If placement of toy has no effect on hand usage, then the percentage of trials on which the right or left hand is used when the toy is on the left should not differ significantly from the observed percentage when they toy is on the right. The difference is not significant: $t = 1.32$, $p = .20$).

Table 48 compares trials where the toy remains at the midline but the position of the box varies. Infants are more likely to use the hand contralateral to the opening when the box is placed farther over toward the side of the opening. The farther the box is displaced in this direction, the more necessary it is to lean, and lean farther, to see in the opening. However, as the toy's position remains constant it is no

Table 47

Hand Used to Retrieve Toy by Location of Toy

	LEFT OPENING			RIGHT OPENING		
	Retrieves with... Left	Right	% of Retrievals with Right	Retrieves with... Left	Right	% of Retrievals with Right
Jack	3	0	0	4	1	20%
Lyndsey	3	1	25%	3	1	25%
Tyler	1	2	67%	1	2	67%
Jamie	2	2	50%	1	2	67%
Emily	2	1	33%	2	3	60%
Rachel	1	3	75%	1	2	67%
Brian	2	2	50%	3	1	25%
Ryan	1	1	50%	2	1	33%
James	1	2	67%	1	2	67%
Erin	3	2	40%	2	2	50%
Sarah	1	3	75%	2	2	50%
Julia	3	0	0	1	2	67%
Mariama	2	0	0	2	3	60%
Kate	1	3	75%	2	3	60%
Rusty	2	3	60%	1	1	50%
Todd	3	1	25%	2	2	50%
Nina	3	1	25%	0	3	100%
Isabel	2	2	50%	2	2	50%
Jennine	1	1	50%	2	3	60%
Jane	1	4	80%	0	4	100%
Bobby	3	1	25%	2	2	50%
Graham	2	2	50%	2	1	33%
Blair	1	3	75%	0	3	100%
Michael	3	2	40%	2	0	0
Chrissy	0	2	100%	2	2	50%
			Mean = 49%			Mean = 56%

closer to the hand contralateral to the opening when the box is displaced.

When they toy is at the midline and the left side of the box is open, if a) the box is left of center (so that they toy appears to the right of the midline) infants use their right hand significantly more often than one would expect by chance ($t = 4.08$, $p = .0004$), however if b) the box is at the midline or to the right, infants do not show this tendency (t-value for col. 2, Table 48 versus expected value of 50% for each child = 0.37, n.s.; t-value for comparison of col. 1 and col. 2, Table 48 = 3.85, $p = .0008$). Similarly, when the toy is at the midline and the <u>right</u> side of the box is open if a) the box is right of center (so toy appears to be toward the left) infants use their left hand more often than one would expect by chance ($t = 3.22$, $p = .004$), however if b) the box is at the midline or to the right, infants do not use either hand significantly more than the other (t-test of col. 4, Table 48 versus expected value of 50% for each child = 0.19, n.s.; t-test of col. 3 versus col. 4 = 2.78, $p = .01$).

Finding #3 is in accord with the lean and look explanation and would seem to disprove the hand nearest toy explanation. However, finding #3 may not be quite as inconsistent with the second explanation as might first appear.

First, the displacements in the present experiment were not large. It is possible that more extreme displacements would produce a stronger tendency to reach with the hand on the same side as the toy.

Second, Bruner and his colleagues noticed that the location of the toy alone did not determine the hand used, and they offer the following modification of their explanation: "... The presence of the

Table 48

PERCENT OF TRIALS ON WHICH TOY IS RETRIEVED WITH THE RIGHT HAND WHEN TOY IS AT MIDLINE, BY LOCATION AND ORIENTATION OF BOX

	LEFT SIDE OPEN		RIGHT SIDE OPEN	
	Box is Displaced toward Left (Toy Appears to be toward the Right)	Box is Centered or Displaced toward the Right	Box is Centered or Displaced toward the Left	Box is Displaced toward Right (Toy Appears to be toward Left)
Jack	33	33	0	0
Lyndsey	50	25	25	0
Tyler	50	50	50	0
Jamie	67	25	50	33
Emily	67	0	67	50
Rachel	50	33	67	0
Brian	100	0	50	50
Ryan	75	50	100	25
James	100	100	50	25
Erin	33	50	100	0
Sarah	100	60	50	33
Julia	100	50	50	50
Mariama	100	100	0	0
Kate	50	67	67	50
Rusty	67	50	50	33
Todd	25	33	0	0
Nina	75	67	33	50
Isabel	50	25	50	67
Jennine	100	50	50	25
Jane	100	100	100	75
Bobby	67	33	33	0
Graham	50	67	50	50
Blair	67	25	50	50
Michael	75	50	33	0
Chrissy	100	60	50	100
Mean =	70%	48%	49%	31%

screen itself creates an asymmetry in the [visual] field, so that for instance when the toy is at the midline, Position Two, behind the transparent short screen, the initial activation is in the obstructed hand two-thirds rather than half of the time" (Bruner et al., 1968: 13-14). That is, if the box is displaced to the left, the toy at the midline will now be perceived to be toward the right. While our results show that the toy's absolute position does not determine the hand used for retrieval, the results presented in Table 48 are consistent with the view that the toy's position relative to the box does determine the hand used.

Finally, Bruner's main point about the hand nearest toy is that this is the first hand activated. Infants first try to reach directly through the barrier with the hand nearest the toy. He adds that they also use this hand to try to reach around the barrier because of a tendency to perseverate with the hand with which they have begun. The results reported here are for the hand used to reach around the barrier, not for the hand first used at the outset of the trial. While finding #3 and the findings to be reported below are likely to call Bruner's explanation of the awkward reach into question, they do not contradict Bruner's observation that the first attempt to reach for the toy by infants of 8 or 9 months is straight through the barrier with the hand nearest the toy.

4) The hand which is initially activated is uncorrelated with the hand that retrieves the toy. Within a single trial an infant will reach to the left opening with the right hand and the right opening with the left hand.

As can be seen from Table 49, the hand which executes the first act of a trial is not more likely to execute the retrieval. (Table 49,

Table 49

COMPARISON OF HAND USED TO EXECUTE FIRST ACT OF TRIAL AND HAND WHICH EXECUTES RETRIEVAL ON SAME TRIAL

	Percentage of Trials on Which First Hand Used = Hand Executing Retrieval	N
Jack	38	8
Lyndsey	50	8
Tyler	50	6
Jamie	57	7
Emily	75	8
Rachel	29	7
Brian	38	8
Ryan	20	5
James	67	6
Erin	67	9
Sarah	50	8
Julia	33	6
Mariama	86	7
Kate	78	9
Rusty	29	7
Todd	55	9
Nina	71	7
Isabel	50	8
Jennine	57	7
Jane	33	9
Bobby	75	8
Graham	29	7
Blair	29	7
Michael	100	7
Chrissy	50	6

like the preceding three tables, is based on all left- and right-open trials where the toy was totally inside the box, on the first visit of Phase 2 and the next visit.) Indeed, it is not uncommon to see an infant try the right side with his left hand, find it closed, and they try the left side of the box with his right hand - or, try the left side with the right hand, then the right side with left hand. (Refer again to Figure 46.) Infants do switch hands. This is counter to the theorizing of Bruner and his colleagues. The awkward reach is not caused by a reluctance to switch hands; indeed, infants switch hands in order to make both of their reaches awkward. It is very important to note that within a single trial, with toy <u>and</u> box held constant, infants reach to the right side with their left hand and the left side with their right hand. Toy position, whether conceived in absolute or relative terms, cannot account for these results. (See Table 50.)

5) The reach with the hand contralateral to the opening is so awkward that infants sometimes try to switch to the ipsilateral hand, but this second reach is rarely completed. The contralateral is once again recruited and used to accomplish the retrieval.

Figure 47 illustrates this behavior sequence. Clearly, infants do switch hands. Our interpretation of their behavior here is that they are driven to try to switch to the hand ipsilateral to the opening by the difficulty of reaching into the box with the far hand; they revert back to the contralateral hand because of the difficulty of continuing to lean and look if one tries to reach with the ipsilateral hand. As infants start to use the ipsilateral hand they start to move to an upright position, but as they move they can no longer see the toy through the opening. It is in order to re-establish a direct line of sight through the opening that we believe infants switch once again to

Figure 47

EXAMPLE OF AN INFANT ATTEMPTING TO CORRECT AWKWARD REACH, BUT REVERTING BACK

RIGHT side open. Michelle leans & looks at toy thru opening awkwardly reaching for toy with her LEFT hand.

She sits up & begins to switch hands, reaching now with her RIGHT hand. However, she is no longer seeing toy thru opening as she does this.

She leans & again looks at toy thru opening... (Note: She leans BECAUSE not continuing to see toy thru opening is a problem for her.)

& maintaining that line of sight, she reaches the RIGHT side with her LEFT hand.

Table 50

HAND USED TO REACH FOR TOY BY
SIDE OF BOX TO WHICH INFANT IS REACHING

	LEFT OPENING		RIGHT OPENING	
	Percent of Reaches to...		Percent of Reaches to...	
	Left	Right	Left	Right
	Executed with Right Hand		Executed with Right Hand	
Jack	50	0	75	0
Lyndsey	80	20	67	33
Tyler	88	25	88	20
Jamie	75	20	67	20
Emily	75	8	75	33
Rachel	90	17	88	10
Brian	50	10	33	50
Ryan	40	50	40	33
James	75	20	80	67
Erin	43	33	50	25
Sarah	80	17	43	10
Julia	75	25	50	17
Mariama	100	0	75	0
Kate	90	13	50	20
Rusty	50	50	40	33
Todd	50	75	90	0
Nina	90	13	90	17
Isabel	50	17	50	10
Jennine	75	25	67	20
Jane	100	100	90	67
Bobby	67	33	67	33
Graham	67	10	67	50
Blair	50	17	38	10
Michael	40	20	50	10
Chrissy	100	75	60	33

the awkward hand.

6) When infants do not lean, their reach is with the hand nearest the opening.

As already noted, when the toy is partly out of the opening, infants do not lean. They sit up straight and reach with the hand ipsilateral to the opening. Indeed, on the rare occasions when they do lean when the toy extends outside the box, they tend to use the contralateral hand.

By one year of age (Stage 4) infants no longer need to look through the opening. They no longer lean and look. Their reaches are with the hand nearest the opening. When leaning disappears, so does the awkward reach. (The reader may wish to refer back to the figure illustrating Stage 4 behavior where the infant can be seen sitting up straight and reaching with the near hand on both sides of the box.) Below about 8-1/2 months, the awkward reach is not seen, but neither do infants lean and look. They do not even try to retrieve a toy from the side. Thus, leaning and looking and the awkward reach appear together; when one is not seen, the other is not seen either.

Although infants of Stage 3 (10-1/2 months) need to look in the opening, they do not need to continue to do so. They lean and look, sit up, and then reach in with the near hand. Sometimes they start to reach with the far hand, but correcting themselves, they sit up and use the near hand. (See Figure 21.) Again, when in the upright position infants reach with the hand ipsilateral to the opening.

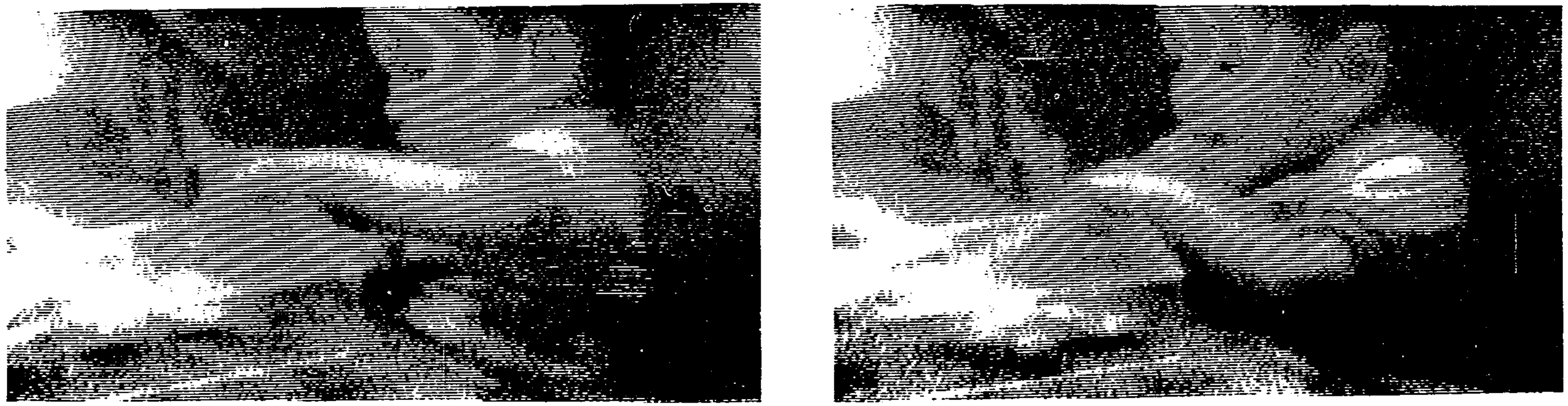
All of this fits with the "lean and look" explanation. However, finding #6 can also be reconciled with the hand nearest toy explanation. When the toy is partly out of the opening it is true that the infant need not lean, but it is also true that the toy is now closest to the hand ipsilateral to the opening. A one year old may be old enough to reach without first looking in, but one might also argue that he is old enough to overcome the tendency to reach with the hand nearest the toy. Similarly, one might argue that it is during Stage 3 that this ability begins to emerge. The infant is finally able to successfully shift hands. In short, finding #6 in and of itself is not sufficient to rule out the explanation suggested by Bruner and his colleagues.

However, the weight of the evidence would seem to eliminate both hand preference and activation of hand nearest toy as the principal causes for the awkward reach. The fact that infants reach with the hand farthest from the opening on right-open as well as on left-open trials shows that this phenomenon is not a simple matter of the persistent use of a preferred hand. Moreover, this phenomenon occurs within a single visit as well as across visits, and, indeed, can occur within a single trial. The other findings are also inconsistent with a hand preference explanation as they demonstrate that the probability of making an awkward reach is affected by variables, should as the location of the box and the location of the toy relative to the box, which are independent of whether an infant tends to use his right or left hand. All findings hold true on both sides of the box.

The fact that infants reach with the far hand on both sides of the box within a single trial is the strongest evidence against the hand nearest toy explanation. Here the position of box and toy remains the same, yet when the infant tries to reach in the right side he uses his left hand and when he tries to reach in the left side he uses his right hand. In addition, even Bruner and his colleagues realized that the absolute position of the toy does not determine the hand used. The hand nearest the toy is not more likely to be the hand used to retrieve the toy, although the presence of the barrier may cause the toy's position vis-a-vis the midline to be misperceived. An inability to switch hands would not seem a principal factor here. The first hand used on a given trial is not more likely to be the hand used for retrieval on that trial. Infants switch hands when they change from trying one side of the box to the other side and they sometimes even try to switch hands at the opening.

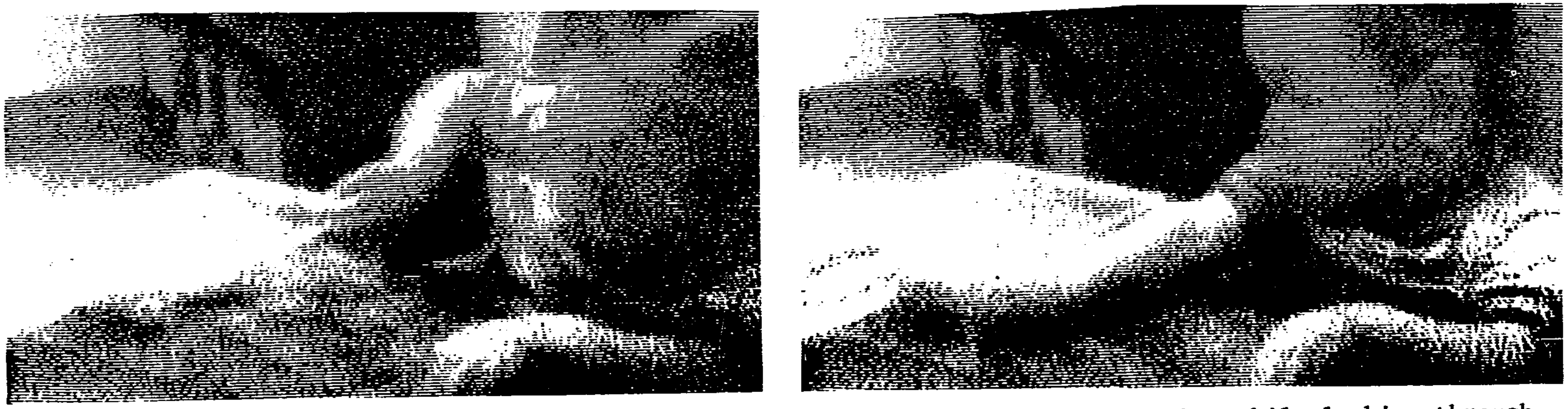
The lean and look explanation alone is consistent with all major findings, but we offer a word of caution. A few infants did not conform to the pattern of behavior predicted by this explanation. They had a strong hand preference and they were ingenious. At about 9 months, they used the same hand on both sides of the box, somehow managing to look in the opening and still recruit the hand nearest the opening. The lean and look explanation contends that babies use the far hand because they cannot otherwise continue to look through the opening. Clearly it is not impossible to look in while using the near hand; at most, it is very difficult. At about 10-1/2 months, infants with a strongly preferred hand often used the same hand on both sides of the box, not bothering to look through the opening when using the awkward hand. Sometimes they looked away and sometimes they looked through the top while reaching. (See Figure 48.) The lean and look explanation, however, said that the awkward reach was made <u>in order</u> to continue to look through the opening. Clearly, for these few infants, there were other considerations, such as using a particular hand. Thus, while most infants displayed the behavior predicted by the lean and look explanation, a few infants did

Figure 48: EXAMPLE OF THE USE OF THE SAME PREFERRED HAND ON BOTH SIDES OF BOX BY AN INFANT WHO NO LONGER NEEDS TO LOOK INTO SIDE OPENING WHILE REACHING



Right side open. Mariama looks in opening.

Then she reaches in, using her right hand, looking through top of box.



Left side open. Mariama leans & looks in.

Then she sits up and reaches while looking through the closed top. However, she continues to use her right hand, making the reach somewhat awkward.

not do so. The behavior of the few can be explained by noting that occasionally other factors, such as hand preference, can override the normal tendency for use of the far hand to accompany leaning and looking. However, perhaps another explanation not yet considered could account for all observed behavior without requiring such "patches" or addenda.

If the lean and look explanation is correct, the next question is why the need to look through the opening and, hence the lean, produces the awkward reach. We know that infants normally use the hand contralateral to the opening when they lean, but why is this the case?

One possibility is that once the infant is leaning, the hand which feels more accessible, in the open, is the hand contralateral to the opening. The reader may understand this better if he leans over rather far to the left or right. In that position which hand feels freer? If you have leaned to the right it will be your left hand, and if you leaned left it will be your right hand. This is especially true if the ipsilateral hand is used to support the body in this position, but it is not necessary that the hand actually be performing any particular function; the ipsilateral hand is under the body and less available for action.

A second possibility is that the infant not only wants to look along the line of reach, he also wants to be able to monitor the arm as it moves. If the infant is leaning to the left side, for example, looking to his right in order to see in the opening, he will not be able to see his left arm as it begins its reach. However, in this position, the infant will be able to simultaneously see his right arm, the opening, and the toy.

A third possibility harks back to the reasoning of Bruner, Kaye, and Lyons. Once the infant is leaning, the hand that started out contralateral to the opening is now the hand closest to the toy. If, for example, an infant leans to the right, the toy thereby becomes left of his midline. Perhaps activation of the hand closest to the toy is part of the answer after all.

A fourth possibility is that infants lean, reaching with the far hand, because in this way they can extend their arm in a straight line for the toy. They must coil their arm back into a very uncomfortable position but once they release it, it can reach for the toy without changing the direction of the arm's movement. If the infant sits up and reaches with the near hand, the reach needs to have two parts. First the hand reaches away from the midline in order to get to the opening and then the hand reaches back toward the midline in order to get to the toy. In older infants this appears as a smooth arc, but it is still two-directional. The reader may want to consult Figures 14, 21, and 39 to see once again what these reaches look like. This explanation would be able to account for the occasional infants who lean, use the awkward hand, but do not look in the opening. Looking in the opening is unnecessary as far as this explanation is concerned; infants use the far hand to reduce the reach to a straight line.

Finally, a fourth possibility incorporates the notion that infants may have a tendency not to switch hands, to continue using the hand with which they have begun. It is rare for the behavior sequence to be: start to reach with awkward hand first, then lean and look. The lean rarely follows the reach. In this sense, infants do not lean in order to use the awkward hand. (Although infants who try to use the awkward hand without leaning and looking sometimes run into problems properly aiming their hand, prompting them to seek the visual assistance of leaning and looking after the reach has already started.) Sometimes infants lean and look first, only then activating the arm. Often, however, the arm, torso, and head move together. As the infant leans, the hand contralateral to the opening comes over and turns the box. (The box is turned so that the opening moves from being on a 90 degree angle from the infant to a smaller angle, perhaps 60 or 45 degrees. That is, the box is turned so that the opening is oriented more toward the front. Infants would often turn the box still farther, but this is prevented by the experimenter.) Having used the far hand to turn the box, infants may be inclined to continue using that hand for the reach. Older infants often turn the box with the far hand and then reach with the near hand. Perhaps, younger infants are not quite able to make this switch over. Moreover, infants are more inclined to turn the box the farther away the opening, for the farther the opening the harder it is to look in or to reach in. This is consistent with Finding #3. Infants may reach with the contralateral hand more often when the box is farther to the side because there is more pressure to resort to turning the box here, and once the contralateral hand is used for the turn, infants may continue using it.

We are inclined to think, however, that this may attribute too much intentionality to the younger infant. It often appears that the arm is activated initially to reach. However, on encountering the box, or having difficulty bending around into the opening, the reach is transformed into a turn. Even instances of leaning and looking prior to reaching may have started out with the reach concurrent with the lean.

When infants lean, their far hand often rests on the top edge of the opening. It is not clear from the data whether infants leaned over and then decided to reach, or whether they tried to reach and lean simultaneously, but the reach was temporarily halted by contact with the edge of the opening.

If the far hand begins to move at the same time as the lean, then it cannot be that conditions present once the infant has leaned force him to use the far hand; and there are simply too many instances of this for it to be ignored. On the other hand, when one leans, one's arm goes with the body. The arm may only be accompanying the body, but once this has begun infants may tend to continue with this arm (fail to switch) or use the arm because it is more visible, more easily pressed into service.

Our observations convince us that leaning and the use of the hand contralateral to the opening are intimately linked, but we are not yet satisfied that we have adequately understood the nature of this association.

SECTION 3

SIMILARITIES BETWEEN COGNITIVE ABILITIES WHICH EMERGE BETWEEN 6 AND 12 MONTHS AND FUNCTIONS ASSOCIATED WITH THE FRONTAL LOBE

SIMILARITIES BETWEEN COGNITIVE ABILITIES LINKED TO THE FRONTAL LOBE FROM WORK WITH ANIMALS AND COGNITIVE ABILITIES WHICH EMERGE BETWEEN 6 AND 12 MONTHS.

I. A$\bar{B}$

There are four major regions of cortex: frontal, parietal, occipital, and temporal. Frontal cortex includes all cortical matter forward of the central sulcus. (See Figures 49 and 50.) Within the frontal cortex, the prefrontal area is the most rostral, the premotor area follows behind, and the motor area is the most caudal. The border between the prefrontal and premotor areas in rhesus monkeys is the arcuate sulcus (its homologue in humans is the inferior precentral fissure), and the border between the premotor and motor areas is the precentral gyrus. We will be concerned primarily with the prefrontal and premotor areas; i.e., the portion of the frontal cortex forward of the precentral gyrus.

Over the course of evolution, the frontal cortex has expanded far more than has the rest of the brain. Indeed, one of the most striking differences between the human brain and that of even our closest animal cousins is the size and complexity of the frontal cortex. This is particularly true of the more anterior frontal regions. For example, the prefrontal region accounts for more than 25% of the entire cortical mantle in humans, while it occupies only 10% of the total cortex even in an animal as advanced as the rhesus monkey (Brodmann, 1912). (See Figure 51.) Similarly, in monkeys the motor area (area 4) is much larger than the premotor area (area 6) (e.g., in marmosets the motor area occupies 79% of all frontal cortex caudal to the arcuate sulcus, and the premotor area only 21%), while in humans this relationship is reversed (the motor area accounts for 12% and the premotor area 88%) (Luria, 1973). No

FIGURE 49: A VIEW OF THE NEOCORTEX IN RHESUS MONKEYS

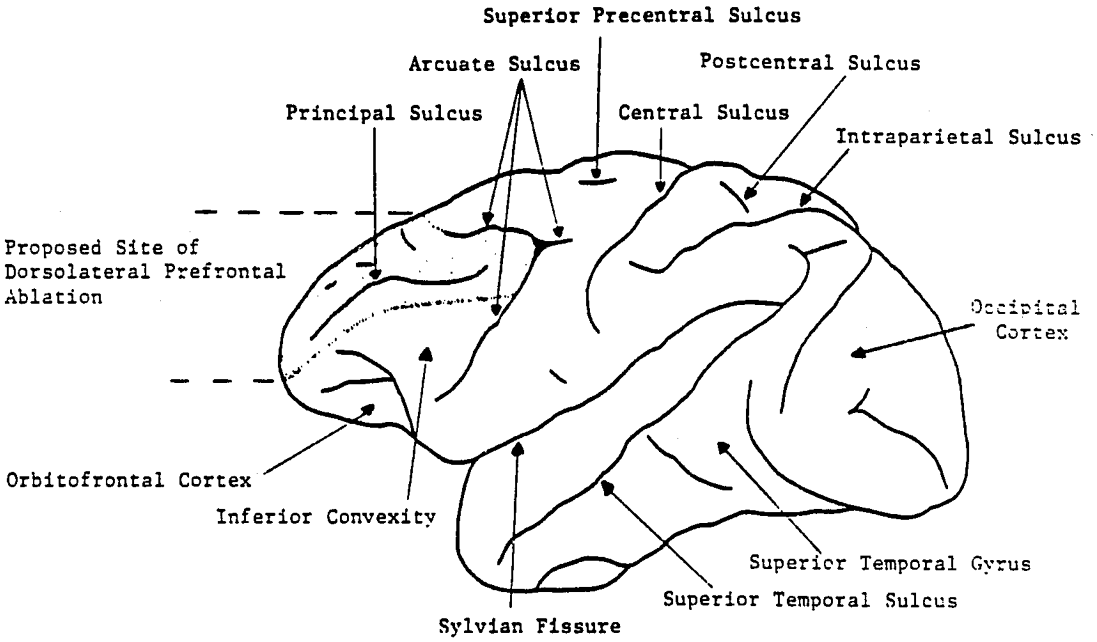


FIGURE 50: A VIEW OF THE NEOCORTEX IN HUMANS

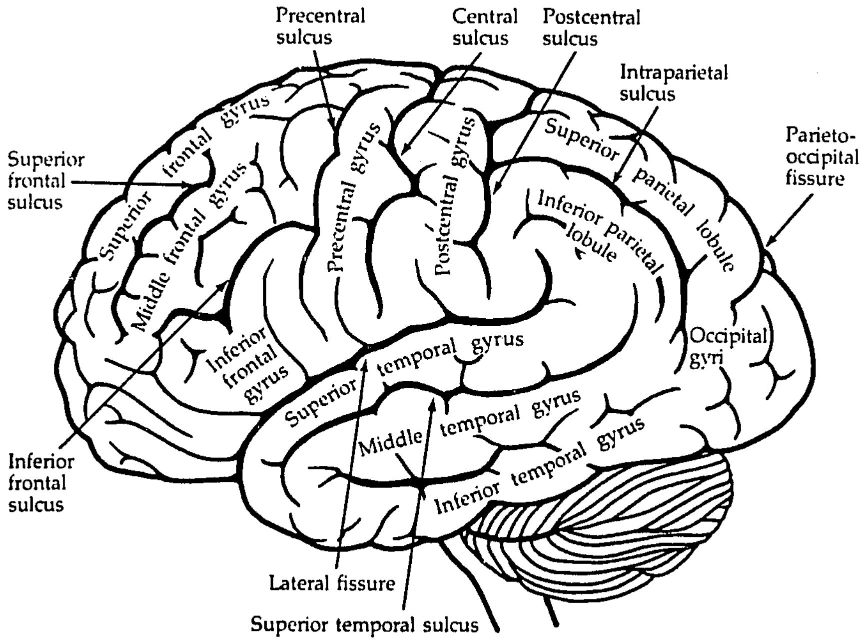
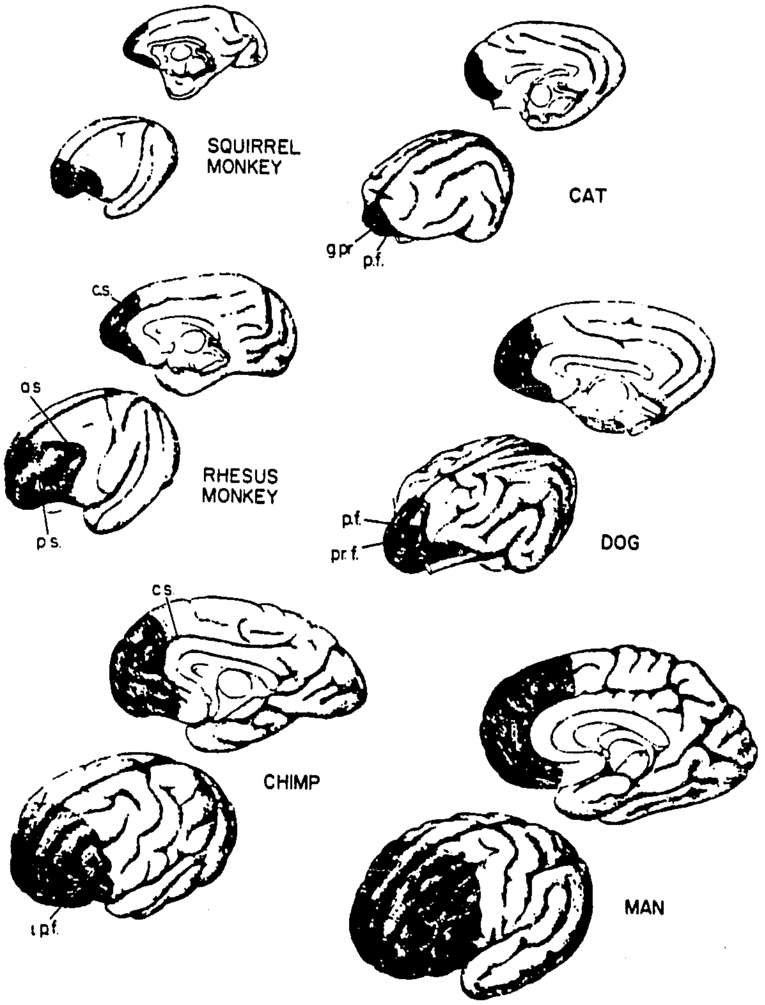


Figure 51

Relative Size of the Prefrontal Coretx in Six Different Species



The prefrontal cortex (marked by shading) in six different species. Abbreviations: a.s., arcuate sulcus; c.s., cingulate sulcus; g.pr., gyrus proreus; i.p.f., inferior precentral fissure; p.f., presylvian fissure; p.s., principal sulcus; pr.f., proreal fissure.

from Fuster, 1980

other functional subdivision of cerebral cortex in humans approaches the size of the frontal cortex.

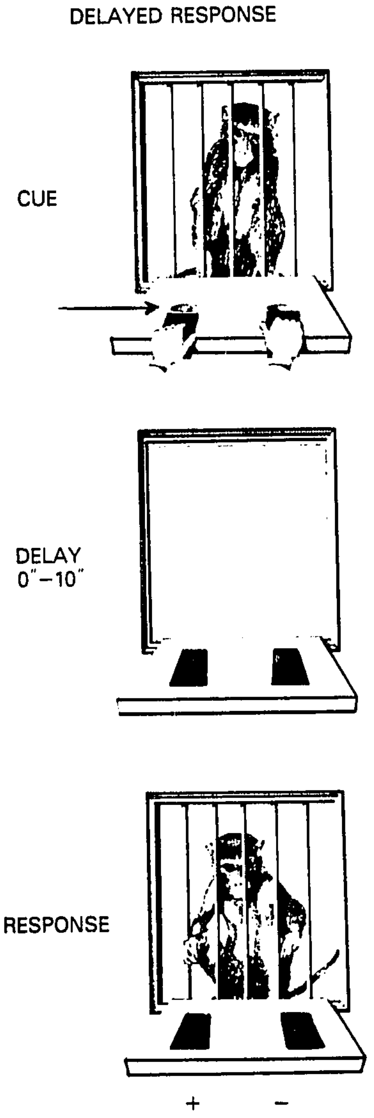
Delayed Response

The experimental task most firmly linked to the prefrontal cortex is a test called "Delayed Response." Delayed Response is almost identical to A$\bar{B}$, although these tasks had separate origins and histories. A trial in either test proceeds as follows: the subject watches the experimenter hide a reward at one of two possible places, a brief delay ensues, then the subject is allowed to reach. In both experiments the hiding is done in full view of the subject (indeed, care is taken to assure close attention), the hiding places differ only in left-right position, the delay is a matter of seconds, and the subject is not usually allowed to correct himself once wrong. (Compare Figure 52, illustrating a typical Delayed Response testing sequence, to Figure 1, illustrating a typical A$\bar{B}$ sequence.)

Scores of lesion studies have demonstrated that correct performance on Delayed Response is dependent upon the integrity of the prefrontal cortex. Although normal adult monkeys, and monkeys with lesions in areas of the brain unrelated to the prefrontal cortex, perform admirably on Delayed Response even at delays of over a minute, monkeys in whom the prefrontal cortex has been destroyed or removed cannot succeed even at delays of 1-5 seconds. (Major reviews of this work include: Nauta, 1971; Teuber, 1972; Rosvold, 1972; Markowitsch and Pritzel, 1977; Rosenkilde, 1979; and Fuster, 1980.)

The link between the prefrontal cortex and Delayed Response has

Figure 52: Schematic Illustration of a Delayed Response Trial



During the cue period of a Delayed Response trial, the monkey watches an experimenter hide the reward. Here, a peanut has been placed in the left well.

There is a delay of zero to ten seconds. In this particular experiment, a screen has been lowered. Thus, the monkey is not able to see the hiding places during the delay period.

In the response phase, the monkey is permitted to reach. Only if he reaches correctly on the first try will he be rewarded.

from Goldman-Rakic, 1982

been confirmed by studies using localized cooling (Fuster and Alexander, 1970; Bauer and Fuster, 1976; Alexander and Goldman, 1977) and localized electrical stimulation (Weiskrantz et al., 1962; Stamm, 1969; Stamm and Rosen, 1969). Localized hypothermia works by reducing the temperature in the cortex bordering the cooling probe, thereby halting metabolic activity in the tissue. Electrical stimulation disrupts functioning by activating neurons in a given area. With all the cells firing at once, there is much noise but little communication. Once the temperature returns to normal or the electrical current is removed, the nerve cells return to their normal level of activity, and functioning in the affected area of the brain is once again normal.

Confirmation of the results of lesion studies provided by studies using cooling or stimulation is important because of ambiguities in the interpretation of lesion results. No deficit may be found following a lesion, even if the destroyed area is important for the behavior under investigation, because of compensatory changes, such as neural reorganization or the adoption of a new behavioral strategy. On the other, a deficit may be found after a lesion, although the intended target site is not necessary for the function under study, because of damage to adjacent tissue or to fibers of passage coursing or because of secondary degeneration in areas of brain which receive or send projections to the affected area. Indeed, even if there is no structural change elsewhere in the brain, a lesion may disturb the biochemistry of distant structures, thereby interfering with their functioning. The blockage function due to cold or electrical current, however, is too transient to produce reorganization of the brain, secondary degeneration, or new behavioral strategies. Moreover, because the effects of cold and of stimulation are reversible, a given animal can serve as his own control repeatedly. With the ablation technique, the investigator is limited to a single before and after comparison, or a between-subject comparison of experimental and control animals.

Yet, deficits which result when a part of the brain cannot function may not indicate what role that part of the brain plays in a normal subject who is performing well. If one removes a part from a machine and the machine can no longer perform many of its jobs, can one then conclude that the function of that part was to perform these jobs? One way to study function directly is through electrophysiological recording of localized neural activity in normal, behaving monkeys. The earliest studies of brain electrical activity during performance of Delayed Response were conducted by Stamm, Niki, Fuster, and their respective co-workers (Stamm, 1969; Stamm and Rosen, 1969; Kubota and Niki, 1971; Niki, 1974; Fuster and Alexander, 1971; Fuster, 1973). Stamm did this by measuring surface negative steady potential shifts, while Kubota and Fuster implanted microelectrodes and recorded single unit activity. Again, the neural area most closely linked to Delayed Response was shown to be the prefrontal cortex. Trials on which there was increased firing of prefrontal neurons after the bait was hidden were most likely to be the trials on which the animal reached correctly.

Lesions, localized inactivation of cortex, and localized electrical recordings, however, can only focus on a tiny fraction of the central nervous system at any one time. Lesion studies of the prefrontal cortex typically include 2 or 3 control groups with lesions elsewhere in the brain. Single cell recordings are usually taken in 3 or 4 areas of the brain as the animal is tested on Delayed Response. But even the most conscientious investigator cannot examine more than a few neural areas using any of these techniques. With 2-deoxyglucose, however, it is possible to map metabolic activity throughout the entire brain. Deoxyglucose metabolic mapping is based on the principle that there is a close relation between the activity of a nerve cell and that cell's metabolism of glucose, the brain's only major source of energy. When radioactively labelled glucose (2-deoxyglucose) is injected into a monkey's blood stream, and the monkey is then tested on Delayed Response, the most densely labelled areas of the brain will be those most active during the test (Plum et al., 1976; Sokoloff et al., 1977). Using this technique, Bugbee and Goldman-Rakic (1981) have demonstrated that local glucose utilization is elevated in prefrontal cortex during performance of Delayed Response, while other areas of the brain (such as temporal or motor cortex) show no changes in activity relative to control conditions.

All of this work taken together, representing as it does such diverse experimental approaches, makes the link between the prefrontal cortex and Delayed Response essentially incontrovertible.

Spatial Reversal

Although Delayed Response appears to be completely identical to A$\bar{B}$ in within-trial procedures, there is a difference between these tasks in across-trials procedure. They differ in the way side of hiding is determined from trial to trial. In Delayed Response, side of hiding is varied randomly. In A$\bar{B}$, the reward is consistently hidden on one side until the subject is correct, then side of hiding is reversed and the reward consistently hidden in this new place until the subject is again correct, then side of hiding is again reversed. With respect to the manner in which side of hiding is determined, A$\bar{B}$ is identical to another task linked to the prefrontal cortex, Spatial Reversal. The only difference between A$\bar{B}$ and Spatial Reversal is that in A$\bar{B}$ the subject sees which choice is associated with the reward at the start of each trial, and in Spatial Reversal he does not.

Spatial Reversal (also known as "Place Reversal") shares much in common with Delayed Response. Both tasks present the subject with two stimuli or hiding places which look identical, differing solely in left-right position. Only one choice is baited, and the subject is rewarded only if he reaches correctly. There are but two differences between these tasks: 1) in Delayed Response the subject is shown which well is baited at the beginning of each trial, in Spatial Reversal the subject is not shown this (in this respect, it is Delayed Response which resembles A$\bar{B}$), and 2) side of hiding is randomly varied across Delayed Response trials, in Spatial Reversal side of hiding remains constant across trials until the subject is consistently correct, then side of hiding is reversed and this procedure repeated (in this respect, it is Spatial Reversal which resembles A$\bar{B}$).

Spatial Reversal first requires the subject to learn a spatial discrimination; the reward is consistently associated with one particular place over repeated trials and the subject must learn this association. Prefrontally operated animals have no difficulty whatever learning the initial discrimination (e.g., Goldman and Rosvold, 1970; Gross and Weiskrantz, 1962). Their characteristic deficit appears when the reward contingency is reversed, and the previous correct place is now wrong. Prefrontally operated animals persistently return to the previously baited location long after the other location has become the site of the reward (e.g., Butter et al., 1969; Mishkin et al., 1969; Goldman et al., 1970; Butters et al., 1971).

Failure on Delayed Response and Spatial Reversal is the hallmark of lesions to the prefrontal cortex. No other area of the brain shows this pattern as clearly as does the prefrontal region. On other tasks, requiring other abilities, animals with prefrontal lesions perform very well. For example, they perform within the normal range on even quite difficult simultaneous discrimination tasks (tasks which require that they learn an association between a stimulus and response, the conditioned stimulus being presented simultaneously with other stimuli) (Jacobson, 1935, 1936; Harlow and Dagnon, 1943; Pribram, 1955; Pribram and Mishkin, 1955; Mishkin and Weiskrantz, 1958; Brush et al., 1961; Pribram, 1961; Gross and Weiskrantz, 1964).

Comparison of Results from A$\bar{B}$ with Those from Delayed Response and Spatial Reversal

The pattern of errors found on A$\bar{B}$ in infants younger than 12 months is almost identical to that found on Delayed Response and Spatial Reversal in monkeys and lower animals who have sustained disruption of functioning in the prefrontal cortex. Damage to no other part of the brain produces this pattern of results:

1) When no delay is imposed, the errors of infants and prefrontally operated monkeys disappear.

   (With _infants_: present study; Gratch and Landers, 1971; Gratch et al., 1974; Harris, 1973. With _monkeys_: Harlow, 1952. With _dogs_: Lawicka and Konorski, 1963; Konorski and Lawicka, 1964.)

2) Infants and prefrontal monkeys fail, however, with delays as brief as one or two seconds.

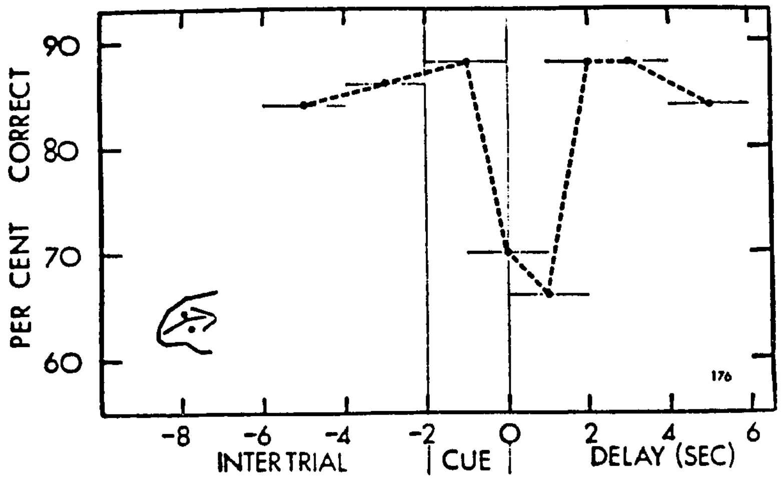
(With infants: present study; Evans, 1973; Gratch et al., 1974. with monkeys: Harlow, 1952; Battig et al., 1960; Goldman et al., 1970; Fuster and Alexander, 1971.)

Brody (1977), in one of the few Delayed Response experiments with infants, found that while 12 month olds could do well at delays at least as long as 9 seconds, 8 month olds could not reach criterion at delays even as brief as 3 seconds.

Normal monkeys perform well with delays greater than 90 seconds (Jacobsen, 1936) and normal dogs can successfully withstand delays as long as 6 minutes (Hunter, 1923; Yarborough, 1917; Konorski and Lawicka, 1964).

The finding that deficits occur even at very brief delays is consistent with results from electrophysiological research that the first few seconds of the delay period is the crucial time for prefrontal involvement. Stamm (1969) and Cohen (1972) have convincingly demonstrated that maximal disruption of performance occurs when stimulation is applied across electrodes in the prefrontal cortex during the first 0-2 seconds following the onset of the delay. (See Figure 53.) Similarly, Stamm and Rosen (1968) showed that the magnitude of the surface negative steady potential shifts over the prefrontal cortex is greatest during the very beginning of the delay period, and that such an increase in prefrontal activity during this period was highly correlated with correct responding. A negative steady potential shift is an index of increased neuronal firing (Caspers, 1963; O'Leary and Goldring, 1964) and, indeed, when microelectrodes were implanted in the prefrontal cortex to record single unit activity, it was found that a large proportion

FIGURE 53



Performance on Delayed Response with an 8 second delay by subject #176 with 2 second trains of stimulation applied across electrodes implanted in the prefrontal cortex (location shown by insert). The time scale is with reference to the start of the delay period. Horizontal lines indicate periods of stimulation.

For every monkey, one pair of electrode points was found which, when stimulation was applied through it, yielded the results illustrated here.

from Stamm and Rosen, 1969

of the cells increased their rates of discharge during the first seconds of the delay (Fuster and Alexander, 1971; Fuster, 1973, 1980; Kubota et al., 1974; Niki and Watanabe, 1976).

Moreover, Fuster (1973) has shown that little of this increase in prefrontal activity is seen if no cue precedes the delay or if the subject is untrained, "those observations indicate that elevated discharge during the delay is to a large extent determined by the relation of contingency between temporally separate events, a relation established by learning and essential for correct performance" (Fuster, 1980: 106). Consistent with this, Walter (1973) has shown that once a person has been instrumentally conditioned, a slow electrocortical potential over the frontal lobes is recorded during the time interval separating two related stimuli (the conditioned stimulus and the stimulus which calls for a motor response). This has been called the contingent negative variation (CNV) or expectancy wave.

3) When a screen is used during the delay period, obscuring the hiding places before the subject is allowed to reach, even a delay of "0" seconds will produce errors in younger infants and in prefrontally operated monkeys, although a screen will not impair the performance of older babies or of monkeys with a normal prefrontal cortex.

(With <u>infants</u>: Szpak, 1977; Fox et al., 1979. With <u>monkeys</u>: Battig, 1960; Goldman et al., 1970).

Other means of disrupting the subject's visual fixation on the correct well, such as making him look up, produce results similar to those found with a screen (in <u>infants</u>: present study; in <u>monkeys</u>: Jacobson et al., 1935). Even infants of only 7 or 8 months can perform perfectly if allowed to stare fixedly at the correct well from the time of hiding to retrieval.

4) Uninterrupted "position cuing" or "bodily strain" are as effective at reducing task demands as is visual fixation. Subjects who err if bodily orientation to the correct well is disrupted, reach correctly if this orientation is maintained throughout the delay.

(With infants: present study. With monkeys: Jacobsen et al., 1935; French, 1959; Miles and Blomquist, 1960; Pribram et al., 1977. With dogs: Lawicka and Konorski, 1963; Konorski and Lawicka, 1964).

The investigators describing the behavior of primates or dogs with frontal cortex ablations might just as well be describing that of infants early in the second half of the first year:

> [Chimpanzees with lesions of the frontal cortex] oriented themselves toward the cup which was being loaded, and had to maintain this gross bodily orientation during the delay period .(sic) If the animal spontaneously shifted its orientation, or if the experimenter distracted the animal by talking to it or moving his hand through the animal's visual field, the number of correct responses fell to a chance level although the disturbance was only of momentary duration. (Jacobsen et al., 1935: 10-11)

> The close observation of the response of prefrontal dogs revealed the following interesting features, to the preparatory stimulus (buzzer) they displayed a clear and strong orienting reaction toward its source; if they preserved this bodily orientation throughout the delay period, they were sure to react correctly after the release, but if they changed their position either spontaneously or due to distraction, their performance was much worse. (Lawicka and Konorski, 1963: 126)

5) In 1973, Harris reported that the 10 month old infants he studied could not reliably retrieve the object hidden at B, even with a "0" second delay, if the experimenter covered hiding place A after covering hiding place B. The infants did not err if the last well they saw covered was B, and many studies have shown that they do not err at no delay if both wells are covered simultaneously. Similarly, Bartus and Levere (1977) report that monkeys with prefrontal ablations, unlike normal monkeys, are severely impaired on discrimination problems if irrelevant stimuli are presented after relevant stimuli. Ordinarily,

prefrontally ablated animals perform well on discrimination problems. As with the Harris findings, this impairment did not require a delay before responding, and it did not appear if the irrelevant stimuli were presented first followed by the relevant ones. Covering the incorrect well last, or presenting irrelevant stimuli last, appears to have the same effect as lowering and raising a screen -- it distracts infants under one year and prefrontally operated monkeys, interfering with their performance.

6) After infants or prefrontal animals have made an erroneous choice, they often correct themselves immediately. That is, when presented with three or more hiding places, their second choice is usually correct, and they often correct themselves straightaway.

(With <u>infants</u>: Webb et al., 1972. With <u>dogs</u>: Lawicka and Konorski, 1963; Konorski and Lawicka, 1964; Lawicka, 1969; Konorski, 1972).

This suggests that the infants and animals with prefrontal destruction remember, at some level, which choice is correct.

(It should be noted that at the age when the $A\bar{B}$ error <u>first</u> appears, when infants are making the $A\bar{B}$ error at delays of 0, 1, or 2 seconds, they do not continue to search once they have reached to a well. They do not correct themselves. At later ages such continued search is always present (unless the infant is severely strained by too long a delay, in which case his behavior shows various forms of deterioration, such as refusal to reach at all or exaggerated perseveration). Similarly, not everyone has found that animals with frontal lobe ablations correct themselves (e.g., Pribram (1971) and Schwartz (personal communication). This may well relate to the severity of the deficit.

7) Infants and prefrontally operated monkeys are correct the very

first time the reward is hidden, and once correct, if the reward is hidden in the same place again, they reach correctly again. However, when the site of hiding is changed they reach back to where they previously found the reward, and they persist in this error over several trials. After each mistake, the experimenter shows them where the reward was hidden. At the outset of each trial, they see the experimenter hide the reward at the new location. Yet, they persist in reaching back to the reward's earlier hiding place. (Hence, the name $A\bar{B}$ for infants who are able to find an object at the first place it is hidden [location A] are unable to find the object at the second place it is hidden [location B]. They search at A, not B.) When a baby or a prefrontal monkey finally does reach correctly, and the reward is now hidden at the first location, they err by reaching back to the second location. (With *infants*: present study; Harris, 1973; Gratch et al., 1974. With *monkeys*: Mishkin, 1964; Goldman et al., 1970).

Thus, it appears that prefrontally operated monkeys and infants below the age of twelve months are not able to stop themselves from reaching to the former site of the reward, even though more recent evidence of the toy's whereabouts is available to them. Indeed, babies sometimes stare at the correct place as they reach to the wrong place. They look at where the toy really is, as if at some level they know the correct choice, but their hands nevertheless go to the old location. (See Figure 43.) At other times, they reach incorrectly, do not bother to check if the reward was there, and then immediately reach to the correct hiding place. Again, it is as if the children know their initial choice is wrong, but reach there anyway (Piaget, 1954; present study). This is strongly reminiscent of the behavior of frontal lobe patients (e.g., Milner, 1964; Luria and Homskaya, 1964); see discussion below.

8) Infants are correct on the first trial of a testing sessions (the trials to A) even in longitudinal studies where they have received previous testing on the same experimental paradigm (Gratch et al., 1974; Szpak, 1977). Lawicka and Konorski (1963) have also noted that prefrontally lesioned dogs perform significantly better on the first trials of each session than on the session as a whole. If prefrontally operated monkeys are given only one Delayed Response trial per day, they perform correctly (Spaet and Harlow, 1943). This is analogous to being given only one "A" trial per day. Similarly, prefrontal monkeys have no difficulty learning the initial discrimination in the Spatial Reversal task (i.e., they have no difficulty learning to go to "A"), however, when the contingencies are reversed, so that B is now the correct response, their impairment becomes apparent (Mishkin, 1964; Goldman et al., 1970).

9) Infants under 9 months of age err by reaching back to the same "absolute" position, rather than to the same "relative" position. They do not seem to pay attention to the spatial relationship between the two hiding places (present study; Butterworth, 1975). Significantly, in research with monkeys, prefrontal neurons have been discovered which fire only when the reward is hidden on the left, or only when it is hidden on the right. Whether or not these neurons are activated depends upon the relative, and not the absolute location of the reward (Niki, 1974; Kojima and Goldman-Rakic, 1982).

10) When the wells differ in up-down position, infants and prefrontally lesioned monkeys fail in the same sort of way seen when the wells differ in left-right position.

(With infantsx: Butterworth, 1981; Butterworth and Jarrett, 1982.
With monkeys: Mishkin and Pribram, 1955).

11) When infants or prefrontally lesioned animals are presented with choices which differ in appearance they seem to do better. Bremner (1978) found that the performance of infants improved if the covers occluding the hiding places were of different color, but not if the surfaces n which the hiding places were located were of a different color. Goldfield and Dickerson (1981), however, found that infants below 9 months were not aided by different covers.

Monkeys with lesions in the dorsolateral region of the prefrontal cortex perform well on Object Reversal (where the two choices differ in appearance) but not on Spatial Reversal (where the choices differ only in spatial position) (Mishkin et al., 1969). However, monkeys with lesions in the orbital region of prefrontal cortex cannot succeed even at Object Reversal (Mishkin et al., 1969). An error with different covers, like a failure to continue searching after an incorrect reach (point 6 above), may be indicative of severe immaturity or damage in the frontal lobe.

12) If a visible cue or landmark marks the location of the reward, then children and animals are able to use this to guide their reaching. Errors disappear.

(With infants: present study; Lucas and Uzgiris, 1977; Cornell, 1978; Acredolo, 1981; Acredolo and Evans, 1980. With monkeys: Pohl, 1973).

The similarities between $A\bar{B}$ on the one hand and Delayed Response and Spatial Reversal, on the other, and the strong association between Delayed Response and Spatial Reversal and the prefrontal cortex, suggest that the prefrontal cortex may also underlie performance on $A\bar{B}$. That is, errors on $A\bar{B}$ may disappear by one year of age because there has been a maturation in the prefrontal cortex.

SIMILARITIES BETWEEN COGNITIVE ABILITIES LINKED TO THE FRONTAL LOBE FROM WORK WITH ANIMALS AND COGNITIVE ABILITIES WHICH EMERGE BETWEEN 6 AND 12 MONTHS.

II. OBJECT RETRIEVAL

The Moll and Kuypers Task

Moll and Kuypers (1977) administered a test very similar to Object Retrieval to frontally lesioned monkeys. They seated a monkey on a transparent disk and placed a piece of food directly beneath the center of the disk. Although the monkey could see the food through the center of this transparent floor plate, the only route to the food was through a hole in the side of the plate. As in Object Retrieval, the subject was given considerable leeway in how to attack the problem and could approach the hole from any desired direction. Moll and Kuypers held the location of the food constant but varied the location of the hole in the floor plate by rotating the plate between trials. In Object Retrieval, too, the opening could be at the top, front, left, or right side. Most important, these tasks presented the same basic problem: they required the subject to detour around a transparent barrier to a visual reward. In both, success required reaching along a route other than the line of sight and it required a two-directional reach, the first part of the reach being away from the goal to circumvent the barrier, and the second part being toward the goal.

The frontal lesions performed by Moll and Kuypers were quite large and included the caudal part of the principal sulcus, the banks and depths of the arcuate sulcus, and the entire premotor area. Thus, prefrontal and premotor cortex were included.

Moll and Kuypers found that monkeys with these frontal lesions persisted in trying to reach on a straight line of sight through the center of the disk. On 90% of the trials, they reached directly to where the food was visible through the floor plate. On the other hand, normal monkeys, and monkeys with lesions confined only to the precentral gyrus or to the arcuate sulcus, had no difficulty retrieving the food reward. On over 80% of the trials, they reached through the hole in the plate and obtained the food.

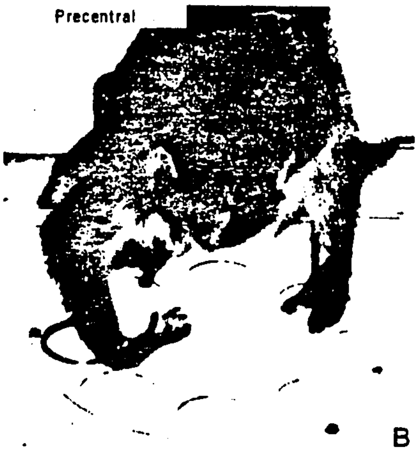
Moreover, Moll and Kuypers demonstrated that if a unilateral frontal lesion is combined with a commissurotomy (optic chiasm preserved), line of sight reaching is found only in the hand contralateral to the lesion. While the hand contralateral to the lesion persisted in reaching at the center of the disk, the ipsilateral hand of the same monkey reached through the hole to the food. (See Figure 54.)

The study by Moll and Kuypers is the only one to date that has explored the areas of the brain involved in the performance of a task closely resembling Object Retrieval. However, other studies have linked the frontal lobe to behaviors and abilities we have observed in the course of Object Retrieval testing. For example, monkeys with lesions of the frontal lobe appear to be markedly deficient in: 1) relating two "things" to one another, 2) inhibiting strong action tendencies (whether learned or instinctual), and 3) keeping track of responses they have already made.

Relating Two Things to One Another

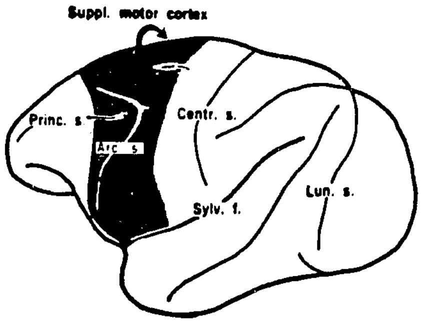
Figure 54

Monkey with with a premotor lesion reaches straight for the food visible through the transparent floorplate.



Monkey with a large ablation of the left precentral hand area reaches for the food through the black-rimmed hole.

Extent of premotor cortical ablation of Moll and Kuypers, based on sketches made during surgery.



from Moll and Kuypers, 1977

Jacobsen and his colleagues (1935) presented frontally lesioned chimpanzees with the task of using a stick to retrieve a food reward. The food was directly in front of the stick. The bars of the cage made the food, but not the stick, out of reach. Chimpanzees with frontal lesions were able to master this problem. Next, Jacobsen complicated the task further by requiring the chimpanzee to use a smaller stick to retrieve a larger stick, to retrieve a still larger stick in order to obtain the reward. All sticks and reward were still within the same visual field. The frontally operated chimpanzees were able to succeed at this multiple stick problem as well. However, when the same number of sticks were divided between two platforms 180 degrees apart, so that all sticks were no longer in the same visual field (and to approach the second platform meant walking away from the goal) the frontally lesioned chimpanzees were unable to master the task. Indeed, the chimpanzees with frontal ablations performed far better on the task requiring manipulation of five sticks, all on the same platform, than they did on the task requiring the use of a single stick, which, however, was on the platform 180 degrees removed from the food.

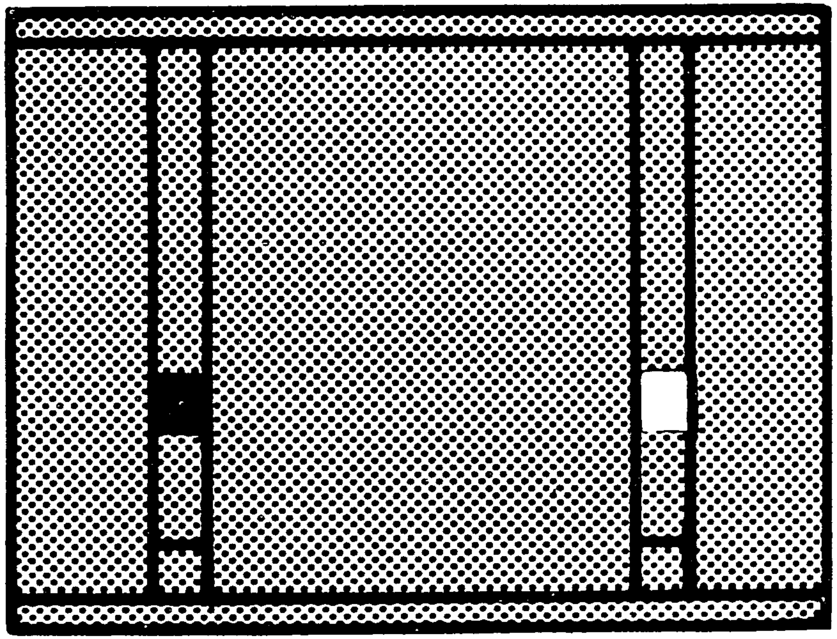
In another experimental procedure first used by McClearn and Harlow (1954), rhesus monkeys were presented with two levers, and were trained to press the lever associated with a particular color cue. Distance between cues and levers was varied. The performance of normal monkeys deteriorated as the distance between cue and lever increased. French (1962) repeated this experiment with frontally ablated rhesus monkeys. He found that once cue and lever were no longer spatially contiguous, the performance of monkeys with frontal lesions was significantly poorer than that of normal monkeys at each degree of separation tested (1, 2, and 4 inches). Moreover, while the performance of frontally lesioned monkeys, like that of normals, improved with practice, improvement in the lesioned monkeys was significantly more gradual. Thus, while normal monkeys performed at criterion after only brief testing, monkeys with frontal ablations never achieved criterial performance at spatial discontiguities of 2 and 4 inches within the span of testing provided. (Figure 55 illustrates the testing apparatus as well as the results of this work.)

The experiments by Jacobsen et al. and by French are reminiscent of the work of Millar and Schaffer (1972; 1973), who showed that infants early in the second half of the first year could learn to press a lever in order to produce a light display if the lever and the lights were in the same visual field, but not if lever and lights could not be seen simultaneously. On Object Retrieval, too, infants below 9 months rarely look one place and reach another. Their reaches are almost exclusively through the side through which they are looking. By leaning and looking, infants early in the first year not only bring the line of sight and line of reach into correspondence, they also make it possible to reach on a single, direct line for the goal, they do not need to reach away from the goal and then reach back.

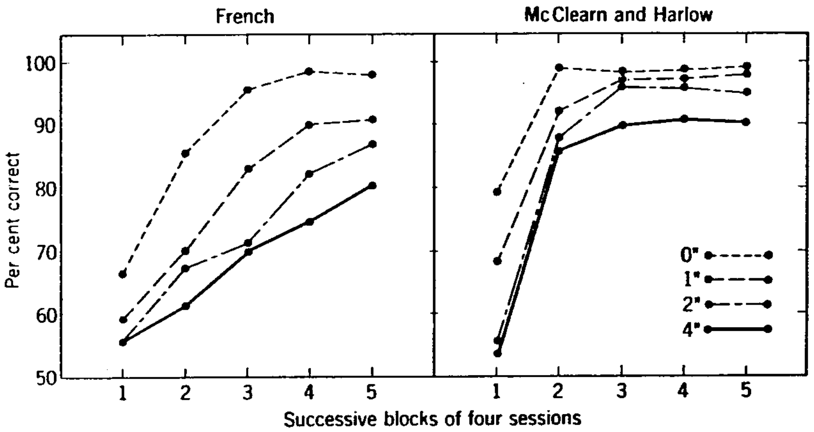
The prefrontal and premotor areas are ideally situated to play a role in the coordination of sensory input and motor acts (such as looking one place and acting another, or using visual information to guide reaching). They receive visual information via inferotemporal cortex, auditory input via temporal cortex, and somatic input via parietal cortex (Pandya and Kuypers, 1969; Jones and Powell, 1970; Nauta, 1972; Haaxma and Kuypers, 1975; Kubota and Hamada, 1978; Fuster, 1980) and

Figure 55

Illustration of Testing Apparatus Used and Results Obtained by McClearn and Harlow (1954) and French (1962)



The Spatial Contiguity Board used in testing monkeys by McClearn and Harlow (1954) and French (1962). The view is from the subject's side. Gray manipulanda are located at the bottom of the vertical channels. Above each is one of the discriminanda, the location of which is variable both vertically and from left to right. Both discriminanda are present on every trial.



Percentage of correct choices by all monkeys as a Function of Successive Four-Day Testing Blocks, during which every animal was given 64 trials under each condition. Data from French (1962) are summarized at the left, and those from McClearn and Harlow (1954) at the right. In both experiments, four subjects were tested.

they project areas fundamental to the control of movement -- the caudate, globus pallidus, substantia nigra, and motor cortex (DeVito and Smith, 1964; Johnson et al., 1968; Pandya and Kuypers, 1969; Leichnetz and Astruc, 1976, 1977; Kunzle, 1978).

Another way of putting subparts into a relation is in an action sequence. We have seen indications that infants may have some difficulty with the temporal order of a behavioral sequence. For example, when they try to imitate A$\bar{B}$ they often cover the well first and then put the toy on top. Similar errors occur in imitation of Object Retrieval. Also, in attempting to relate a "means" (such as raising the box) to an ends infants encountered a variety of problems before they finally achieved mastery. They were capable of raising the box and of reaching on a straight line for the toy months before they were able to put these acts together so that raising the box could be used to aid them in retrieving the toy. Jacobsen and colleagues (1936) taught chimpanzees to manipulate an assortment of latches in order to open a box containing food. After these animals received frontal lesions, their performance was severely impaired. In particular, they tended to perseverate in manipulating a latch which had already been opened. However, when each of these latches were presented singly, the operated animals were able to skillfully open them. Therefore, it was the combination, the need to put different tasks together, which created the problem for the chimpanzees.

In a more recent study, Deuel (1977) trained monkeys to open a complex latch box in which correct performance required a series of actions including sliding a bolt along a track, lifting the bolt out, turning the crank 180 degrees, and depressing a knob. The monkeys were not only required to perform each of these actions correctly, but also to perform them in the correct sequence. Monkeys with prefrontal lesions were severely impaired on this task, although monkeys with lesions in the parietal lobe were not. The prefrontal monkeys could perform each subunit correctly but they performed them in the wrong order.

Frontally operated hamsters can correctly perform the component actions of nest-building -- picking up nest material in the mouth, carrying it to proper location, manipulating it into the correct position -- however, they fail to chain these instinctive behaviors into the proper sequence (Wishaw, 1980). When infants imitate A$\bar{B}$ and Object Retrieval, they, too, repeat the component actions properly, but the sequence is off, the behaviors are not in the proper relation to one another.

Inhibition

Frontally operated animals appear to have inordinate difficulty in counteracting an engrained action tendency. For example, they are impaired on tasks which require reversing or extinguishing a conditioned response. Animals with frontal lesions have no difficulty learning an initial discrimination (e.g., Jacobsen, 1935, 1936; Harlow and Dagnon, 1943; Harlow and Settlage, 1948; Pribram et al., 1952; Pribram, 1955; Pribram and Mishkin, 1955; Mishkin and Weiskrantz, 1958; Gross and Weiskrantz, 1958), but, they are severely impaired in reversing that discrimination, persisting much longer than do other animals in repeating the initially reinforced response (Harlow and Dagnon, 1943; Settlage et al., 1948; Warren, 1962; Gross, 1963; Mishkin, 1964; Teitelbaum, 1964; Warren et al., 1969, 1972; Butters et al., 1971, 1972, Treichler, 1973). Similarly, while frontally lesioned animals can learn an operant response without difficulty, they are abnormally slow to extinguish that response (e.g., Butter et al., 1963; Butter, 1969; McEnaney and Butter, 1969; Warren et al., 1969; Rosvold, 1972).

The results from Object Retrieval and A$\bar{B}$ testing suggest that infants under one year also have difficulty resisting prepotent tendencies. In Object Retrieval we have seen the difficulty infants have in *not* reaching directly to where they see the toy. When means-end behavior first appears, we have seen that infants have great trouble *not* doing the same thing with both hands. After they have raised the box, when one hand goes down to reach in, the other tends to come down, too, instead of continuing to hold the box up so that the hand attempting to reach may enter the box. The A$\bar{B}$ error may be interpreted as an inability to inhibit a conditioned tendency to reach where the infant has been rewarded in the past. This is quite similar to the frontal animal's difficulty in reversing a conditioned response. Instances where the infant can be seen looking at the correct well as he reaches back to the wrong well, and then corrects himself without even checking to see if the toy were in the well first reached to, strongly suggest that the infant has erred not out of ignorance, but out of difficulty in stopping himself.

Much of the work that indicates a failure in inhibition in frontal animals (in particular, the work on reversal and extinction tasks) does so by demonstrating response perseveration; frontal animals repeat the previous response for much longer than do normal animals. Therefore, it is particularly nice that one study suggests that frontal animals have difficulty suppressing response tendencies by demonstrating that frontally operated animals repeat the previous response <u>fewer</u> times than do normal animals. Jacobsen, Wolfe, and Jackson (1935) trained chimpanzees on an apparatus so arranged that by pushing successively on the first 3 pegs and pulling on the fourth, a food reward could be obtained. Normal chimpanees mastered this task; frontally lesioned ones did not. Their characteristic error consisted of errors of "anticipation", i.e., they tended to pull on pegs 2 or 3. An error of perseveration would have been to continue to push on peg 4. That is, the frontal chimpanzees had trouble waiting. It was pulling that produced the reward, and they had difficulty suppressing the tendency to pull.

One can also see the difficulty of frontal operated animals in inhibiting or suppressing an action tendency with responses which appear to owe their strength, not to learning, but to innate predispostions. (The automatic reach for the toy in Object Retrieval would be an example of an unlearned action tendency.) For example, most animals, including most frontally lesioned animals, find it easier to act than to not act. When presented with a testing situation most animals find it very difficult to do nothing (e.g., Nadel et al., 1975). Go/no-go alternation is a task which requires the animal to alternate responding with not responding. Animals with ablations of the frontal cortex perform poorly on this task, because they fail to "not go" (Allen, 1940, 1943; Konorski, 1963; Rosvold and Mishkin, 1961; Brutkowski, 1964; Mishkin, 1964; Gerbner and Pasztor, 1965).

Most animals, including frontally lesioned ones, prefer novel stimuli to familiar ones (e.g., Douglas, 1972; Stevens, 1973). Frontally lesioned animals perform better on delayed non-match to sample (where they are rewarded for choosing the stimulus they have not seen before) than they do on delayed match to sample (where they are rewarded for choosing the familiar stimulus). Indeed, while frontal animals are often (although not always) significantly worse than controls on delayed match to sample, they are rarely worse than controls on delayed non-match to sample (Mishkin, 1964; Fuster, 1980). Note that memory is required for both of these tasks so that the difference in performance must be attributable to something other than memory.

Frontally operated animals appear to be pulled by the reward as if by a magnet (this behavior is called the "magnet reaction"). When an animal is shown the reward at one location, but must act at a different location in order to obtain it, frontal animals appear to be unable to overcome the impulse to approach the reward; they therefore fail the task (Stepien and Stepien, 1965; 1970; Stepien, 1972). Gross and Weiskrantz (1962) have found frontally lesioned monkeys to be severely impaired in learning to walk <u>away from</u> a visual or auditory cue. They are perfectly capable, however, of learning to approach a cue (e.g., Jacobsen, 1935; 1936; Harlow and Settlage, 1948; Pribram et al., 1952). We have shown that infants can learn to reach to the hiding well marked by a landmark in A$\bar{B}$. We predict that infants would not be aided by a landmark if it marked where the toy <u>was not</u>; i.e., if they had to reach away from the landmark.

Infants below about 8 months are easily distracted. Almost any stimulus will attract their attention, diverting them from the task at hand. The attention of animals with frontal lesions changes often and rapidly, as well. They are unable to keep themselves from attending to extraneous stimuli and this distractibility interferes with their performance (Brush et al., 1961; Konorski and Lawicka, 1964; Hannon and Kamback, 1972; Fuster, 1980). This behavior can be interpreted as a difficulty in suppressing orienting reactions. Something catches the eye, a normal animal resists being diverted by it; the attention of the frontally lesioned animal, however, is captured.

We have also noted that infants early in the second half of the first year tend to grasp whatever they come in contact with. Thus, they often grasp the box en route to the toy. They also have difficulty releasing the grasp. A release of the grasping reflex from normal inhibition in the adult animal has been reported in frontally ablated monkeys (Fulton et al., 1932; Richter and Hines, 1932; Fulton and Kennard, 1934). This is often referred to as "forced grasping."

There is electrophysiological evidence that the frontal cortex exerts an inhibitory influence over other areas of the brain. The frontal cortex is connected by particularly well-developed bundles of ascending and descending fibers with the reticular formation, and inhibits and modulates reticular activity (French et al., 1955; Hernandez-Peon, 1966; Nauta, 1971). (The reticular formation plays a central role in attention and arousal.) Disruption of prefrontal function through ablation or electrical stimulation abolishes spindle bursts, recruiting responses, and other forms of synchronous electrographic activity associated with cortical inhibition (Lindsley et al., 1949; Velasco and Lindsley, 1965; Weinberger et al., 1965; Robertson and Lynch, 1971; Skinner, 1917.) Skinner and Lindsley (1973) interpret the electrophysiological findings as evidence that the frontal cortex, in collaboration with the medial dorsal thalamus, exerts inhibitory influence over sensory inputs; thereby regulating attention. Also, the prefrontal and premotor areas, through their projections to the caudate (Goldman and Nauta, 1977), putamen (DeVito and Smith, 1964; Johnson et al., 1968; Kemp and Powell, 1970, 1971), globus pallidus (DeVito and Smith, 1964; Johnson et al., 1968; Leichnetz and Astruc, 1977), substantia nigra (DeVito and Smith, 1964; Leichnetz, 1976, 1977), and motor cortex (Pandya and Kuypers, 1969; Jones and Powell, 1970) are in a position to exert inhibitory influence on motor activity.

Both prefrontal and premotor cortex project to the superior colliculus (Goldman and Nauta, 1976; Kunzle, 1978), an area of major importance in the visual guidance of behavior. Disinhibition of the optic tectum in lower animals (their equivalent of the superior colliculus) results in attempts to attack prey objects directly, ignoring the intervening transparent barrier, although normal animals easily detour around the barrier to the target (Ingle, 1973; Ewert, 1974; Comer and Grobstein, 1977; Ingle, 1982). This is precisely the error which infants make on Object Retrieval and which frontal monkeys make on the similar Moll and Kuypers' task (1977): they reach directly for the reward on a straight line of sight instead of reaching around the barrier.

Keeping Track of Previous Responses

Various tasks have been devised for monkeys which allow considerable latitude in how they can be solved, requiring only that the subject not repeat any choice he has already made on that trial. For example, the animal may be presented with a number of wells, all of them baited. There is a brief delay, then he is permitted to uncover one well, a brief delay, he is permitted another choice, delay, response, etc. If the animal uncovers a well he has already chosen earlier on that trial he receives no reward for that choice and it is scored as an error. Criterial performance requires the animals to uncover all the wells on each trial with a minimum of repetition. Animals with ablations of the frontal cortex perform far worse than do normal animals on such tasks. Frontal animals keep repeating previous choices. This is not perseverative behavior, for they do not go to the same well time and again. Instead they seem not to have crossed off choices they have made from their mental list, so their sequence of responses might look like: well 2, well 5, 6, 2, 5, 3, 5, 6, 2, 3, 5, 6 (Brody and Pribram, 1978; Schwartz and Goldman-Rakic, personal communication.)

This is reminiscent of infants as they begin to be able to resist the lure of the line of sight. For here, at the age of about 9 months, the number of sides tried by the infant on any given trial skyrockets. A typical sequence might be: front, top, left, front, top, left, front, top, front, top, front, top, left, front, top, left, and finally right. As the infant approaches his first birthday, however, once he has tried a side and found it closed, he does not re-check it. The number of sides tried per trial is dramatically reduced.

Thus, over a variety of experimental paradigms, on a variety of behaviors, infants early in the second half of the first year resemble animals who have received lesions to the frontal lobe. A$\bar{B}$ and Object Retrieval appear to be very dissimilar tasks, yet both closely resemble tasks linked to the frontal cortex. Performance on A$\bar{B}$ and Object Retrieval may improve during the same time span because both tasks require abilities moderated by the frontal cortex and a developmental change in the frontal cortex may be occurring during the second half of the first year of life.

SIMILARITIES BETWEEN COGNITIVE ABILITIES LINKED FROM WORK WITH HUMAN ADULT PATIENTS AND COGNITIVE ABILITIES WHICH EMERGE BETWEEN 6 AND 12 MONTHS

A$\bar{B}$

The behavioral profile of infants below one year resembles not only that of animals with lesions to the frontal lobe, but also that of human adults with damage to the frontal lobe or related structures.

In drawing comparisons between infants and adult patients, we will focus on adults with documented damage to the frontal lobe itself and on adults suffering from Korsakoff's amnesia or amnesia due to an aneurysm in the anterior communicating artery (ACA).

Patients with Korsakoff's disease have damage to the mediodorsal thalamic nucleus (MD) (Victor et al., 1971) or the mammillary bodies (Gamper, 1928; Brierly, 1966) or both. MD and the mammillary bodies both have extensive reciprocal connections with the frontal lobe. No other area of the brain is as strongly associated with the prefrontal cortex as is MD. With the increase in size of the prefrontal cortex over phylogeny has come a parallel increase in the size of MD (LeGros Clark, 1932). The largest increase within the prefrontal cortex has come in the dorsolateral region, and similarly its associated region of MD, the parvocellular portion, has witnessed more enlargement during evolution than other sectors of the nucleus (Pines, 1927; Clark, 1930). The premotor area also projects to and receives projections from MD (Tobias, 1975; Kievit and Kuypers, 1977). The prefrontal region is the only cortical area to send direct projections to the hypothalamus.

Direct prefrontal-hypothalamic projections terminate in the ventromedial nucleus and the mammillary bodies (Meyer, 1949). Going in the opposite direction, there is a major mammillary projection via the mammillothalamic tract to the anterior thalamus, which relays it to MD (Cowan and Powell, 1954).

ACA-related amnesia has received less attention than other amnesias, but ACA is located so close to the frontal lobe that it is difficult to operate on that artery without causing hemorrhaging in the frontal lobe (Cohen, 1982). Korsakoff and ACA amnesics appear to have symptoms of frontal lobe dysfunction superimposed on their memory disorder. For example, Korsakoff patients are described as having a similar lack of initiative (Meggendorfer, 1928), similar lack of planfulness (Butters & Cermak, 1980), and similar perseverative tendencies as patients with lesions to the frontal lobe (Talland, 1965). On formal tests of exploratory ability, Korsakoff patients, like frontal lobe patients, evince a profound lack of interest in investigating uncertain or novel situations (Zangwill, 1966). Like frontal lobe patients, however, and unlike many other brain-damaged patients, they have normal IQs (Butters & Cermak, 1980; Squire, 1982). The principal difference between their behavioral characteristics and those of frontal lobe patients is that the latter are not amnesic. Other groups of amnesic patients (e.g., patients who are amnesic due to electroconvulsive shock therapy over the temporal lobe) and patients with damage elsewhere in the brain, do not display this pattern of behavior (Butters & Cermak, 1980; Squire, 1982; Squire et al., 1982; Cohen, 1982).

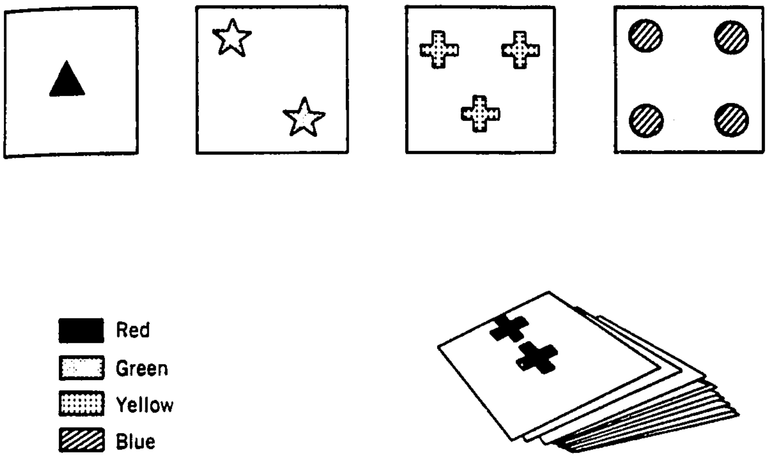
Recall that in the A$\bar{B}$ experiment, infants do fine until side of hiding is changed. Then they err by returning to where the toy used to be. They perseverate in this error over several trials, and repeat the error when side of hiding is again changed. This difficulty in shifting responses, continuing to repeat an old response when a new one is called for, is characteristic of frontal lobe patients and Korsakoff and ACA amnesics.

One of the standard tests of frontal lobe function is the Wisconsin Card Sorting Test. Here, the patient is asked to sort a deck of cards. (Figure 56 illustrates what some of these cards look like.) The patient is shown that the cards may be sorted on the basis of color, shape, or number, but he is not told which sorting criterion is correct. He will have to deduce this from the experimenter's feedback after each card he sorts. The experimenter will tell him each time whether he was right or wrong. Frontal lobe patients do not have trouble figuring out which criterion is correct. However, the test is not over yet. Without warning, the experimenter switches criteria. Now the patient must sort the cards according to a different principle. Here is where the behavior of frontal lobe patients becomes distinctive. They persist in using the first criterion for far longer than do normal or other brain-damaged adults (Milner, 1964; Drewe, 1974). Korsakoff and ACA patients are the only other population so far tested to perform on the Card Sort as do frontal lobe patients (Squire, 1982; Cohen, 1982).

Similarly, on the Goldstein Sorting Test, patients with frontal lobe damage can correctly group items into categories, but they cannot change categories. Even when they are shown various methods of shifting, they are unable to use these methods when retested (Goldstein, 1944; Barbizet, 1970).

If a frontal lobe patient is asked to draw a circle he can readily

Figure 56



Wisconsin Card Sorting Test, showing the material as presented to the subject.

from Milner, 1964

do so. But, when next asked to draw a cross, he draws a circle again. He often continues to draw circles in response to the next several requests for a cross. Finally, he draws a cross. Then he is asked to draw a circle, but now he draws a cross (Luria and Homskaya, 1964).

Oscar-Berman and Zola-Morgan (1980a and b) tested Korsakoff amnesics on spatial and visual discriminations and reversals similar to those which have been administered to animals. Like animals with ablations to the frontal lobe, Korsakoff patients performed well on the discrimination tasks, but were impaired on the reversal tasks.

Examples are legion. Frontal lobe, Korsakoff, and ACA patients persist in making a response which used to be correct even though this now leads to repeated failure. They have great difficulty reversing or switching their behavior. They, like infants, also repeat choices or responses which they have already been informed are incorrect. One might call this "re-testing rejected hypotheses" or "failing to keep track of responses they have made." While infants very early in the first year, like patients with very severe frontal pathology, may rigidly persist in one "hypothesis" (e.g., reach only at one side of the box in Object Retrieval), infants midway in the second half of the first year and adults with more circumscribed destruction to the frontal lobe try several "hypotheses" but they do so inefficiently, retrying ones which have already been shown to be incorrect. Monkeys with frontal lobe damage cannot manage to uncover wells without repeating any choice. Frontal lobe patients cannot manage to choose each of 12 pictures without selecting any picture twice (Petrides, cited in Milner, 1982). When frontal lobe patients are asked to name as many words as they can beginning with a certain letter or to draw as many abstract figures as they can using only four lines, they typically produce far fewer responses than do control subjects, but what is more striking is their inability to avoid repeating answers they have already given (Barbizet, 1970; Milner, 1973).

Infants do not make the A$\bar{B}$ error if no delay is imposed, yet they fail with delays of even a few seconds. Results similar to these have been obtained with frontal lobe and amnesic patients. For example, Milner (1964) reports that frontal lobe patients were impaired on three of four delayed comparison tests. When no delay was imposed, however, the frontal patients showed no deficit. In one such test, patients were presented with a color or a sound, the stimulus was removed, then a second color or sound was presented and the patients asked if the color was the same shade or the sound the same intensity as the first stimulus. Frontal lobe patients performed well if there was no delay, but failed at a 60 second delay. (Normal subjects can succeed with delays of several minutes (Prisko, cited in Milner, 1971).) Cermak et al. (1971) report a representative finding with Korsakoff patients -- perfect recall at 0 seconds but significant deficits compared with control subjects (e.g., non-amnesic alcoholics) at delays as low as 3 seconds.

If the infants are distracted by the use of a screen or by being made to look up during the delay period, the A$\bar{B}$ error can be found at shorter delays than would otherwise be true. Again, the same pattern emerges with adult patients. While Korsakoff patients have a normal digit span memory, they tend to forget even a short string of numbers seconds after a distractor has been interposed. As soon as their attention is diverted from the to-be-recalled information their performance deteriorates rapidly (Talland, 1965). For example, patients with Korsakoff's disease show a sharp drop in retention even over intervals of a few seconds if they are required to do a simple counting task during the delay period (e.g., Samuels et al., 1971). (This method of distraction is called the Peterson and Peterson technique.)

The susceptibility of infants below 12 months, adults with frontal lobe damage, and adults with Korsakoff or ACA amnesia to interference effects can also be seen in the ubiquitous finding that they can correctly find the reward at the first hiding place, deduce the first criterion or category for sorting, and accurately recall the items on the first word list they are presented, but they are impaired at subsequent hiding places, additional categories, and subsequent word lists. Previous responses and stimulus appear to exercise an unusually strong proactive interference effect on these subjects. Hence they are correct at the outset of testing, and they perform better on subsequent trials the longer the inter-trial period and the more items on the new trial differ from those on previous trials (e.g., Winocur and Weiskrantz, 1976). Frontal lobe patients and Korsakoff and ACA amnesics show a deficit in release from proactive interference which is not seen in other amnesics. This is demonstrated by experiments which ask subjects to recall a list of, say, articles of clothing. Everyone performs well. Then another list of clothing is presented, and other. In recalling these subsequent lists, items from the first list intrude and performance becomes poor. Finally, the fifth list is not articles of clothing, but, say, kinds of animals. Here, everyone except frontal lobe, Korsakoff, and ACA patients show recall as accurate as for list 1; that is, they show a release from proactive interference (Squire, 1982;

Squire et al., 1982; Cohen, 1982).

The reader may recall that some babies seem to indicate with their eyes that they know where the toy really is in AB̄ (they stare fixedly at the correct location) even as they reach to the wrong place. (Refer back to Figure 43.) They seem to know their reach is wrong, for even without looking into the well to which they have reached, they immediately correct themselves. Frontal lobe patients tested on the Wisconsin Card Sort can often tell the examiner what the new criterion is -- they, too, know the correct answer -- but they nevertheless continue to act in accord with the old criterion. For example, it is not uncommon to hear a frontal patient say, "Shape is probably the correct solution now so this sorting by color will be wrong, and this will be wrong, and wrong again" (Milner, 1964; Nauta, 1971).

Examples of patients with frontal lobe damage being able to repeat the instructions for a task, but not being able to make themselves act in accord with them, or being able to recognize their own errors but not correct them, are plentiful. Their behavior seems somehow out of their control. Luria, in particular, has emphasized this dissociation between patients' verbal and motor behavior (Luria and Homskaya, 1964; Luria, 1966). Excerpts from two case reports should suffice to illustrate this point. The first patient is a woman with frontal lobe damage who was studied by Konow and Pribram in 1970. In the excerpt below, she has just been asked to draw the letter "O", and did so, but was then asked to draw a square.

> Asked to make a square, the patient scrawled an "O", not a square -- nevertheless she went over and over her "O" laboriously, never managing to give corners to the figure. This pattern of behavior was repeated many times and in different forms. For instance, on another occasion the letter

> "A" was written in response to almost any command. When asked to draw a square the patient began drawing an A, simultaneously exclaiming "that's not a square -- I guess I'll draw you an A" (Konow and Pribram, 1970: 490).

The second patient received a gunshot wound to the frontal lobe and was studied by Teuber:

> [He] has in many ways what people call a classical frontal lobe syndrome.... Here is one of his typical exploits: One summer he had been in a rest camp where he performed some unskilled work.... [He] was put to work in the garden where he was assigned to another man who was digging ditches; our patient had a big pair of shears with which to cut roots.... And while a ditch was opened, a huge thing appeared: four black strands lying side by side. The patient was standing there, and the subsequent episode was described by both the patient and his companion. He said, "Ha ha, it's not a root. It looks like a root (going through the motions of cutting). It looks like a root. It's not a root. Why are the fire alarms ringing?" By cutting the strands he had shorted out all the cables that led to the fire alarms all over the camp. He assures us that he did this because he couldn't help it. But he knew he shouldn't have done it. And when he makes mistakes on tests, this is precisely what he says, "I knew what I was supposed to do, but I couldn't help it." (Teuber, in discussion to paper by Konorski and Lawicka, 1964: 287-288).

Luria (1966) describes similar behavior in adults with premotor pathology, as is illustrated in Figure 57. Here the patient was to alternate drawing a square-topped figure with a triangular-topped figure. The patient succeeded in drawing the first, but had difficulty switching to the second. Although he was aware of his error, he could not correct it.

The dissociation between verbal report and action is one of the few behavioral characteristics on which frontal lobe patients differ from Korsakoff and ACA amnesic patients. While verbal report and behavior also appear to be dissociated in amnesic patients regardless of the etiology of the disease, here action that learning and recall can be demonstrated while the patient verbally denies any such knowledge. This seems to be almost the reverse of the dissociation characteristic of

FIGURE 57

DRAWING BY A PATIENT WITH A HEMATOMA
OF THE LEFT PREMOTOR REGION:
DISSOCIATION OF VERBAL AND MOTOR BEHAVIOR

"I did as instructed. I noticed that something was wrong, but couldn't alter it."

Figure to be copied is to the left, underlined.
Patient's attempt to reproduce it is shown to the right.

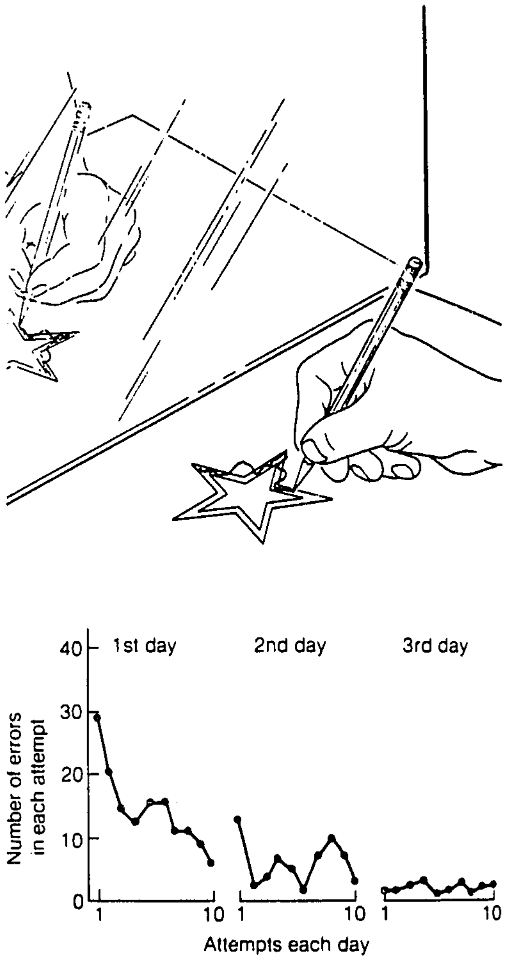
(from Luria, 1966)

frontal lobe patients. For example, HM, a much-studied patient with amnesia attributed to hippocampal damage, was trained on a mirror-drawing task over a three day period. Each day, HM claimed to be completely unaware that he had ever performed the task before, yet his performance improved each day, showing a distinct learning effect (Milner, 1962; Blakemore, 1977) (See Figure 58).

In numerous paradigms, amnesic patients have demonstrated unmistakeable evidence of conditioning, with retention over minutes and days, while at the same time verbally acknowledging no recollection of the task. Two amnesic patients tested by Weiskrantz and Warrington (1979) are representative. (One patient was post-encephalitic, the second had Korsakoff's syndrome.) They were able to acquire a conditioned eye-blink response to an aversive stimulus (air puffs), but they were unable, even when seated in front of the apparatus to remember anything about their training or to recall having received air puffs to the eye.

There is perhaps a commonality in the dissociation between action and verbal report in frontal lobe patients and amnesic patients. Despite the conscious, verbalized efforts of the frontal lobe patient, his behavior is governed by prepotent tendencies, often conditioned tendencies built up on the basis of previous reinforcement. The behavior of the amnesic patient, too, shows evidence of the establishment of conditioned responses, even though the patient is unaware of this. The ability to acquire a conditioned response, to learn a simple association, appears to be undisturbed in either population. However, the frontal lobe patient appears unable to override tendencies thus established and the amnesic patient appears unaware that such tendencies have become established.

FIGURE 58



Amnesic patient, H.M., shows clear improvement in motor tasks. In this test, his task is to trace between the two outlines of the star while viewing his hand in a mirror. The reversing effect of the mirror makes this a difficult task initially. Crossing a line constitutes an error.

(after Blakemore, 1977)

Object Retrieval

Adult patients have never been tested on Object Retrieval. However, there is evidence that vision exerts a pull on the behavior of frontal lobe patients similar to that seen in infants below 12 months of age on Object Retrieval. Recall that the pull to reach directly to where they see the toy is so strong in infants that available tactile information and previous learning experience often cannot override it. In adult patients, this power of vision can be seen, for example, when they are asked to hold out a finger when the examiner makes a fist. Upon seeing the fist, frontal lobe patients make a fist, even though they can repeat the instructions back correctly (Luria, 1973). If a patient with frontal lobe pathology is instructed to raise his hand in response to a tap of the pencil, he often echoes the visual stimulus by tapping the table instead of raising his hand (Luria, 1966). Another standard task requires the patient to hold up two fingers when the experimenter holds up one finger, and to extend a single finger in response to the experimenter's two. Frontal lobe patients cannot resist mimicing what they see and so fail this task. (This behavior is known as "echopraxis.")

This dominance of vision may be seen as a specific instance of a more general problem, that of inhibiting a prepotent tendency. The characteristic deficit in reversing or switching behavior may be seen as an instance of this as well. Many frontal lobe behaviors may be interpreted as instances of disinhibition, and many diagnostic tests take advantage of this characteristic problem of persons with frontal lobe damage. One such test requires the patient to give a long squeeze when he hears a short signal, and a short squeeze in response to a long signal. Frontal lobe patients may start out correctly, but their performance soon deteriorates as they begin to match the duration of their squeeze to the duration of the sound cue, even though they can repeat the instructions correctly (Marushevskii, 1959, cited in Luria, 1966). The problem posed by this test is that it asks patients to perform contrary to their initial tendency. Similarly, the Stroop Test challenges patients by presenting the name of a color printed in another (e.g., the word "blue" is printed in red) and requiring the patient to report the color in which the word is printed. People are accustomed to reading for meaning and ignoring the color of the ink. The Stroop Test requires that one do just the opposite -- ignore the meaning of the word and attend to the color of the ink. Frontal lobe patients cannot do this. In the example given, they would answer "blue" (Perret, 1974). Korsakoff and ACA patients perform similarly, although other amnesic patients do not (Cohen, 1982).

People, like animals, are predisposed to act, rather than not act. Frontal lobe patients, like frontally lesioned animals, fail Go-No Go Alternation because they have great difficulty not-going (Drewe, 1975). Similarly, frontal patients fail a test requiring the subject to press a bulb in response to a red signal but do nothing in response to a green signal. They fail because they press equally for both signals, even though they can at the same time make the correct verbal response (Toczek, 1960).

The grasping reflex seen in infants early in the second half of the first year, in animals with frontal lesions, and in human adults with frontal cortex damage, also indicates a lack of inhibition. In children over one year and in the mature, normal adult, the higher centers of the brain inhibit this reflex. Automatic grasping upon contact and difficulty relaxing the grasp have been reported in patients with large lesions of the frontal cortex and with more circumscribed damaged restricted to the premotor cortex (Fulton & Kennard, 1934; Kennard et al., 1934; Seyffarth & Denny-Brown, 1948; Luria, 1966; Heilman & Valenstein, 1972).

Luria (1966) also reports that patients with premotor damage have difficulty discontinuing one movement and going on to the next. Actions once begun tend to continue of their own momentum and premotor patients are impaired in inhibiting this tendency. This is reminiscent of infants reaching to the left side of the box in Object Retrieval, but instead of changing the direction of the reach once they have gotten there, they continue along the original trajectory and thus end up reaching away from the box. Perhaps some infants reach too deeply into the box for the Lego toy against the front wall because here, too, they fail to change direction. Once they have cleared the front wall they continue that motion, when what is called for is a reversal of direction back to the base of the wall.

Frontal lobe patients, like infants early in the second half of the first year, also have severe difficulty inhibiting the pull of whatever stimuli happen to be present at the moment. A 7 month old begins to uncover a well in A$\bar{B}$ and then gets interested in the cloth, forgetting what he set out to reach for. He begins reaching for the toy in Object Retrieval and gets fascinated by the tape on the box. The examiner taps on the box or squeaks the toy to regain his attention to the intended task. This works for a short time, but then he gets distracted by a spec on the table. His attention is regained for a few moments only to be lost again.

Frontal lobe patients, too, get distracted in the course of doing something. They keep losing their train of thought or action. Stimuli which would normally be ignored grab their attention. They are exceedingly vulnerable to interference from any irrelevant stimulus (Rylander, 1936; Robinson, 1946; Luria et al., 1964; Batuyev, 1969). Therefore, questions and instructions directed to patients with frontal lobe pathology must often be repeated several times. The patients start out responding but then get sidetracked so that they must be continuously reminded about what they were trying to do.

> Usually these patients begin to perform the task set, but as soon as a stranger enters the ward, or the person in the next bed whispers to the nurse, the patient ceases to perform the task and transfers his gaze to the newcomer or joins in the conversation with his neighbor. (Luria, 1973: 275)

Frontal lobe patients are also distracted by irrelevant, but firmly established, connections. Instead of remaining within a limited set of connections (like the thread of a story or an argument), they are unable to inhibit themselves from going off on an tangent. They are pulled by this free association or that, not able to sustain the goal-directed quality of behavior. This makes it extremely difficult to obtain even a simple personal history from these patients; in fact, this information is sometimes the hardest to obtain because of the web of associations it calls forth (Luria, 1966).

It should be noted that difficulty in maintaining a train of thought or in sustaining concentration, like difficulty in switching behaviors or in resisting the effects of interference, is not, by itself, sufficient to make a diagnosis of frontal lobe pathology. These problems are found after severe damage to diverse neural areas. However, they appear with unusual consistency following even minor lesions to the frontal cortex and, when patients are equated for IQ and other measures of general cognitive functioning, frontal lobe patients evince the particular problems discussed here in more severe form than do patients with damage anywhere else in the brain.

Errors in Object Retrieval may be attributed, in part, to problems with inhibition. They may also be conceived of as due to problems in relating things to one another. For example, infants appear to have difficulty relating line of sight to line of reach. Early in the first year they rarely look one place and reach another. When they do begin to do this, it is by first looking along the line of reach, and then sitting up and reaching. Infants also have difficulty doing one action with one hand and something different with the other hand, e.g. raising the box with one hand and reaching in with the other. Again, actions which a child of one year can perform simultaneously are first solved by making them successive. First, the box is raised, the child looks in, then with the box comes down and the reach is executed. Infants also find it difficult to relate individual actions to form the proper temporal sequence. They can perform each sub-part accurately, but the sequence goes awry. When they must attend to more than one stimulus simultaneously or coordinate multiple actions they run into difficulty. The youngest children often handle this by simply attending to one thing. For example, the toy so captures their attention that they appear to ignore the box altogether. As they get to be about 8-10 months, they begin to show advances here, but the earliest solutions often involve doing two things successively rather than simultaneously. Finally, in the last quarter of the first year, one sees more and more instances of infants simultaneously coordinating vision and touch and simultaneously coordinating the efforts of their two hands.

Again, problems similar to those seen in infants below one year can be seen in frontal lobe patients. They, too, have unusually severe problems in doing two things at the same time and in attending to more than one thing at once.

> [Deficits may be observed in premotor patients on tasks requiring complex movements.] Such movements include, for example, a complex action in which the hand is thrust forward while, at the same time, the fist is clenched and then the fingers are made into a "ring". As he carries out one component of this complex movement (for example, thrusting the hand forward), the patient cannot concurrently place his hand in the required position, and he has to perform the two components in succession....When a patient with a lesion of the premotor division is asked, for example, to change the positions of both hands at the same time and with both positions different (e.g., to make a fist with one and to extend the other with the palm up), he will have real trouble with the task....As a rule, smooth and simultaneous positioning of both hands proves impossible for such patients. They either perform the elements of the combined movement in succession or omit one hand from the combined movements. The disturbance of smooth sequence in motor acts leads to a disintegration of complex skilled movements, the principal symptom of a lesion of the premotor divisions of the cortex. (Luria, 1966: 197)

Tasks which require the simultaneous use of several facts prove particularly difficult for frontal lobe patients. They are unable to solve math problems such as: A son is 5 years old. In 15 years his father will be twice as old as he. How old is his father now? The following series of replies recorded by Barbizet (1970: 84-85) provides a representative illustration of the performance of frontal lobe patients.

> Q. What is the length of one quarter of the Eiffel Tower?
> A. After long hesitation, he said that he did not know.
> Q. What is the height of the Eiffel Tower?
> A. 300 meters.

Q. What is half of 300?
A. 150.
Q. What is half of 150?
A. 75.
Q. What is the length of one quarter of the Eiffel Tower, which measures 300 meters?
A. (After long cogitation)...200 meters (and despite many attempts he failed each time).

Korsakoff and ACA amnesics display similar problems. For example, on dichotic listening tasks they are unable to attend to both stimuli simultaneously, although other amnesic patients perform well here (Cohen, 1982).

Just as infants, particularly those below 8 months, often attend to but one piece of information, one stimulus, so do frontal lobe patients, especially those patients whose lesions are large. Instead of carefully observing a picture and correlating the informative details, patients with severe frontal lobe pathology often fixate on one detail and make no attempt to correlate the details of the scene (Luria, 1966). Similarly, when shown a series of pictures depicting the scene in a story, severe frontal lobe patients can describe individual pictures or details, but they cannot find the story line running through the pictures (Nichols and Hunt, 1940). It is common for a frontal lobe patient to mistake one doctor for another because they both wear glasses, and glasses were the single stimulus to which the patient attended (Barbizet, 1970).

Frontal lobe patients, and infants in the second half of the first year, can handle one thing at a time but they have difficulty relating these individual facts or motor schemes to one another. They fail to perceive a connection or they recall it incorrectly, as when they try to repeat a motor sequence but get the temporal order wrong. Perhaps the finding that frontal lobe patients have normal recognition memory, but are deficient in recalling the order in which things have happened stems also from a problem in relating things to one another. A recency judgment requires relating two or more items to one another. If patients are shown a series of pictures or words, adults with frontal lobectomies can accurately identify which of two items they have seen before (patients with lesions to the temporal lobe cannot), but they cannot identify which of two items they have seen most recently (Milner, 1974). Korsakoff and ACA amnesic patients, too, are disproportionately impaired in recalling temporal order; other amnesic populations do not show this selective deficit (Cohen, 1982).

Certainly, over a variety of behaviors, the deficits seen in infants below 12 months of age resemble those seen in adults with lesions to the frontal lobe or closely related structures. In the previous two chapters, these behaviors have also been shown to be characteristic of animals with damage to the frontal lobe.

Many neuroscientists have offered hypotheses about what role the frontal lobe plays in cognition, what functions it subserves. Similarly, many developmental psychologists have offered hypotheses about which abilities are emerging between 6-12 months, what the common functional capacity is that underlies the diverse behavioral changes seen during this time period. To this writer, the abilities dependent upon the frontal lobe and the abilities on which infants make major strides during the latter part of the first year are two: a) the ability to relate one thing to another in time or in space and b) inhibition, the ability to resist, stop, or switch.

The ability to form simple conditioned stimulus-response associative links is not dependent upon the frontal cortex, and indeed may not be dependent upon cortex at all. Aplysia show sensitization and can learn to acquire an avoidance response in a conditioning paradigm where a neutral stimulus is paired with a painful one -- and aplysia have no cortex (Kandel, 1981). Associative learning has also been demonstrated in infants who have virtually no cortex (Brackbill, 1971; Berntson et al., 1982).[56] Imagine for a moment that on each $A\bar{B}$ trial (except for the first), the infant did *not* see where the toy was hidden. The only information he had to go on was his past history of reinforcements. Given the laws of conditioning, one would predict that the infant would act in this scenario exactly as infants act under standard $A\bar{B}$ testing: one or two trials to establish a habit, many more trials to extinguish a habit, etc. That is, I am suggesting that the frontal lobe may serve to inhibit, or damp or suppress, the conditioned tendency built up over past trials. This enables the child to act on the basis of information in recent memory. However, this inhibitory control is weak in the young infant, and when memory is taxed, the conditioned tendency controls behavior. The task is particularly hard because not only must the infant override his tendency to return where he was previously successful, but he must also inhibit the pull of distracting stimuli during the delay. Memory appears to be fragile and so do plans of action. It is hard for infants and for frontal lobe patients to hold things in their head without visual support. Intentional behavior begins to emerge during the first year, but during this early period it is often disrupted by automatic, instinctive reactions.

Others before me have suggested the role of frontal cortex in spatial and temporal integration or in inhibition, and others have suggested that it is these abilities which are maturing during the latter half of the first year of life. In concluding this chapter I would like to quote what some have said:

a) the role of the frontal lobe

> Immediate consequences usually produce immediate reaction, especially if they are habitual, but it is the reaction to the projection of the consequence in space and time that appears at fault. (Denny-Brown, 1951: 79)

> For monkeys with frontal brain lesions, the ability to learn is apparently impaired in those contexts in which contiguity relations, either temporal or spatial, are less than optimal. (French, 1962: 729)

> First, it should be noticed that the ability to form strong behavioural stereotypes from several motor acts which follow each other always in the same succession is, of course, not restricted to prefrontal animals, but, on the contrary, is most characteristic of normal animals on all phylogenetic levels, man included. In fact, such stereotypes form a basis of all automatized reactions, constituting the major part of the whole of animal behaviour. Therefore, one should not ask, why in prefrontal animals, these stereotyped motor acts are so readily established, as we have seen in our experiments, but rather, why they fail to be suppressed according to the demands of external situation, as is the case in normal animals. One of the possible explanations of this disorder is the lack, or rather the weakening, of a special inhibitory mechanism. In other words we suppose that in a given conflicting situation, when the individual has to suppress a definite stereotyped reaction under the influence of some, rather weak stimuli requiring a different reaction, a prefrontal animal is unable to do so not because the stereotype is too strong, but because the inhibitory influence is too weak. (Lawicka and Konorski, 1961: 130-131)

b) the abilities maturing between 6-12 months

> [A] new cognitive competence emerges during the last third of the first year....A competence we have called "activation of relational structures." The 9- to 12-month-old

> child is capable of actively generating representations of previously experienced absent events -- as well as potential future ones -- and comparing these representations with the perceptions generated by the situation he is in at the moment. (Kagan, 1976: 187-188)

> To respond is clearly easier than not to respond, and although the capacity for the latter may first manifest itself at various ages depending on particular conditions, it does seem that a major transition point in the development of this capacity is to be found in the third quarter of the first year. (p.16)
>
> Behavior in the early months of life has frequently been characterized as "stimulus-bound," denoting a tendency to be absorbed in one particular feature of the environment without regard to any other feature. This gives early behavior its rather rigid character, for the young infant lives in the here-and-now without concern for any event separated in time and space from that which happens to preoccupy him at the moment....The ability to connect various events is thus as yet absent. It is only later that the infant can break out of these confines and begin to consider different events simultaneously and jointly instead of sequentially and separately, thereby bringing about a marked increase in the temporal integration of his behavior. (p. 18) Initially each stimulus is treated in isolation; and although the memory store may be checked for representations of that same stimulus, it is not compared with different stimuli or their different representations. In time, however, the infant becomes capable of relating stimuli to one another....As a result, the strange stimulus can be considered simultaneously with the familiar standard, even though the latter is centrally stored and must therefore be retrieved. (p. 22) (Schaffer, 1974)

POSTNATAL MATURATION OF THE FRONTAL LOBE

The human nervous system is not fully mature at birth, and the frontal cortex is one of the clearest examples of a structure which matures postnatally (Schade and van Groenigen, 1961; Yakovlev and Lecours, 1967; Dekaban, 1970; Johnson et al., 1976; Brown and Goldman, 1977; Alexander and Goldman, 1978; Goldman-Rakic, 1981).

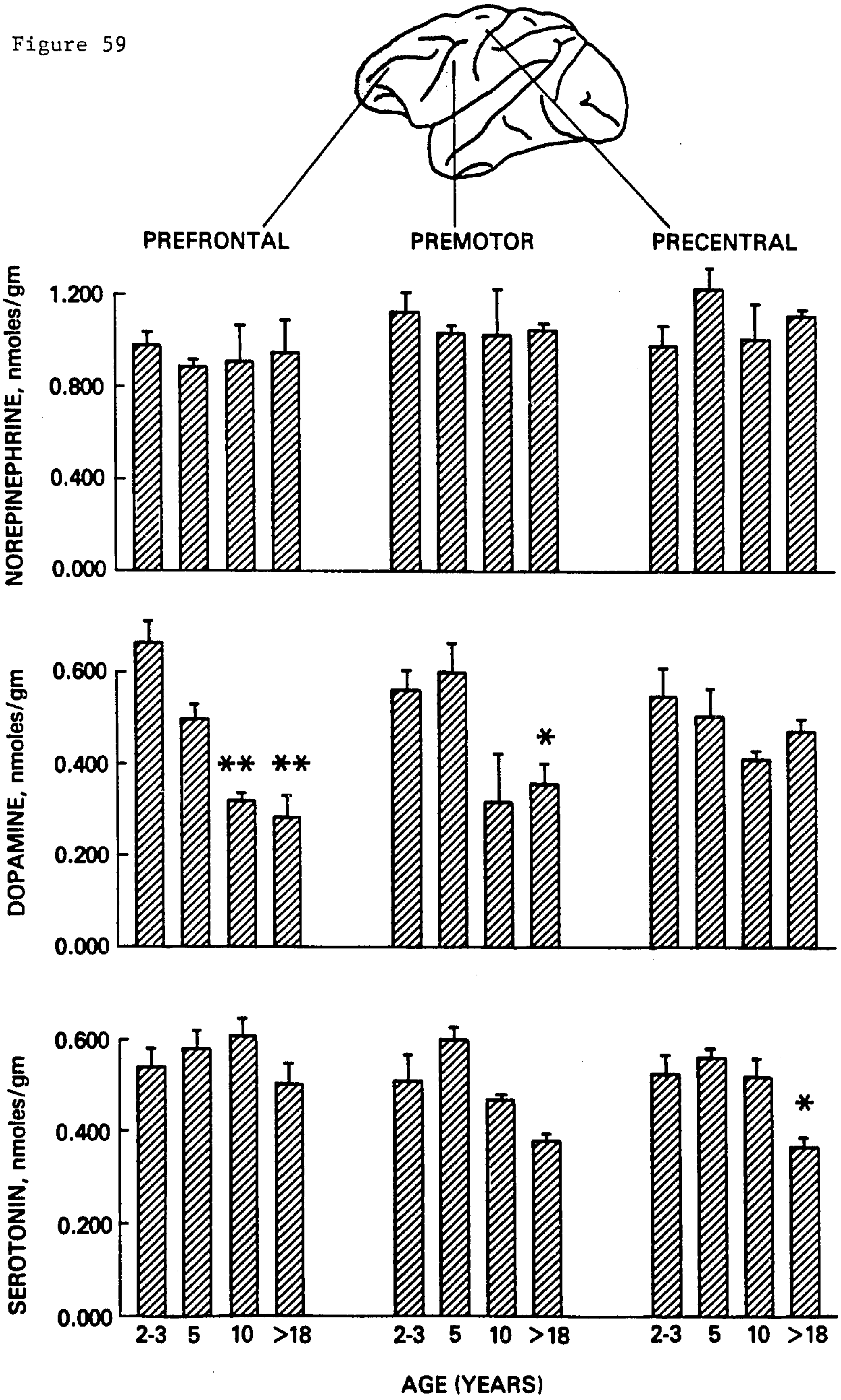
Although all neurons in the frontal cortex are generated before birth (Rakic, 1979), they remain immature for some time. The immaturity of the frontal cortex early in life, like that of many other regions of the brain, has been shown by diverse indicators. For example, most of the layers of frontal cortex are narrower in the infant than in the adult and the subregions are cytoarchitectonically less distinct (Larroche, 1966). After neurogenesis, the cells require contact with afferents and efferents to reach full functional maturity. The system of afferents to the frontal cortex is relatively sparse at birth. Prenatal ablation of the prefrontal cortex does not produce degeneration of neurons in the mediodorsal nucleus of the thalamus in the monkey or the rat, suggesting that connections between the thalamus and the prefrontal cortex have not yet fully developed (Goldman and Galkin, 1978; Kolb and Nonneman, 1978). Note that in the adult, anterograde and retrograde degeneration of the mediodorsal nucleus is the defining characteristic of a prefrontal lesion. In the newborn human, synaptic density in the frontal lobe is low, as is the number of synapses per neuron (Huttenlocher, 1979). Dendrites (that portion of the neuron specialized for receiving input and conveying this information to the cell body) develop as they interact with afferent projections (Pinto Lord and Caviness, 1979; Berry, 1982). In the mature brain, the dendritic arbor often contains an intricate network of branches. In the frontal cortex of human infants, where the system of connections has barely begun to be elaborated, the dendrites of pyramidal neurons in layers 2, 3, and 5 are rudimentary and lack extensive branching (Schade and van Groenigen, 1961). Efferent projections from the frontal cortex also evidence considerable immaturity in the newborn. Ablation of the prefrontal cortex produces little degeneration of prefrontal fibers to the caudate nucleus in 2 month old monkeys, although in mature monkeys such as lesion produces considerable degeneration in these fibers (Johnson et al., 1976). Similarly, available staining methods have not been able to detect evidence of myelin sheaths (which enhance the efficiency by which a message can be conveyed) around the axons of frontal cortical neurons in human infants during the early months of life (Yakovlev and Lecours, 1967). Indeed, the frontal lobe is probably not fully mature until puberty (Turner, 1948; Rabinowicz, 1974), although the orbital region develops earlier than does the dorsolateral region (Goldman et al., 1970; Goldman et al., 1971; Miller et al., 1973; Goldman, 1976; Goldman, 1974; Brown and Goldman, 1977). Note that immaturity of the frontal cortex at birth is a minimum condition for the hypothesis under study here. For if it were fully mature in the neonate, one could not relate behavioral changes after birth to frontal cortex maturation.

In addition to the dendrites and axons which establish the structural framework for communication among nerve cells, the chemical neurotransmitters which carry the messages must also be present and capable of performing their functions. Among the 30 putative transmitters which have been identified in the central nervous system, the most heavily studied have been the monoamines. Examples of monoamines are dopamine and norepinephrine (which are catecholamines) and serotonin (an indoleamine). The frontal lobe is particularly rich in dopamine. In the brain of young adult rhesus monkeys (aged 2-3 years), the concentration of dopamine is highest in the prefrontal cortex, declining in a roughly linear fashion along the anterior-posterior axis (Brown et al., 1979; Goldman-Rakic and Brown, 1981). Thus, dopamine concentrations decrease as one moves from premotor to precentral, to postcentral, to parietal cortex, reaching the lowest level in the visual cortex. Norepinephrine exhibits a similar frontal-occipital distribution gradient, but its pattern is somewhat more irregular (Goldman-Rakic et al., 1982). Serotonin shows no evidence of being selectively concentrated in the frontal lobe.

Dopamine levels in the frontal lobe appear to be related to frontal function. In an important set of experiments, Brozoski et al. (1979) trained monkeys on Delayed Alternation (a task linked to the prefrontal cortex) and on Visual Discrimination (a task on which monkeys with prefrontal ablations perform well). After behavioral baselines were established, the monkeys were administered DMI (which protects norepinephrine terminals) and then their prefrontal cortex was injected with a neurotoxin which selectively and permanently destroys axon terminals of catecholamine neurons. (DMI insured that the major result of this would be a selective reduction of dopamine, but not norepinephrine, content.) When retested, the dopamine-depleted monkeys showed a profound deficit on Delayed Alternation, a deficit nearly as severe as that seen after surgical ablation of prefrontal cortex. The monkeys were not globally impaired, and indeed continued to perform at pretreatment levels on the Visual Discrimination task. Subjects in whom norepinephrine or serotonin was depleted showed little change in Delayed Alternation performance. Moreover, when the dopamine-depleted animals received injections of dopamine agonists such as L-Dopa (which increase levels of dopamine in the brain), their performance on Delayed Alternation returned to pre-deficit levels. Drugs which do not act on the dopaminergic system did not produce significant behavioral recovery.

A second source of evidence that level of dopamine is related to functions subserved by the frontal lobe comes from work with aged monkeys (monkeys roughly 20 years of age or older). Several investigators have shown that their behavioral profile is remarkably similar to that found in young adult monkeys following prefrontal ablations (Bartus et al., 1978; Bartus and Dean, 1979). The level of dopamine in the prefrontal and premotor cortex of aged monkeys is significantly lower than is true for monkeys in their prime (Goldman-Rakic and Brown, 1981). (See Figure 59.) This decrease is much larger than is true for the dopamine concentration in other cortical areas. No comparable decline in the level of norepinephrine or serotonin in the frontal cortex occurs over the same age range. Additional evidence for prefrontal dopamine deficiency in old age comes from the observation that Parkinson's disease in human adults is frequently accompanied by cognitive deficits suggestive of frontal lobe disorder (Lieberman et al., 1978; Loranger et al., 1978) and L-Dopa therapy is reported to improve memory (which is thought to be a frontal lobe function) in these patients as well as in patients suffering from other forms of dementia (Arbit et al., 1970;

Figure 59



(from Goldman-Rakic et al., 1983)

Gottfries, 1978).

Thus, there is some evidence that high dopamine levels are necessary for proper prefrontal functioning. In the brain of the infant, the level of dopamine is low. The dopamine concentration in the brain of the rhesus monkey reaches adult levels at around 5 months of age, increasing significantly over what it had been just a few months earlier (Goldman-Rakic and Brown, 1981). It is at 5-8 months that monkeys begin to succeed at Delayed Response (Harlow, 1959; Harlow et al., 1960; Harlow et al., 1968). Moreover, in addition to measuring endogenous monoamine levels, Goldman-Rakic and Brown (1981) also studied the rate at which monoamines are synthesized by their cells of origin in the brainstem. They found that in prefrontal cortex, catecholamine synthesis increased steadily from birth to 3 years; in premotor cortex, adult levels were reached by 8 months.

Most experts agree that the character of behavior changes in human infants during the second half of the first year reflects fundamental biological changes. The behavior changes are simply too abrupt and found too universally to be based on experience alone (Emde et al., 1976; Kagan, 1976; Fox et al., 1979).

Indeed, electrophysiological evidence indicates that 6 to 12 months is a time of major neural development in the human infant. The basic resting electrical activity of the brain at birth is characterized by irregular oscillations of very low frequency (2-5 cycles per second). By 12 months, the dominant frequency is within the 5-6 cps range (Dekaban, 1970). Emde and Walker (1976) report that the amount of children's quiet sleep increases between 8 and 11 months of age. Gibbs and Gibbs (1950) report that spontaneous K-complexes first appear during the second half of the first year. K-complexes are a well-defined component of the adult EEG, characteristic of quiet-nonREM sleep. This increment in quiet sleep, along with changes in electrophysiology and organizational characteristics of sleep patterns indicates CNS maturation during this period (Anders and Weinstein, 1972).

Little is known about the maturation of the frontal cortex during the first year, and we know of no evidence of a sudden or particularly pronounced developmental event in the frontal cortex between 6-12 months. However, even the little we do know indicates that the frontal cortex undergoes profound changes from 1-12 months. Neurons, at least in layer 3 of the middle frontal gyrus, have probably acquired their full complement of synapses by the end of the first year (Huttenlocher, 1979). The mean number of synapses per neuron in this region increases rapidly from roughly 10,000 at birth to roughly 100,000 by one year of age; increase thereafter is much slower (Huttenlocher, 1979). Similarly, the density of neurons here declines markedly during the first year. As Figure 60 shows, after one year the decrease proceeds more gradually (Schade and van Groenigen, 1961; Huttenlocher, 1979). (The neonatal human brain appears to have more neurons in regions such as the frontal cortex than does the adult brain. Thus, neuronal loss is an aspect of maturation. For example, the average number of neurons per cu.mm in layer 3 of the middle frontal gyrus in the neonate is about 10^5, while in the adult it is only slightly over 10^4). The frontal cortex has a rich system of interconnections with other neural regions. These regions, and their connections with the frontal cortex, are also maturing during this time. It may well be that a maturation within this system, rather than within the frontal cortex itself, is associated with

FIGURE 60

NEURONAL DENSITY IN LAYER 3 OF MIDDLE FRONTAL GYRUS

AS A FUNCTION OF AGE

Open circles = data derived from study by Huttenlocher, 1979
Closed circles = data obtained by Schade and van Groenigen, 1961
Confidence limits = ± 1 S.D.

(from Huttenlocher, 1979)

the cognitive changes under study.

A final body of evidence bearing on the possibility that changes in behavior during the second half of the first year are related to a frontal cortex maturation comes from work with monkeys. Rhesus monkeys become able to succeed at Delayed Response between 5-8 months of age (Harlow, 1959; Harlow et al., 1960; Harlow et al., 1968). Given the more rapid rate of maturation in monkeys, the age at which Delayed Response ability first appears in the monkey is roughly comparable to the age at which human infants are first able to succeed on AB̄ (9-12 months). Moreover, research with rhesus monkeys has linked frontal cortex maturation with the emergence of successful Delayed Response performance (e.g., Alexander and Goldman, 1978).

Thus, the frontal cortex undergoes much of its development after birth, global developmental changes in the CNS appear to be occurring during the second half of the first year, the frontal cortex in particular changes more dramatically in some ways during the first year than at any other time during postnatal life, and on the best behavioral test we have of frontal lobe function (Delayed Response) rhesus monkeys first start to succeed at an age, which roughly translated into human terms, would make them about one year old.

> When Supreme Court Justice Potter Stewart left the bench last July, he moved down the hall to the sunny, wood-paneled offices that the late William O. Douglas had used in retirement. "We're all creatures of habit," he says, "and I generally take the wrong turn when I get off the elevator in the morning."
>
> "Ex-Justice Stewart Reads for the Blind,"
> Newsweek, Nov. 16, 1891, XCVIII (48), p.20

CAVEAT

While performance deficits on certain tasks are characteristic of infants and of adults and animals with frontal lobe damage, if the tasks are made sufficiently easy deficits are not seen in these populations and if the tasks are made sufficiently difficult these deficits are seen in normal adults with intact frontal lobes. That is, reality presents more of a continuum, than much of the discussion thus far might suggest. Deficits are a matter of degree rather than of presence or absence.

Deficits are not Total

a) If the delay in the A$\bar{B}$ task is reduced, infants will succeed. For example, a 9 month old who fails with a delay of 5 seconds will succeed with a delay of 2 seconds.

b) Frontal lobe patients have been shown to be unable to select each of 12 pictures without repeating any particular choice (Petrides, cited in Milner, 1982). However, they succeed easily at the same task if only 6 pictures are used. Moreover, in order to produce the deficit even with 12 pictures the position of the pictures must be re-scrambled after each choice the patient has made. If the pictures remain in the same position throughout, frontal lobe patients can succeed at the task (Petrides, cited in Milner, 1982).

c) If frontal lobe, Korsakoff, or ACA patients are warned before testing on the Wisconsin Card Sort that at some point the examiner will switch to a new criterion, their performance is as good as normals. This is very typical; if these patients are told what to expect they often perform well.

d) If the motivation of infants is increased by using food rather than a toy as bait, then the infants can perform well at much longer delays than one would otherwise expect.

If frontally lesioned monkeys are starved, their behavior on Delayed Response, improves considerably (Pribram, 1954).

The deficits of frontal lobe patients, too, can be substantially or totally reversed if they are properly motivated:

> The development of the sign of outspokenness also appears to be due to a difficulty in maintaining the state of inhibition against the hostile or improper word that before lobotomy would not be spoken, but which after lobotomy is expressed. Here, too, however, if the situation is extremely important to the patient, he may continue, at least temporarily, to sustain the inhibition and not speak the word. To repeat, he has not "lost his inhibitions"; rather, he has experienced a reduction in his ability to sustain the inhibitions. (Arnot, 1952: 490)

e) If infants or frontally lesioned animals or adults are given a visual cue, such as a landmark, or are not distracted during the delay period so they are able to cue themselves behaviorally or verbally, then they perform admirably on $A\bar{B}$ and similar tasks.

In short, the problems of infants and frontally lesioned populations are, to some extent, a matter of degree. Many tasks diagnostic of frontal lobe damage, if made only slightly easier, present no challenge to frontal lobe patients. These same tasks, if made slightly harder, often confound even normal adults.

Normal Adults Can Be Shown To Display These Deficits

a) The $A\bar{B}$ error does not disappear at one year; a longer delay is simply needed to reinstate. Hunter, who first devised the Delayed Response experiment, showed that 15-16 month olds fail at delays of 15-20 seconds (Hunter, 1917). Similarly Weisberg (1970) found that infants of 16-20 months erred with a 16 second delay. Normal adult monkeys will fail Delayed Response if delays over 2 minutes are imposed (Jacobsen, 1936). In this context, the $A\bar{B}$ error of infants younger than a year is only a matter of degree; they simply need a shorter delay than do older children and adults before errors appear.

b) Infants of 7-8 months sometimes get distracted in the course of reaching in $A\bar{B}$ and forget what they were starting to do. But certainly all adults have had moments when they have entered a room or started to go for something and then forgot why they were doing that.

Similarly, unwanted but deeply engrained habits or associations have been known to intrude on the behavior of normal, healthy adults. An adult may start out with his intention clearly in mind but if he does not pay attention at a crucial choice point once the behavior has begun he may take the well-trodden path instead of the intended one. Judge Potter Stewart's behavior described in the passage at the beginning of this chapter is not unlike that of the infant committing the $A\bar{B}$ error. Drivers, too, should recognize the all too common error of taking the habitual route when a variation from it was intended. A close friend of mine, whose phone number for many years was 498-abcd, moved and his phone number became 498-mnop. Even a year after his move I found myself occasionally dialing the old number, even though when I picked up the phone I had the new number clearly in mind.

d) Frontal lobe patients have difficulty holding up 1 finger in response to seeing 2, but normal adults find this difficult as well, the more difficult the faster one response is to follow another. Normal adults also have difficulty doing two things at the same time; hence the comic effect of watching someone try to rub his belly and pat his head at the same time.

e) Koslowski and Bruner (1972) demonstrated that infants in the second year of life show an inability to resist reaching on a start line of sight for a toy instead of using the required indirect approach. This was demonstrated with a "lazy susan" lever which could rotate 360 degrees. The toy was placed 180 degrees from the infant. Children early in the second year insisted on trying to reach straight for the toy although it was out of reach, instead of rotating the lever. They ignored the lever and fixated on the toy, or they tried to use the lever to pull the toy straight back toward them. It was not until late in the second year that they mastered this task.

Rock (1967) has demonstrated vision to be dominant over touch even in normal adults. He had his adult subjects each hold a square. A cloth was placed over the arm and hand. A hole in the cloth was just large enough for only the square to be visible. Rock also had his subjects don lens which magnified everything by a factor of two. Thus, each subject saw the square through the distorting lens while he was holding the square in his own hand. Next, subjects were instructed to look away, cover their eyes, and then with the hand which had held the square feel a series of squares and decide which square was the same size as the one they had just held. The subjects, normal adults, chose the square which was twice as large as the one they had held. (If subjects are warned beforehand that their lens are magnifying lens, then this error in judgment is not found.)

In short, given an easier task or increased motivation, abilities usually not seen until almost one year can be seen months earlier, and given a more complicated task, fatigue, or diminished motivation, even normal adults will appear to lack these abilities. While the competences we have discussed may be wholly absent before 7 months or so, once they first appear they are never again all or none.

FOOTNOTES

1. The reason for three wells was to allow us to discriminate between reaches to the same relative position from reaches to the same absolute place. For example, if the two wells used on a given trial were left and center, and the baby reached to the center well, if the right and center wells are now used will the baby reach to the relative right again (now the right well) or to the same physical place (the center well)? One of our hypotheses was that babies reach to the same relative position.

At first we tested all of the youngest infants, that is, all of the infants who had not been able to find a totally hidden object on their last visit, using a two-hole apparatus. Our reasons for doing so were three-fold: 1) the wells were shallower here and it was easier for the infant to be able to see the toy in a well; 2) this apparatus was all black and thus provided fewer distractions; and 3) the warm-up trials at a center hiding place could be performed between the two wells, while during the $A\bar{B}$ trials only the right and left wells would be used (in contrast, on the three-hole apparatus, warm-up trials would use the center well alone which would then also be used during actual $A\bar{B}$ trials as well).

The two-well apparatus was a modification of the Wisconsin General Testing Apparatus (WGTA) designed by Szpak (1977). It consisted of a non-movable tray (44-1/2 x 14-1/2 inches). Two wells (7 x 7 x 1-1/2 inches) were symmetrically located on the tray. The wells were 12 inches apart. The entire apparatus was black in color and rested on a table (36 x 24 x 30 inches).

After a time, we ceased using this apparatus, even for the youngest children, and tested everyone on the three-hole apparatus. Our reasons for abandoning the two-hole version were: 1) it was often difficult to put the smallest children in some position where they could reach both wells--the three-well apparatus had a lower tabletop and smaller table surface, thus eliminating this problem; 2) we did not want differences between younger and older infants to be attributable to differences in the apparatus used with the two groups; and 3) our concerns about the three-well apparatus for use with the youngest children did not turn out to be major (for example, by using all but the smallest toys, the infant could always see the toy in an uncovered well).

As some of our infants who could not yet find a totally hidden object, or who made the $A\bar{B}$ error with a zero-second delay, were tested on the two-well apparatus and others on the three-well, we have been able to compare the results obtained with the two pieces of apparatus. We have never detected any effect of apparatus, and so in the results discussed here we include together the results obtained with both pieces of apparatus.

2. A$\bar{B}$ testing began for these children with three warm-up trials. Using a toy that would not later be used in the actual A$\bar{B}$ Experiment, and using only one hiding place, the children were first asked to find a toy that was only partly covered. On the next two trials, the toy was totally covered. If the infant could find the totally hidden toy, then he was tested in the A$\bar{B}$ experiment proper.

2. Cloths are intrinsically interesting to 5-7 month old infants. This makes it something of a problem to determine if the baby is reaching for the toy under the cover or for the cover itself. With the babies we followed longitudinally, we were able to find no satisfactory alternative. Any cover we tried seemed to have intrinsic interest for many of the children. However, with the infants in the cross-sectional control sample, we hit upon the idea of covering the wells with our hands. A hand, bare of jewelry, did not attract the interest that cloths did, and with the three-well apparatus a hand was able to fully occlude a well. In general, results were far more clearcut when we covered the wells with our hands. The ambiguity that so troubled us with cloths was thereby largely eliminated.

3. In addition to these precautions, the infants' side and hand preferences were independently assessed. On the infant's first visit to our laboratory, the last visit, and at least one visit in between and usually two, the infant was presented with five different pairs of identical objects. On each of these five trials, the two objects were presented simultaneously and placed equidistant from the baby, one directly in front of the left hand and one directly in front of the right hand. As the objects were identical and were equally accessible to the baby, the only determinant of reaching here should be preference for using one hand over the other or for reaching to one side rather than the other.

4. The four people who did the coding here are: Lou Anne Aber, John Kinyon, Peri Ozkum, and Adele Diamond.

5. Copies of the coding forms for the A$\bar{B}$ experiment and the accompanying instructions appear in the Appendix.

6. Finding the toy at A, the first hiding place, was so easy for Harris' infants that they were correct whether A was covered last or B was covered last.

7. In order to distinguish simply erring on trials to B from consistent reaching to A on these trials, we would have liked, in the present study, to have presented the baby with more than two choices. That is, we would have liked to have covered all three wells on each trial. However, because of the argument just presented we felt strongly that all wells should be covered simultaneously. We were not able, within our budget and level of ingenuity, to devise a way to do this. Each solution we tried presented its own problems. Our most nearly successful attempt here was during pretesting, to connect three cloths to a wooden frame, which when moved into place was thereby able to cover all three wells at the same time; but we found that too often it was unclear which well the baby was reaching for when this frame was used.

8. In order to investigate the Piagetian assumption that actually reaching and finding the toy is the crucial variable, and out of the pragmatic concern that infants might not put up with non-reward for too long, we allowed the infants to reach to the correct well, retrieve the toy, and play with it on a small minority of the trials, even though on that trial the infant's first reach had been incorrect. Each infant received ten such trials, no more than a total of two in any given session. The trials where incorrect reaches were followed by reinforcement were a very small fraction of the total number of trials given any infant; but across all children this provided us with 250 trials with which to work.) We found absolutely no effect of reinforcement on subsequent performance. Specifically, if an infant has just erred, received <u>no</u> reward, and that trial is repeated, the infant erred on 66% of the repeat trials. If an infant has just erred, but was allowed to play with the toy nevertheless, and then the trial was repeated, the infant still erred on 66% of the repeat trials. Thus, this procedural difference between the present study and other studies is probably unimportant. When an infant is permitted to play with a toy after an error, he does not perform differently from times when he is allowed no play following an error.

9. We will be using the term "repeat trial" throughout. It is important that its meaning be clear to the reader. A repeat trial is a trial which duplicates the previous trial in all experimental procedures. Specifically: a) the toy is hidden in the same well as on the previous trial; b) the same two wells are used (which is to say, the same two wells are covered); c) the same delay length is used; d) identical covers are used on both trials (on neither trial were different covers used); and

e) neither reach was coded as "accidental" or "clearly not for toy." (Coders were trained to be very conservative in their judgments of accidental or clearly not for toy. These ratings were used rarely and highly reliably by the coders. They were reserved for instances such as, "Infant stares at himself in mirror; while so doing, his hand touches apparatus, brushing aside one of the covers; infant continues looking at himself in mirror," or "Infant reaches to a well and removes cover; he continues to look at and play with cover; he does not search in well," or, finally, "Infant turns his back on apparatus and tries to get up; in so doing he brushes aside a cloth uncovering a well; he then notices toy in well and retrieves it to play with." When a reach was rated as accidental or clearly not for toy, that trial was eliminated from analysis.)

Within a single session, the number of repeat trials following a correct reach was small, varying from three trials up to six. Therefore, our requirement that an infant err on not more than one of these trials is less stringent than it might first appear.

10. The range of repeat trials following correct reaches administered to any one subject over all sessions varied from 12 to 26. Perhaps, one might wonder, our overall success rate is inflated because those subjects who received more repeat trials performed more accurately? That this is not the case can be seen by taking the average of the average percent correct for each child. (This weights all children equally; each contributes only his median percent correct.) The average of each average percent correct is 80%.

11. The number of reversal trials given a child over all of his testing sessions ranged from 14 to 21. Could those children who received more reversal trials somehow be biasing our results? No. When the median percent correct for each individual child is averaged across children, and thus each child is counted equally, the rate of correct performance on reversal trials is still 34%.

There is no sex difference here either. Males are correct 35% of the time on reversal trials. (The average of their median percents is also 35%.) Females are correct 34% of the time on reversal trials. (The average of their median percents is 34% as well.)

12. The t-test for correlated data was used, since in comparing the percents in Tables 5 and 8 each subject was matched with himself. The distribution of the differences of each pair of proportions in Tables 5 and 8 is normal and few proportions are greater than 90 or less than 10; therefore no transformation of the numbers, such as that using arcsin, was judged necessary.

13. Using the McNemar x^2 test, Butterworth found the change in accuracy in condition one to be significant at less than .001 (x^2 = 22.04), in condition two at less than .001 (x^2 = 18.05), and in condition three at less than .01 (x^2 = 9.09).

14. We started with a delay which we thought might be too easy for the infant because we have found it better to underestimate an infant's ability than to overestimate it. Infants who are given too difficult a task too early often give up or "tire out," and we are often not able to bring their performance back up even with very brief delays.

15. The test for matched samples was used because comparison is within subject. Data were not transformed because the distribution of the differences is roughly normal and few percents are greater than go or less than 10.

16. See footnote 17.

17. There were not enough trials, even over the many months during which we followed the babies, to test all hypotheses on all children. In order to test questions 3, 4, and 5 here we divided the 25 infants into three groups, testing only some of them on any given question. This is why results for only 9 infants are reported in answer to question 3.

18. An alternative interpretation of this observed difference between longitudinal and cross-sectional subjects has been suggested by Linda Acredolo (personal communication). In her own work, infants tested in the laboratory performed much more poorly than infants tested in their own homes (Acredolo, 1979). In a second study, she repeated the same laboratory procedure for half the subjects and replicated her earlier finding. The other half of her subjects were given a long play period in the lab before testing began. Their performance on the experimental trials was dramatically better than that of the first group. Indeed, it was on par with that previously observed in the homes (Acredolo, 1981). Acredolo argues that infants tested at home or after having much time to get used to new surroundings feel more secure and at ease. As the experimental space was free of landmarks, Acredolo attributes better performance after the play period to increased "emotional security," which might have allowed the infants to attend more carefully to the task at hand.

Generalizing from this, Acredolo has suggested that since the infants we tested longitudinally were more familiar with our laboratory and with us, perhaps they felt more secure during the experiment, and perhaps this enabled them to better attend to the relevant stimulus information. That is, perhaps the infants tested only once in the present study were too anxious, or too distracted by the novel surroundings, to give their full attention to our task.

19. There is reason to believe that our experimental procedure may have underestimated the tendency to reach to the same relative position. We pitted reaches to relative position against reaches to the center well. (In all of our tests, a reach to the same absolute position was a reach to the center well.) Now, the center well was used more often, and the toy was hidden there more often, than either the left or right well. This is true because every trial involved the center well, but only half the trials involved the left or right well. (All trials used the center and left wells, or the center and right wells.) Therefore, the children may have built up some association between the center well and the toy.

For another possible source of underestimation of relative reaching, see our comments concerning the four subjects who had older siblings in footnote 24. The tendency of these four children to reach to relative position may have been underestimated.

20. These conclusions are based on individual binomial tests for each child. Significance levels are presented in Table 13.

21. There was no sex difference:

Tends to reach to:	Relative Position	Absolute Position	Neither
Number of Boys	4	5	2
Number of Girls	5	4	5

22. "No preference" is a between-infant phenomenon, not a within-infant phenomenon. Among infants 9 months old or above, 9 consistently reached to the same relative position, 8 to the same absolute, and 8 showed no clear preference.

23. Four of the children we tested had older siblings (Lyndsey, Ryan, Kate, and Julia). None of these children showed a significant tendency to reach to relative position. Perhaps this is simply a coincidence. But then, perhaps not.

The older sibling was usually present during testing. Babysitters are expensive and hard to find. Although we had a playroom on the floor where the older child could play, and an observation room next door where the child could watch the parent and younger sibling throughout the testing session, the older brother or sister usually insisted on being in the same room as the parent (sometimes even in physical contact with the parent). It was hard for the older child, who was only 2-4 years old him or herself, not to interrupt at all throughout our three experiments. In trying to be helpful, the child sometimes got in the way. Even when playing obediently on his or her own, the child sometimes made noise which distracted our testee. At various times, Lyndsey, Ryan, Kate, and Julia were distracted by their sibling.

Perhaps babies need particularly strong concentration in order to show relative rather than absolute reaching. Recall the point made in footnote 19 -- a reach to the same absolute position in this study was a reach to the center well and over the course of the study the toy was hidden in the center well more often than in either of the other wells. If a baby were not attending carefully during a particular session, the best guess (given that the child remembers little from the present trial, but has had much experience with this task over months of testing) would be the center well. Given no information about a particular trial, a baby would maximize his or her chances of being correct by reaching to the center well. A reach to the same relative position necessitates paying attention to the trials immediately preceding the test trial.

This would seem to be in accord with the findings of Acredolo (1979, 1981), cited in footnote 18. She found that babies performed better at home and in a familiar laboratory, than in an unfamiliar laboratory. This difference could well be due to the fact that the infants in familiar surroundings were more relaxed and less distracted, and thus were able to pay closer attention to the task presented them.

24. We did not see how to include more than one test in a given visit. For once an infant has reached, his or her information about the hiding places is no longer purely observational.

25. One might argue that even on the sight trials which we included in our analysis infants moved in subtle ways, tensing their muscles or straining toward the correct well. We did attempt to code straining, its intensity and its direction. We found no relationship between the presence or absence of straining during the delay period on the sight trials and the infant's reach on the next trial. We were not able to investigate the effect of intensity or direction of straining because the inter-coder reliabilities of these more subtle questions were too low. At the very least, regardless of how subtle movement must be before it is no longer considered activity, and regardless of whether one wants to call "actively watching" activity, certainly the quality of the infant's experience, the extent of the movement,

is much different on sight trials from that on regular trials.

26. Actually, we set out to test a 2 second increase or decrease in delay, not 2 or 3 seconds. However, in verifying the actual length of delay from the video tape recordings, we found that almost half of the changes we made were 3 seconds, not 2. Hence, we describe our manipulation as a change of 2 or 3 seconds.

27. It is important that the reader bear in mind that we are *not* proposing that if one chooses any delay brief enough so that an infant performs perfectly and then one increases that delay by 2 or 3 seconds you will find the A$\bar{B}$ error. For example, if Jack (in the session illustrated on the next page) had been started with a delay of 1 second, he undoubtedly would have performed admirably. Increasing the delay to 3 seconds would still not have challenged him, however. (As the diagram indicates, he performed perfectly at 3 seconds.) If one starts with a delay length much too brief to challenge a particular child, then an increase of 2 or 3 seconds is likely to still be too brief to produce the A$\bar{B}$ error.

28. The fifteen infants who were not tested here were tested on the effect of increasing the delay 2 or 3 seconds beyond that needed to produce the A$\bar{B}$ error. As explained earlier, we were not able to test all infants on all conditions.

29. Table 23 would seem to indicate that memory is improving more rapidly early in the second half of the first year and tends to improve somewhat less rapidly as we near one year of age. (Graph 4, summarizing the same data, will also appear to suggest this.) We believe this may be an artifact of the study. Once infants committed the A$\bar{B}$ error with a delay of 10 seconds, we were more hesitant to continue increasing the delay because we wanted to see if the A$\bar{B}$ error might disappear if we remained at the same delay length. Therefore, infants were tested with delays of 10 and 12 seconds over more visits than we continued testing for the shorter delays. We believe this may have led to a slight underestimation in the length of delay appropriate for the A$\bar{B}$ error at 11 months of age and older. We believe this underestimation was only slight, however, because of the small range of delay lengths capable of yielding the A$\bar{B}$ error at any given time. (Recall the evidence on increases or decreases of 2 or 3 seconds in delay.) We mention this only to caution the reader that the apparently smaller increases in delay necessary to produce the A$\bar{B}$ error toward the end of the first year of life may not be what they seem.

One little boy, Blair, required considerably shorter delay than any of the other children. He remained at the 0 second delay at least twice as long as any other child, and by 12 months of age he was making the A$\bar{B}$ error with only a 5 second delay. Therefore, the means on Graph 4 are given once for all the children, and once for everyone but Blair. When sex differences in length of delay tolerated are discussed, we will likewise look at the boys with, and without, Blair. It should be noted, however, although Blair needed unusually brief delays, the *character* of his performance looked just like that of everyone else. The pattern of his reaches over trials looked just like that of the other children. Blair was simply progressively more slow on delay length. Yet, even here, he was progressing.

30. In addition to these items, coders were also asked to judge: "Eyes widen or light up," "Waves hands," and "Mouth Open." The intercoder reliability on these two items, however, was below .85 and they were eliminated from the analysis.

    Detailed instructions to coders on how to answer these and other items are presented in the Appendix. The primary instruction here was that the infant's behavior be *in response to the toy*. For example, we were not interested if the baby happened to smile because the parent tickled him.

31. See footnote 32.

32. Although we may have underestimated the upper limit of how long the infants could remember by using toys rather than food, the fact that we tested the infants repeatedly probably served to maximize the length of delay they could withstand. Subjects tested only once could not withstand delays as long as could the subjects tested longitudinally at comparable ages. Indeed, of the 21 subjects tested with food, only 7 were able to tolerate delays longer than the average delay length used with the longitudinal subjects at the same age, even after the food was introduced.

    One of the reasons why infants perform better when their level of interest is higher maybe that they persist more in straining toward or staring at the correct well during the delay. It was not uncommon for the experimenter to be unable to distract the infant during the delay when we had hidden something he wanted badly. Normally, the counting of the experimenter during the delay was sufficient to make the infant look up. When visual fixation or bodily strain is maintained toward the correct well during the entire delay, infants are able to reach correctly at delays under which they otherwise err.

33. Jane, Erin, Graham, Kate, Isabel, Lyndsey, Jamie, Rachel, Brian,

Sarah, Julia, and Nina

34. Blair, Jack, Tyler, Emily, Ryan, James, Todd, Jennine, and Michael

35. Mariama, Rusty, Bobby, and Chrissy

36. This is always referred to in the literature as "partially hidden." According to Strunk and White (1979:55), however, partly is the correct usage, not partially.

37. These infants were given at least three trials with a single hiding place, toy totally covered. Their hands were usually held and a "0" second delay was used, just as was done when two wells were covered. On each of the sessions in question, the infant succeeded in uncovering the toy on all three trials. If there was an ambiguity, such as, "was the infant really going for the cloth and not the toy?" we administered further trials to the baby.

38. Seven of our infants inadvertently covered the partly hidden toy they were reaching for on one or more trials. Each of these children stopped reaching as soon as this happened. None of them retrieved the toy on any of these trials as long as the toy remained hidden.

39. There is some suggestion in the data that search might be a behavior that appears toward the end of Stage 3, being a developmentally later response to the toy's disappearance than crying or equanimity. However, our data are too ambiguous on this point to be able to draw any definite conclusions.

40. We tried this with only two infants during the visit when they could find a hidden object but could not perform well enough to make the $A\bar{B}$ error with even a 0 second delay. Both infants, however, were aided by the sound cue.

41. The resourcefulness of babies should not be underestimated. They found several ways to try to make our experiment easier for themselves. In addition to kicking the table to produce a sound cue, infants tried to strain toward the correct well or to keep their eyes glued there. Two infants also adopted the strategy of reaching to both wells simultaneously (although we counted these reaches as errors). Perhaps the infants adopted other strategies as well, which we were not clever enough to detect.

42. It has been reported that the $A\bar{B}$ error still occurs, albeit greatly attenuated, when transparent rather than opaque covers are used (Bower and Wishart, 1972; Brown and Bower, 1973; and Butterworth, 1977). We have never tried this ourselves, and we are not sure how to understand it. In the Object Retrieval Experiment to be discussed later, we placed a toy inside a transparent box. We found that the infants always reached to where they saw the toy, but when encountering a solid obstacle the youngest babies were stymied. When transparent covers are used in the $A\bar{B}$ experiment, do babies first reach to where they see the toy, only reaching back to the toy's old location when they encounter an unexpected barrier between their hand and the toy? Is the error with transparent covers primarily seen in younger infants? If children are tested with more than a single trial criterion, will the $A\bar{B}$ error still be found with transparent covers? We do not know the answers to these questions. We would be surprised if older infants (infants 9 months of age or older) displayed the $A\bar{B}$ error with transparent covers when a criterion for the error, such as the one used in the present study, is used. We would also be surprised if infants did not usually reach to the visible toy, even though they have had successful experience at A, although on finding that the toy is not readily available at B some children might try A.

43. A refinement of the experimental apparatus would enable the investigator to control these variables more accurately than was possible in the present study. A grid should be placed on the table. On way to do this would be to use a tabletop of clear Plexiglas and fasten a grid below it, as was done by Field (1981). This would allow more accurate control of "distance of box from baby" and "distance of box from midline." Also, we recommend fastening a still finer grid beneath the bottom of the box (a transparent base should be used for the opaque box). This would allow more accurate placement of the toy within the box.

44. All numbers in this paragraph are based on front-open trials only.

45. Note that while the criteria for judging line of sight to be through the top or the front are mutually exclusive, they are not exhaustive. Many trials were judged to fall between these two extremes.

46. Even 6-7 month old infants were able to succeed on over half of the top-open trials, regardless of which box was used or where it was placed, because even this early many children would pull the box toward themselves, thus enabling them to see in the opening and retrieve the toy.

47. Twenty-five children were studied longitudinally, but only 23 began testing by 31 weeks of age.

48. It should be noted, however, that most of the children who failed when the box was moved over the toy or when they accidentally pushed the toy inside the box lost contact with the toy, so that the tactile sensation of the toy was in the past, even if by only a second. Thus, although they still had much present tactile information specifying the opening, in terms of direct tactile contact with the toy, it was past tactile input competing with present visual input.

Many of these children, even if they maintained contact with the toy, had one or more fingers stuck outside the box. This obstacle, however minor, may well have aided the line of the line of sight in "overruling" the available tactile information.

49. This was judged by the first reach following the show and return sequence. Not infrequently, infants repeated the show and return sequence two or three times, or produced the sequence themselves following an experimenter-produced sequence. We did not code such repetitions as failures to profit from the sequence. Instead, if more than one show and return sequence occurred in a row, uninterrupted by attempts to reach for the toy, we judged success or failure by the infants' actions following the last consecutive show and return sequence -- a reach for the toy through the front was counted as a success; anything else as failure.

50. Top-open may have been easiest because: 1) the size of the opening was larger on the top than on the front or the side (the area of the top opening was 20.25" for the deeper box and 36" for the shallower box, while the area of the front and side openings were 11.25" for the deeper box and 12" for the shallower box); 2) line of sight was more often through the top of the box than elsewhere (the surest way to produce a line of sight not through the top was to position the box far away from the baby, but the maximum distance the box could be placed from the child was constrained by his arm span); and 3) a reach for the toy could easily be converted into grasping the box instead and pulling it closer, whereas the means-end behaviors which aid retrieval when the opening was on the front or the side are more differentiated from a reach for the toy and require more planfulness.

It is possible that infants' achievements seen on top-open and front-open trials did not appear until later on side-open trials because side-open was not introduced on the first visit, although front- and top-open were presented from the start, or because line of sight was least often through the left or right side of the box.

51. Infants who were unable to retrieve the toy on this trial were not tested on the other trials in the sequence because those trials would have been too difficult for them. All babies in the longitudinal sample were able to retrieve the toy easily on trial 1 by the time testing on this sequence began. Infants tested only once, who were not yet mature enough to pass trial 1, are not included in the group of 50 children whose results are reported here. Infants in Phase 1 will try only the side of the box through which they see the toy. They will not attempt to reach through any other side of the box and they will not attempt to change their line of sight so that they might see the toy through a different side. It is these infants who were not yet ready for the more difficult testing sequence described here.

52. On trial 2, if the infant gave up a second time, the trial was terminated at that point.

53. Failure on trial 4 was defined as the inability to retrieve the toy before the toy was "trailed" or the box was "tipped." That is, despite the fact that the infant was encouraged and was given unlimited time, he or she twice gave up without having retrieved the Lego block.

54. Recall that all children were tested with the Lego block in the center of the box, one half were tested with the opaque box, and one half with the toy outside. That is, of the children who failed trials 2 and 4:
    38 were tested with toy in center of box, transparent box
    19 were tested with toy inside, bordering front wall, opaque box
    19 were tested with toy outside, bordering front wall, transparent box.

    Among the children who successfully retrieved the Lego block on trials 2 and 4:
    31 were tested with toy in center of box, transparent box
    16 were tested with toy inside, bordering front wall, opaque box
    15 were tested with toy outside, bordering front wall, transparent box.

    Six children were not able to retrieve the toy on trial 2, but did retrieve it on trial 4. Of these children:
    6 were tested with the toy in center
    3 were tested with the opaque box
    3 were tested with the toy outside.

    No children succeeded on trial 2 and failed trial 4.

    The success rates in all of these groups for toy in center, opaque box, and toy outside were 100%.

55. The only contiguous relationship which Piaget investigated was one object placed on top of a larger object. His work and conclusions were extended to other contiguous relationships by Bower.

56. Recall that frontal lobe patients have difficulty producing a long squeeze in response to a brief tone or a brief squeeze to a long tone. Not only is the tendency to match across modalities in this way strong in adults, but it appears in the first few months of infancy. It, like the ability to acquire a conditioned response, does not depend upon the frontal cortex. For example, Spelke and Gelman (1982) found that infants of 3-4 months looked longest to a visual display which corresponded numerically to the auditory stimulus they were presented.

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APPENDIX A

<u>Infant Study Interview</u>

Baby's Name ______________________________ Sex __________

Birthdate ____________ Full Term? ______ Present Weight __________

Usual Bedtime? _______________ Usual Waking Time? ____________

Usual Nap Times ____________ _____________ ________________

Best times for appointments? __________________________________

Age at which child: First Sat Up On Own _______ Started Crawling _____

First Step _______

Mother's Age at birth of child ________________

Education ____________________________

Occupation ___________________________

Ethnic Identity _______________________

Father's Age at birth of child _________________

Education ____________________________

Occupation ___________________________

Ethnic Identity _______________________

Are you home with the baby all the time? Does anyone else help with childcare? Day care?

Were there any pregnancy or delivery problems?

Has the infant had any serious health problems?

Do you have any other children?

Name	Sex	Birthdate	Serious Health Problems

The objective of this study is to see if the development of memory, or of the understanding of the concepts "left" and "right," might account for some of the changes in babies' behavior during the latter part of the first year of life. We will be looking at how your child goes about finding hidden objects and we will see if he or she can figure out the rules of different games that involve reaching for objects. A second researcher will be behind a one-way mirror recording your child's behavior. All subjects receive a $3.00 compensation. All data are confidential.

Adele Diamond

Jerome Kagan   Adele Diamond

The nature and purpose of this research have been satisfactorily explained to me and I agree to allow my child to participate in the study as described above. I understand that we are free to discontinue participation at any time if I so choose, and that the investigator will gladly answer any questions that arise during the course of the research.

Signature of Parent   Date

Harvard Infant Study

WILLIAM JAMES HALL
33 KIRKLAND STREET
CAMBRIDGE, MASSACHUSETTS 02138

This is just a reminder of your next appointment with us.

It is to be on
(day of the week) ____________________
(date) ________________________________
(time) ________________________________
in Room 1272.

If for any reason you will not be able to keep this appointment please call us at 498-2077 or 495-3885. We will make every effort to reschedule you as close to this date as possible. If at any time you are afraid that your baby might be coming down with a cold, we would be glad to try to see you a day or two earlier, rather than risk delaying a visit for several days.

As always, we ask that you not practice any of our experiments with your baby. We are not trying to find out how quickly or how slowly different babies develop. We are trying to understand why babies make the mistakes they do. Therefore, we would like the babies in our study to make mistakes as long as possible.

If we have enclosed a parking permit with this note, please bring the permit with you when you come and place it inside the windshield of your car.

We would like to express our thanks to you again for helping us to understand the world of the child.

Yours,
Adele Diamond
Adele Diamond

Harvard Infant Study

WILLIAM JAMES HALL
33 KIRKLAND STREET
CAMBRIDGE, MASSACHUSETTS 02138

Just a reminder of your upcoming visit with us !

It is scheduled for
(day of the week) ______________
(date) ________________________
(time) ________________________
in Room 1272.

Adele Diamond
498-2077 495-3885

APPENDIX B

A$\bar{B}$

Baby's Name ________________________ Date __________ Visit # ____

Trial # _____ Apparatus: 2 HOLE or 3 HOLE Coder's Initials _____

DIF COVERS- Are the covers the same or different?

SAME DIFFERENT sides of blue cloth DIF - 1 blue, 1 white

DIF TOY - Was this toy used on the last trial or is it a different toy?

SAME TOY DIF TOY 1st TRIAL

SIDE HIDE - Side of hiding: RIGHT CENTER LEFT

MOM EYES - Where does mother look from the time the toy is placed in a well until the time the baby reaches (i.e., where does she look during hiding, delay, and release)?

CORRECT WELL WRONG WELL AWAY, OTHER MIXED

PARTIAL - Is any part of the toy visible to the baby under the covers?

PARTIALLY HIDDEN TOTALLY HIDDEN

HELD - During the delay are the baby's hands restrained at all?

YES BARELY (MUCH STRAINING) NO

SIDE REACH- Where does the baby reach? (If the baby only touches the left cover and then uncovers the right, SIDE REACH = RIGHT. ALL = both if apparatus is 2 hole.)

RIGHT CENTER LEFT ALL NONE OTHER

FOR TOY? - Does it appear to you that the baby was reaching FOR THE TOY (as opposed to for the cloth or to just continue a movement)?

YES, CLEARLY YES, (?) UNCLEAR NO, (?) NO, CLEARLY

AFTER ERR - What does baby do after s/he has reached at the wrong place? (If baby does more than one thing, number the actions in the order in which they happen.)

__ Acts like expected toy to have been there: looks confused, looks around on floor, in cover, or in well.
__ Amuses self otherwise: with mirror, with cloth, with spec on table, etc.
__ Searches at correct well.
__ Gets annoyed, frustrated, or angry.
__ Before baby can do much, E shows where the toy was.
__ Other.

SEE WHERE - If the baby was WRONG, does s/he see where the toy really was hidden? (Is the baby clearly shown what the right choice would have been?)

YES NO not applicable

REWARD - If the baby was WRONG, does s/he get to play with the toy before the next trial?

__ YES, gets toy from well his/her self.
__ YES, given toy by E.
__ NO, not allowed to play with toy.
__ NO, not interested in playing with toy, even though allowed.
__ OTHER.
__ not applicable — Baby was correct.

COMMENTS:

AFTER baby's hands have been released: E fully covers a toy which had been only partially covered (e.g., as baby is going for the toy, E pulls cover over it):

E SEARCH --

__1. Stops searching immediately & gives up.   __2. Visual search only continues.
__3. Continues reaching & then stops - both visual search & reaching stop.
__4. Continues reaching & then stops - but visual search continues.
__5. Continues getting toy with little difficulty.

__9. n/a

E RETRIEVAL --

__1. Never finds toy without E's help.
__2. Finds toy by accident.
__3. Eventually finds toy - not by accident.
__4. Continues getting toy with little difficulty.

__9. n/a

Baby himself accidentally pushes a partially covered toy all the way under the cover:

B SEARCH --

__1. Stops searching immediately & gives up.   __2. Visual search only continues.
__3. Continues reaching & then stops -- both visual search & reaching stop.
__4. Continues reaching & then stops -- but visual search continues.
__5. Continues getting toy with little difficulty.

__9. n/a

B RETRIEVAL --

__1. Never finds toy without E's help.
__2. Finds toy by accident.
__3. Eventually finds toy -- not by accident.
__4. Continues getting toy with little difficulty.

__9. n/a

AFTER baby's hands have been released: E partially uncovers a toy that had been totally covered (e.g., at end of trial, instead of totally uncovering the toy or giving it to baby, E partially uncovers it):

__1. Baby never goes for toy.   __2. Baby goes for toy.   __9. n/a

INSTRUCTIONS FOR A$\bar{B}$ ON-THE-SPOT FORMS

RIGHT & LEFT = BABY'S right and left.

SIDE HIDE

Remember to also indicate OTHER WELL USED. (Write initial in right margin.)

SIDE REACH

A well must be uncovered for it to count as a reach.
A reach which stops short of uncovering the well will be coded as a PRIOR REACH on video form. Even a reach which appears accidental to you, if it results in uncovering the well, gets coded here.

FOR TOY?

If there is no reach, use the answer NO, CLEARLY here.

AFTER ERR

If E does not allow baby to correct himself (i.e., if E shows him where the toy is before he has time to correct himself), the answer here is: BEFORE BABY CAN DO MUCH, E SHOWS WHERE TOY WAS.

Use ACTS LIKE EXPECTED TOY TO HAVE BEEN THERE very conservatively. A simple look or search is not sufficient here. Only use this if baby leans over to look in well, looks a long time in the well and/or cloth, or looks bewildered or surprised that the toy is not there. If the baby merely peeks in, DO NOT USE THIS.

SEE WHERE

Answer this YES or NO even for SIGHT TRIALS (trials where the subject is not allowed to reach).

REWARD

Answer this even if the baby is correct.

APPENDIX C

AB̄ from Video

Baby's First Name ______________ Visit # ______ Date ______ Trial # ______

Apparatus: 2 hole or 3 hole

Coder's Initials ______

Check the on-the-spot form. Complete? Are LEFT and RIGHT accurate?

------- HIDING -------

TOY - What toy was used? (Use number.) ____

LIKE TOY 1 - Your rating of baby's level of interest in the toy: 0 1 2 3

LIKE TOY 2 - Evidence upon which your rating was based. What evidence is there that baby is interested in toy?

When the toy is presented, the baby:

Watches toy attentively A P E n/a

Smiles.................. A P E n/a

Eyes widen or light up A P E n/a

Vocalizes happily........ A P E n/a

Bounces up & down........ A P E n/a

Waves hands.............. A P E n/a

Tries to grab toy........ A P E n/a

Bangs table excitedly.... A P E n/a

If allowed to have the toy:

Goes eagerly & directly for toy ___

Chooses it over other toys ___

Plays with it ___

Maintains interest in it over play period ___

Reluctant or unwilling to relinquish toy ___

SEE HIDE - Did the baby see where E hid the object? YES, CLEARLY YES, ? UNCLEAR NO

COVER USED - Covers = CLOTH PLASTIC

IF DIFF - If a blue & a white cover were used, over which well was the WHITE cover placed?

RIGHT CENTER LEFT n/a

WELLS COVER - What wells were covered? 1. R & L 2. R & C 3. C & L 4. all 3

5. Right only 6. Center only 7. Left only 8. none

SIMULATE - If E covered only one well, or no well, did she move her hands as if she were covering the well(s)?

YES NO n/a

EYES H - Where does the baby look while the toy is still visible (including while the toy is in the process of being covered)? Start from the point where E catches the baby's attention with the toy before putting it in the well? ___ ___ ___ ___ ___ unable to tell

LENGTH - How long is each of these looks: Q, M, or L? ___ ___ ___ ___ ___ unable to tell

Coding Form for A$\bar{B}$ from Video -- Side 1 (continued)

------- DELAY -------

COVER LAST - Did E finish covering any well after the other(s)?

Yes, RIGHT   Yes, CENTER   Yes, LEFT   NO   unable to tell   n/a

BUMP - Is the cloth raised because the toy is sticking up?   YES   NO   unable to tell

RATTLE - Is the toy making any noise?   NO

ONLY at beginning of delay   ONLY at end of delay   THROUGHOUT the delay

EQUIDIST - Are each of the covers equidistant from the baby?   YES   n/a

2 RIGHT is MUCH closer   4 CENTER is MUCH closer   6 LEFT is MUCH closer

3 RIGHT is SLIGHTLY closer   5 CENTER is SLIGHTLY closer   7 LEFT is SLIGHTLY closer

LOOK UP - Does E say something to make the baby look up (such as counting or saying baby's name)?

YES   NO   unable to tell

STRAIN - Any evidence of reaching or straining during the delay:

	to correct well	to other well used	to 3rd well	unclear	no	n/a
Starts to reach before hands are held............	____	____	____	____	____	____
Gets loose & starts to reach after hands are held.	____	____	____	____	____	____
Body is turned toward:	____	____	____	____	____	____
Struggles with torso &/or brings mouth down......	____	____	____	____	____	____
Much straining with arm(s) toward:	____	____	____	____	____	____
Slight straining with arm(s) toward:	____	____	____	____	____	____

STRAIN TO - Direction of straining: NO STRAINING   n/a

At beginning of delay: ____   Toward end of delay: ____   Throughout delay: ____

APPEAR - Would it appear to a casual observer that there was NO DELAY?   YES   NO

DURATION - Delay Length. Time from moment toy is covered until baby's hands are freed. (Note: Do not use time until E says "okay." Do not use E's count.) Round to nearest second. ______

Coding Form for A$\bar{B}$ from Video -- Side 2

EYES D - Where does baby look during the delay period?

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ (No. = _____) n/a

LENGTH D - How long is each of these looks: very quick (Q), moderate (M), very long (L), or extra long (X)?

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ n/a

REFLEX - Evidence of grasping or sucking reflex:

	Present	No Evidence
GRASPING	_____	_____
SUCKING	_____	_____

------ CHOICE -------

Check SIDE REACH. If only one cover was used, a look in the other well counts as a reach. OTHER = UNCLEAR.

LANDING - Which cover is closest to where baby's hand first lands? R C L EQUAL n/a

PRIOR REACH - Earlier incomplete reaches before pulls off cover (or quits): SIDE ___ ___ ___ ___ ___

__ NONE HAND ___ ___ ___ ___ ___

HAND - Which hand did the baby reach with? BOTH NO REACH

RIGHT RIGHT (Left held) LEFT LEFT (Right held)

KIND REACH - Check the adjective which best describes this reach: __9. NO REACH __1. Nondescript

__2. Confident, Decisive, with Assurance __3. Enthusiastic, with Gusto

__4. Unsure, Hesitant, Indecisive __5. Accidental __6. Uninterested

EYES C1 - Where does baby look after his hands are released before he finally chooses?

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ (No. = _____) n/a

LENGTH C1 - ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ n/a

EYES C2 - Where does baby look while reaching to the well he has chosen? ___ ___ ___ ___ ___ no reach

------- AFTER -------

FORGOT - Evidence that the baby forgot that a toy was hidden. (Number in order, if necessary.)

__ Looks bewildered or confused. __ Finds something else to amuse himself with.

__ Mildly upset or unhappy. __ Extremely upset or unhappy.

__ No search whatsoever. __ Begins to reach and then stops.

__ Begins to uncover a well, but while in the process of doing so, becomes interested in the cloth.

__ OTHER: ____________________ __ NO EVIDENCE __ n/a

Coding Form for AB from Video -- Side 2 (continued)

SQUEAK - If E squeaks toy under the cloth, or if baby accidentally does so, what is baby's reaction? (Check all appropriate.) __ N/A

__ No Reaction __ Looks bewildered, confused __ Starts to reach __ Uncovers toy

CLOTH - What does the baby do with the cloth once he has it? (Check all appropriate.)

__1 Discards it. __4 Plays with it. __7 Picks up toy only.
__2 Discards it immediately. __5 Picks up both toy & cloth at same time. __8 Never takes a cloth.
__3 Transfers it to other hand. __6 While holding it, grabs toy. __9 N/A

__ Tries to drop or shake it loose, but fails (at least initially).
__ Continues holding cloth without attending to it. __ Searches in cloth for toy.

SEARCH - If baby was wrong, where does he search for the toy? (Number in order, if necessary.) __ CORRECT

__ In the well __ Under the other cover __ On the floor __ on the tabletop __ NOWHERE
__ In the cloth __ In the 3rd well __ Behind parent __ AROUND __ N/A

PROLONGED - For how long does the baby search? PROLONGED (≥5) BRIEFLY (<5) NO SEARCH n/a

B to A - Does baby reach immediately to B, not search at all, or just barely, & then reach right away to A?

YES NO

LATENCY - How long before baby goes to correct well after choosing an incorrect well first? Round to nearest sec.

_____ sec.s CORRECT NEVER GOES E doesn't let him. n/a

LIKE TOY 3 - Your rating of baby's level of interest in the toy: 0 1 2 3

LIKE TOY 4 - Evidence that baby wanted the toy:

	Eyes Widen	A	P	E	n/a
When toy is uncovered, reaches for it ___	Watches toy attentively	A	P	E	n/a
Disappointed/ upset when not allowed to have toy ___	Mouth open...............	A	P	E	n/a
Plays with toy ___	Smiles...................	A	P	E	n/a
Reluctant/ unwilling to relinquish toy ___	Vocalizes................	A	P	E	n/a
Maintains interest in toy throughout play period ___	Bounces..................	A	P	E	n/a

SLEEPY - Was there any evidence during this trial that the baby was sleepy? YES NO

FRUSTRATE - Was there any evidence during this trial that the baby was frustrated, annoyed, or bored?

MUCH YES SLIGHT NO

Instructions for A$\bar{B}$ from Video

Remember to check the ON THE SPOT forms for EACH TRIAL. Are they correct? Are they complete?

TOY

01 - 09: toys that squeak

01 duck
02 turtle
03 lady bug
04 elephant
05 tiger

09 other sqeaky toy

11 - 19: toys that rattle

11 keys
12 bell cage
13 bumble bee (amoeba)
14 toy keys
15 elephant rattle
16 gorilla ring

19 other rattle toys

21 lego rectangle
22 lego bridge
23 green stick
24 silver measuring cup
25 pacifier

31 clown
33 teddy bear

35 cookie or cracker
36 bottle

50 green car
51 tea cup
52 tiny girl
53 watch
54 blue ring
55 orange car

41 radio
49 other - unspecified

LIKE TOY 1

0 = No interest. Baby does not want toy at all & will not take it if it is presented.
1 = Low interest. Baby is uninterested or bored with toy, but will pick it up if there is nothing else to do.
2 = Interested in toy.
3 = High interest. Baby loves the toy & wants it <u>very</u> much. Very high motivation to get that toy. Use this VERY conservatively.

If any answer to LIKE TOY 2 = EXTREME, then LIKE TOY 1 = 3 unless you see a good reason why not.

LIKE TOY 2

ONLY record evidence that occurred at the beginning of THIS TRIAL. IGNORE evidence from the end of the last trial.

ONLY code a behavior if it is done IN RESPONSE to the TOY. Do not code any of these behaviors if they are not in response to the toy. A smile to the Experimenter, for example, does not count.

A = Absent P = Present E = Extreme n/a = not applicable
Reserve E for truly extreme instances. Use it conservatively.

If the baby is allowed to play with the toy, and so the toy is presented once before the play & again before it is hidden, use BOTH presentations of the toy in answering the questions under, "When the toy is presented."

Do NOT code EYES WIDEN unless the baby is looking AT the toy. Do not code EYES WIDEN if that is only part of smiling or putting the toy in the mouth.

ANY vocalization that indicates that the baby wants the toy gets coded under VOCALIZES HAPPILY.

For TRIES TO GRAB TOY use n/a if baby's hands are held <u>and</u> the baby is moving (especially if his hands are moving). That is, if there is evidence that the baby might have tried to grab the toy. If the baby's hands are held and he remains still, the answer here is NO.

If baby's hands are held during presentation of toy, unless his hands are still, BANGS TABLE = n/a.

CHOOSES IT OVER OTHER TOYS: If no other toys present, write n/a. If, when a new toy is presented, he stares fixedly at that toy, ignoring the toy still in his hand, then CHOOSES b PRESENT for this new toy.

WATCHES TOY ATTENTIVELY must be present at least 50% of the time the toy is visible for this to be PRESENT.

SEE HIDE

Only use YES, CLEARLY if there is <u>no</u> doubt that the baby has seen the toy in the well. Use this category very conservatively.

SIMULATE

Use this ONLY in situations where E has been using 2 WELLS all along. That is, these trials = one well covered & one well uncovered -- on these trials, did E bring one of her hands to the uncovered well when covering the other or not?

For the 2 HOLE apparatus, SIMULATE = n/a <u>ALWAYS</u>.

One cover is almost NEVER used for OLDER LONGITUDINAL babies unless it is a SIMULATE TRIAL.

EYES H

1 = the toy or the well where the toy was hidden

2 = Right well]
3 = Center well] Use these ONLY for the other well(s) used in that trial
4 = Left well]

5 = 3rd well
6 = E's face
7 = E's hand
8 = inbetween 2 wells
9 = away, other

The difference between 6, 7, & 9 is not crucial -- do not take a lot of time trying to decide if a look was to 6, 7, or 9.

This starts when parent restrains baby's hands & baby first sees toy. It ends when covers are placed over the wells.

LENGTH H

Q (very quick) = 1 second
M (moderate) = 1 second, but 3 seconds
L (long) = 3 - 5 seconds, inclusive
X (extra long) = 5 seconds

RATTLE

If BELL CAGE, BEETLE, or KEYS are used listen VERY CAREFULLY. If baby kicks or bangs the table, making the toy rattle, this gets coded under RATTLE.

EQUIDIST

Judge only vis-à-vis CORRECT WELL & OTHER WELL (the 2 wells in use during a given trial).

LOOK UP

If it is unclear WHY the baby looks up, write UNCLEAR. If there is any indication whatsoever that the baby looked up in response to what E did, answer YES. Answer YES if E does ANY distraction (such as swaying) - E does NOT need to say anything.

When E says OK as signal for parent to release baby's arms do not count this as E saying something to make baby look up.
Do NOT count it if E talks but baby never looks up.
Do NOT count it if baby does look up, but not in response to anything E says.

STRAIN

Use STARTS TO REACH BEFORE HANDS ARE HELD even if baby's hands are already being held if: this happens BEFORE well is covered, or this happens AFTER well is covered, but before DELAY really begins.

Use GETS LOOSE & STARTS TO REACH if the baby starts to reach before he was supposed to, even if he is allowed to complete this reach. The baby does not have to get his arm completely free from parent as long as the movement is clearly a REACH. For SIGHT TRIALS, use this for any reach from the time the baby's hands are held until after E removes the toy from the well.

To judge if body is turned, look at which arm is freer, which well does the baby have more direct access to. Pay particular attention to orientation of baby's body toward the end of the delay. Judge only vis-à-vis the 2 wells in use on a particular trial.

SLIGHT STRAIN = barely perceptible straining.

STRAIN TO

1 = correct well
2 = to other well used
3 = to 3rd well
4 = unclear, global, or other
5 = no straining
6 = n/a -- no delay (or baby is off camera)

USE FOR REACHING as well as STRAINING. This refers to reaching and straining, but not to BODY TURN.

Use n/a (6) for beginning & end if straining is in the same direction throughout.

Use n/a (6) for throughout if answers are different for beginning and end.

If end & beginning are the same, but different in middle - give END & BEGINNING the same no. & throughout another no.

DURATION

Do not round off if <1.0 and do not round off if 2.5, 3.5, 4.5, etc.
Use .4 as the smallest possible category.
If tape cuts on after delay has already started, you cannot code DURATION, it is n/a.

EYES D

See instructions for EYES H.

If the baby looks one place the whole time, and then turns to reach -- even if this turn occurs while his hands are still held -- code this second look under EYES C1, NOT under EYES D.

NO. (for EYES D and for EYES C1)

This refers to the number of consecutive looks between wells. Thus the following series of looks would receive a 3 here: R, L, (at E), L, (away), R, L, C.

Count number of looks between any wells, not just the two used on that trial. E.g., if the center and right wells are covered, and the baby looks from the left well and back again to the left well, No. = 2.

LENGTH D

See instructions for LENGTH H.
Fill in length, even if there is only one look.

REFLEX

Look at whether baby: sucks mother's finger during delay
maintains grasp of mother's finger after delay
maintains grasp of cloth while playing with toy

LANDING

If there is only one well used, LANDING = n/a for that trial.
Fraction of a second difference doesn't count.
On 2-hole, center = equal.

HAND

If a baby clearly does NOT search & eventually removes the cloth accidentally, count this as a NO REACH. If you are in any doubt WHATSOEVER, count it is a REACH.

If baby leans over & really looks in an uncovered well that counts as a reach. If well is uncovered, baby does NOT need to actually reach. If look or reach to uncovered well only begins, or is half-hearted, call it a PRIOR REACH.

PRIOR REACH

If the baby starts to reach, but then stops reaching, code that reach here. Did the baby start to reach then change his mind? This can be true whether he reaches again to the same well or to a different one.

On SIGHT TRIALS, any and all reaches get coded here. Given Piaget's theorizing, any reach toward the correct well on a SIGHT TRIAL, even if it is before the wells are covered or after the delay, gets coded here.
This should be distinguished from problems of manual dexterity in removing cloth. It is NOT a prior reach if the baby begins a reach with one hand, completing it with the other.

KIND REACH

Use UNINTENTIONAL or ACCIDENTAL if baby doesn't seem to realize what he is

doing, or if he is not attending while he is reaching.
Use ACCIDENTAL if the baby went for THE CLOTH, instead of for the toy.

The difference between 2 & 3 is not crucial -- do not spend a lot of time trying to decide; just pick one.
Do NOT confuse energetic (as many young children are) with ENTHUSIASTIC or CONFIDENT.

EYES C1

See instructions for EYES H.

Always answer No. = .

This referes to period from the end of the delay to the beginning of the reach. Use 0 if there is essentially no time between release of hands & choice, i.e., if reach begins immediately, EYES C1 = 0.

If the baby never makes a final choice, keep coding where the baby is looking until E draws his attention to where the toy is (a look to E's hand or E's face often indicates the E has begun to draw his attention -- do not code this.)

LENGTH C1

See instructions for LENGTH H.
Fill in length, even if there is only one look.

EYES C2

See instructions for EYES H.

FORGOT

This applies ONLY to the baby's behavior BEFORE he reaches. Do NOT count anything he does after he has chosen a well under FORGOT. This behavior, after an incorrect reach, gets coded under AFTER ERROR and SEARCH.

Use n/a if you are not sure whether the baby forgot or not.

Use NO EVIDENCE only when you feel it was pretty clear that the baby had not forgotten.

Use FINDS SOMETHING ELSE TO AMUSE HIMSELF WITH for blank affect, for smiling into mirror, or if the baby goes for the cloth.

Do NOT number NO SEARCH WHATSOEVER, put a check mark there if no search occurs. For all other answers, if more than one answer is appropriate, number them.

Use BEGINS TO UNCOVER A WELL, BUT WHILE IN THE PROCESS OF DOING SO, BECOMES INTERESTED IN THE CLOTH for ANY instance of begins to uncover a well and GETS DISTRACTED. E.g., looks up at E or examines cloth. Do NOT use this category if the baby simply follows the movement of the cloth as he withdraws it and then immediately goes back to the toy -- that is a good example of NOT LETTING himself get distracted, of keeping the goal in mind.
Use n/a if unclear if any of these are true or not.

B to A

If the baby uncovers a well, but does NOT look in that well, but instead goes immediately to another well, B to A = YES.

SEARCH

Use more than one number per item when necessary.
Applies to: a) search behavior after initially reaching to an incorrect well, &
b) (PRE) search behavior in young babies BEFORE any reach or before they give up.
Use n/a if unclear whether baby searched or not.

IN THE WELL always refers to the well the baby reached to on that trial.

UNDER THE OTHER COVER always refers to the well where the toy really was hidden.

If the baby reaches CORRECTLY, but does not realize it and searches:
1) Give him credit for the reach -- it is not a PRIOR REACH.
2) Code where he searches (under SEARCH) and for how long (PROLONG)
BUT ALSO CHECK CORRECT under SEARCH!
If baby is correct, first answer here should be 00.

Use PRE for the young babies who never reach or who seem to find the toy by accident. I want to distinguish the babies who cannot find a totally hidden object and do not search at all from those babies who still cannot reliably find it but nevertheless search all over.

PROLONGED

BRIEF = 5 seconds PROLONGED = 5 seconds
Applies to: a) search behavior after initially reaching to an incorrect well,
b) (PRE) search behavior in young babies BEFORE any reach or before they give up.
Use n/a if unclear whether baby searched or not.

LATENCY

See instructions for DURATION.

Time from when baby 1st looks in incorrect well (1st sees toy is not there) until baby touches the cover over the correct well to remove that cover. Time from SEEING toy is not in well to REACHING for other well.

When baby is wrong, latency can still = 0, if baby does not look into well he reaches to (B to A).

Do NOT start timing from the time baby TOUCHES incorrect cover -- to early.

Do NOT wait to start timing while baby continues searching in the incorrect well -- a glimpse that the toy is not there is sufficient.

Do NOT stop timing if the baby touches the correct cover BUT DOES NOT REMOVE IT -- wait until the baby goes to REMOVE it, then stop timing the moment he TOUCHES the cover for that removal.

LIKE TOY 4

Do NOT answer MOUTH OPEN. Put a line through it.

RELUCTANT/UNWILLING TO RELINQUISH TOY: If the baby is trying to get the toy back, or complains, this is PRESENT. If the baby simply looks BLANKLY this is absent.

DISAPPOINTED/UPSET WHEN NOT ALLOWED TO HAVE TOY: this must be clearly visible.

FRUSTRATE

Do NOT code frustration due to not finding the toy or due to prolonged search here.

The purpose of this question is to ask, "Did the baby not perform as well as he might have because he was frustrated, annoyed, or tired?"

Only use frustration during AFTER if you think that indicates the baby was tired or frustrated throughout the trial or if it persists into the next trial -- in which case FRUSTRATE is coded for the next trial ONLY.

During DELAY or carry-over from previous trial. Judge only by behavior during hiding and delay phases.

REMEMBER: always write down separately:
comments made by E or Parent, &
your observations & hypotheses -- about changes in a baby over the months or about why a baby errs.

For situations where the baby goes to both covers SIMULTANEOUSLY but only removes one of the covers, or clearly meant to remove only one even if both come off, code as follows:

SIDE REACH (on on the spot forms) = ALL
HAND = hand which pulls cover off

If the baby grasps the other cover, rather than simply touching it, for REFLEX, GRASPING = PRESENT.

APPENDIX D

OBJECT RETRIEVAL

Baby's name________________________________ Date____________ Time__________

Visit #__________ Height above table________ in. Coder's initials______ Trial #______

* * HAVE STOPWATCH READY * *

SETTING - How did Experimenter put object in box?

___Placed object on table and then placed box over it.

___Placed object on table and then slid box over it.

___Placed box on table and then placed object inside it.

___Held box in clear view and placed object inside it.

___Out of view, placed toy in box. Then put box & toy on table.

* LATENCY - Time from release of baby's hands (or setting down of box) to baby's touching the object for the first time: _____secs.

START INSIDE - At the outset of the trial, is toy wholly within box?

___All inside. ___Part outside. ___Unclear.

SEE INSIDE - At start of trial, can baby see through the open side?

___Yes, a direct line to toy from baby's eyes was through opening

___Yes, baby could see through the opening.

___No, baby is not looking through open side even though toy is placed so that he/she could easily do so.

___No, baby cannot see through open side.

___Unclear.

DIMENSIONS - Which box was used? 2" x 6" 2 1/2" x 4 1/2" Other__________

TRANSPARENT - Box used was: transparent opaque

ORIENTATION - Which side of the box is open?

Front Top Left Right Back

TOY - Which toy was used?

COMMENTS:

Tape started at__________ and ended at __________.

Instructions for coding OBJECT RETRIEVAL: on-the-spot

SEE INSIDE

1 = Baby could see toy through the opening
2 = The opening was visible; baby could see it, but to look at the toy baby had to use a DIFFERENT ROUTE (could not see toy THROUGH opening)

TOY

01 - 09: toys that squeak

01 duck
02 turtle
03 lady bug
04 elephant
05 tiger

09 other squeaky toy

11 - 19: toys that rattle

11 keys
12 bell cage
13 bumble bee (amoeba)
14 toy keys
15 elephant rattle
16 gorilla ring

19 other rattle toys

21 lego rectangle
22 lego bridge
23 green stick
24 silver measuring cup
25 pacifier

31 clown
33 teddy bear

35 cookie or cracker
36 bottle

41 radio
49 other - unspecified

50 green car
51 tea cup
52 tiny girl
53 watch
54 blue ring
55 orange car

APPENDIX E

Baby's First Name ____________ Visit # _____ Coder _____ Trial # _____

	SITE		BODY PART /E	ACT	OVERLAP	CHAR	INHIB	WHY STOP	INTER-RUPT	ELICITOR
	BOX	N								
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										

SEQUENCES: ACTS: ___ - ___ ACTS: ___ - ___ ACTS: ___ - ___

Baby's First Name ________ Visit # ______ Coder ________ Trial # ______

					EYES						RAISES BOX				GOES IN, BUT NO TOY how far was he	
	DURATION	#	EFFECT	COMPARE < = >	PRE					POST	HI BOX	COMP BOX	SEE TOY THRU OPEN	WHEN REACH	IN BOX	FROM TOY
1.	.		: 1 2													
2.	.		: 1 2													
3.	.		: 1 2													
4.	.		: 1 2													
5.	.		: 1 2													
6.	.		: 1 2													
7.	.		: 1 2													
8.	.		: 1 2													
9.	.		: 1 2													
0.	.		: 1 2													

	AIM PROB					RIGHT HAND								LEFT HAND							
	PROBLEM	FINGS	G/S	#	REACT TO F TOUCH	F	FINGS IN	FINGS TOY	FINGS EDGE			OTHER		F	FINGS IN	FINGS TOY	FINGS EDGE			OTHER	
									FINGS	EDGE	G/S		LINE				FINGS	EDGE	G/S		LINE
1.																					
2.																					
3.																					
4.																					
5.																					
6.																					
7.																					
8.																					
9.																					
10.																					

Instructions for coding OBJECT RETRIEVAL from Video

SITE

Acts by E do NOT get a site.

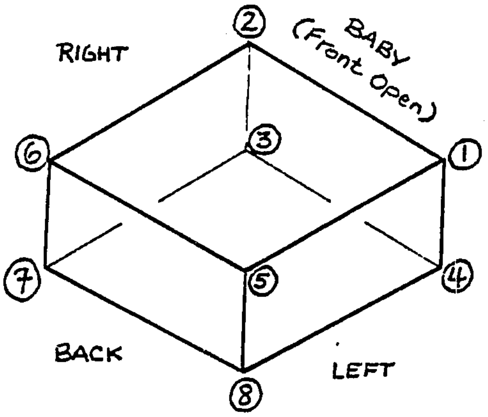
If a site is primarily an edge, do NOT also write the adjacent sides -- only the primary site

If the EYES are looking at the toy through the top of the box, site = T (for top of box) -- in cases like this, site will always equal the side through the baby sees the toy.

If the EYES look away, site equals UP AT E, E's HAND, OR AWAY -- there is NO need to be any more precise than this.

If the baby is aiming to go through a side of the box or to touch the box, & misses the box or stops himself before ever touching, site = where on the box the baby was aiming:
e.g., if the baby starts to reach for the toy on a route that would have been through the front of the box, but halts that reach in midair, site = F (for front of box). (N will always be checked here as well because the baby never touches the box.)

Avoid using corners as sites if they blur the picture. E.g., if the baby is trying to raise the box, he was probably primarily acting on FT -- It is UNIMPORTANT to me that half of his hand was on corner 1 rather than on the FT edge. Similarly, if the baby is trying to reach through the front, I want to know that the site is F -- It is UNIMPORTANT as far as site is concerned that half his hand hit the FT edge.



N

This = NEVER TOUCHES BOX.
On acts directed toward the box, where the baby never in fact touches it, put a ✓ here.

BODY PART

L = left hand
R = right hand
E = Experimenter
P = Parent

If any act is primarily with one part of the hand, like pointing: write L (1)
or hitting: write R (P)

ACTS

Include the OBJECT of the act where appropriate -- e.g., grasps box, or grasps toy. In describing the act, try to be very concrete -- what does the baby actually do? Then in parenthesis be interpretive -- what do you think the baby was trying to do?

Always code EYES as an act under the following 2 circumstances:

1) When the baby adjusts his torso or head in order to get a better/different look -- e.g., tilts head down to see through front, leans forward & looks in top.
2) When there is a pause between acts with the hands or a pause at the beginning of a trial -- here you would code, e.g., looks at toy thru F.

FRONT OPEN, front of box in air, back of box remains on table = RAISES  BABY

TOP OPEN, " " " = TILTS  BABY

TOP OPEN, front of box remains on table, back of box in air = TIPS  BABY

Front & Back of Box in Air (picks entire box up off of table) = LIFTS  BABY

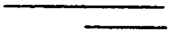
Orientation of Box is Changed = TURNS

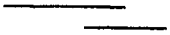
Hitting, Pounding, Banging, Etc. = HITS

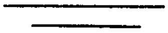
Pulls Box TOWARD Self = PULLS

Pushes Box AWAY from Self = PUSHES

OVERLAP

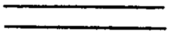
1 =  2ND ACT ENDS AT SAME TIME 1ST ACT ENDS

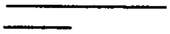
2 =  2ND ACT CONTINUES AFTER 1ST ACT ENDS

3 =  2ND ACT IS WHOLLY CONTAINED WITHIN 1ST ACT

4 =  2ND ACT FOLLOWS 1ST (USE THIS SOLELY WITH TRAILING)

5 =  ACTS BEGIN TOGETHER (2ND CONTINUES AFTER 1ST ACT ENDS)

6 =  ACTS ARE EXACTLY SIMULTANEOUS (THEY START & END TOGETHER)

7 =  ACTS BEGIN TOGETHER (1ST CONTINUES AFTER 2ND ENDS)

E-4

CHAR

1 = AWKWARD (AS W/ FAR HAND: SIDE OPEN)
2 = TENTATIVE
3 = SPASTIC
4 = SLOW & CAREFUL
5 = QUICK & CONFIDENT
6 = MARKED DETERMINATION
7 = TRIUMPHANT
13 = FORCEFUL
17 = PROLONGED
19 = DECISIVE

8 = ACCIDENTAL
9 = ASKING FOR HELP
10 = DONE IN FRUSTRATION
11 = WARY
12 = HALF-HEARTED
14 = FEARFUL
15 = ABSENTMINDED
16 = SOCIABLE
18 = PLAYFUL
20 = AMUSES SELF W/SOMETHING ELSE
21 = BORED
22 = FRUSTRATION VOICED DURING ACT, BUT ACT NOT DONE IN FRUSTRATION
23 = CONFUSED
24 = UNINTENTIONAL
27 = EXTREMELY BRIEF

INHIB

✓= Evidence that the baby stops himself ONCE the act has started, i.e., the baby stops himself MIDWAY thru the act
X= Evidence that baby could NOT stop his act midway (e.g., drops toy, but continues act of retrieving & only then goes back in for toy)

WHY STOP

1 = E Resisted/Intervened
2 = Bad Angle (As In Using the Far Hand on Side Open, or When Hand is Oriented in an Awkward Position)
3 = Other Hand Didn't Hold Box Up High Enough (When RAISING Box)
4 = Parent Intervenes
5 = Difficulty Grasping Toy
6 = Box Out of Reach Without Straining
7 = Toy Out of Reach
8 = Toy Falls Off Table
9 = Parent Held Baby Too Close to Box
0 = Box m'v't Catches Baby's Attention/Interrupts Act

INTERRUPT

✓= This act was not directed toward the goal of getting the toy (usually either because baby gives up or gets interested in something else)

ELICITOR

E = Experimenter elicits the act
P = Parent elicits the act
O = Other external elicitor
5 = Box hit baby

Examples of when this is used:

1) Experimenter speaks & it distracts the baby who looks up at E. Write E under Elicitor.
2) A loud noise distracts the baby. Write O.
3) Baby has given up. Mother nudges him back to the table. He gives the box another try. Write P under Elicitor for the 1st act AFTER the Interrupt.

Do NOT use this if the baby gets interested in E's hand or E's ring WITHOUT E having done anything to call the baby's attention to her

SEQUENCES

Do any acts seem to go together as one unit?
Usually, if acts are part of a sequence they will overlap one another.

= No. of times the act occurred.
Use this for repeated acts if you do not want to distinguish the acts from one another in any way.

EFFECT

BM = Box moved	1 = Slight movement
TM = Toy moved	2 = Much movement
N = Noise	

More than one can be coded for an act if necessary.
Do NOT use 1 or 2 for noise.
If BM & TM are both coded for a single act, use 1 & 2 to refer to BM.

COMPARE

Where appropriate, compare this act to a similar one during this trial or an earlier trial.

A1 means the baby put MORE energy, confidence, determination, or enthusiasm into this act than into Act 1 of the same trial.

A4 T2 means the baby was less certain, more hesitant, less enthusiastic, had less faith in this act than in Act 4 of Trial 2. Indicate Trial # only when comparing acts from different trials.

REVIEW TRIAL AFTER YOU HAVE CODED ALL ITS ACT FOR COMPARE.

REVIEW SESSION AFTER YOU HAVE CODED ALL ITS TRIALS FOR COMPARE.

EYES

ONLY use categories for LOOKS THRU SIDE

LOOK ALONE	TOUCH ALONE	LOOKS THRU SIDE	LOOKS AT TOY	LOOKS	
				TO &	FRO
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

ANSWER EACH TIME BABY: REACHES FOR TOY
HITS
TOUCHES
POINTS
TESTS SIDE

ANSWER EACH TIME E : TRAILS TOY
SLIDES BOX
TOUCHES TOY IN BOX

LOOKS THRU SIDE

0 = LOOKS AT HAND, NOT TOUCHING OR NEAR TOY
1 = LOOKS THRU SIDE HE IS REACHING DURING ENTIRE REACH
2 = LOOS THRU SIDE HE IS REACHING UNTIL HE TOUCHES TOY
3 = LOOKS THRU SIDE HE REACHING DURING BEGINNING OF THE REACH BUT NOT DURING THE END OR THE REACH. (STOPS LOOKING BEFORE TOUCHING)
4 = LOOKS THRU SIDE ONLY BEFORE REACH BEGINS
5 = DOES NOT LOOK THROUGH THAT SIDE AT ALL IN CONNECTION WITH THIS ACT (NEITHER JUST BEFORE THE REACH NOR DURING IT--LOOKING THRU ANOTHER SIDE OF BOX THRUOUT)
6 = LOOKS AWAY
7 = LOOKS AT TOY, TOY NOT IN BOX
8 = LOOKS THRU, OR AT, SIDE THEY ARE REACHING BUT NOT AT TOY THRU THAT SIDE
9 = LOOKS THRU SIDE REACHING, THEN TO ANOTHER SIDE, THEN BACK TO SIDE

REACHING

29 = LOOKS THRU OPENING AT END OF ACT

30 = LOOKS AT TOY, THEN AT HAND, THEN AWAY

31 = AT OPENING, THEN AT TOY THRU ANOTHER SIDE

32 = " " " " " THRU OPENING

33 = AT TOY THRU-OUT; TOY STARTS OUTSIDE BOX, CONTINUES LOOKING AT IT THRU OPENING AS TOY RE-ENTERS BOX

34 = THRU ANOTHER SIDE, THEN THRU SIDE REACHING

35 = THRU ANOTHER SIDE, THAN AT HAND

36 = AT HAND, THEN THRU ANOTHER SIDE

37 = THRU SIDE REACHING THEN AT HAND

38 = AT EXP HAND, THEN THRU ANOTHER SIDE

39 = THRU ANOTHER SIDE, THEN AWAY

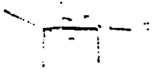
40 = THRU ANOTHER SIDE, THEN AT EXP HAND

41 = AT TOY THRU-OUT, 1ST NOT IN BOX, THEN THRU ANOTHER SIDE

45 = AT TOY THRU OPENING

50 = AT EXP.

51 = THRU FT EDGE



55 = AT TOY

E-8

LOOKS AT TOY

0 = LOOKS AT TOY AT BEGINNING, LOOKS AWAY, THEN BACK TO TOY AT END OF REACH.

1 = LOOKS AT TOY DURING ENTIRE ACT

2 = LOOKS AT TOY BEFORE HE TOUCHES, BUT NOT AFTER

3 = LOOKS AT TOY ONLY AFTER HE TOUCHES IT (DURING RETRIEVAL)

4 = DOES NOT LOOK AT TOY AT ALL (UNTIL RETRIEVAL IS ALMOST COMPLETED)

5 = LOOKS AT HAND, RATHER THAN AT TOY

6 = LOOKS AT HAND AT BEGINNING, THEN FOLLOWS IT TO TOY (SO SEES TOY BEFORE TOUCHES AND THROUGHOUT REST OF REACH)

7 = LOOKS AT OPENING(SIDE ACTING ON) AND AT TOY, BUT THRU A DIFFERENT SIDE.

8 = LOOKS AT OPENING

9 = LOOKS AT E HAND

2___ = LOOKS AWAY FIRST AND THEN ___

E.G., 22 = LOOKS AWAY FIRST AND THEN LOOKS AT TOY BEFORE HE TOUCHES IT, BUT NOT AFTER

(repeat above list for 21 thru 29)

4___ = LOOKS AWAY AFTER; 1ST____

(repeat above list for 41 thru 49)

SEE INSIDE (BLUE SHEET): SEE OPENING (2) INDICATES BABY CANNOT SEE TOY THROUGH OPENING, BUT <u>CAN</u> SEE THE OPENING ITSELF

TO TIME EYES: TIME TO SEEING INTO THE OPENING, THE BABY DOES NOT NEED TO SEE THE TOY THROUGH IT

RAISES BOX

USE ALSO FOR TIPPING & TURNING (SIDE TO FRONT)

HI BOX

1 = SLIGHTLY RAISED (<10°)
2 = HALFWAY UP (10° - 60°)
3 = VERY HIGH (>60°)

COMP BOX

> = ANGLE IS > ACT __
= = " " = ACT __
< = " " > ACT __

SEE TOY THRU OPENING

WAS THE THE BOX RAISED HIGH ENOUGH FOR BABY TO SEE TOY THRU OPENING?

1 = NO
2 = YES, BUT DID NOT SEE IT
3 = YES, BUT BABY HAD TO LEAN IN ORDER TO SEE TOY THRU OPENING
4 = YES, EASILY

WHEN REACH

FOR RAISING:

0 = BOX DOES NOT COME DOWN
1 = BABY GRASPS TOY BEFORE BOX COMES DOWN
2 = HAND TOUCHES TOY BEFORE BOX COMES DOWN
3 = HAND ENTERS BOX BEFORE BOX IS DOWN (BUT FINISHES RETRIEVING TOY W/ BOX DOWN)
4 = AS HAND BEGINS TO REACH, BOX COMES DOWN (REMOVES HAND FROM EDGE AS BOX COMES DOWN)
5 = HAND BEGINS TO REACH ONLY AFTER BOX IS DOWN (PULLS BACK BACK TO REACH)
6 = DOESN'T BEGIN TO REACH
7 = NO ATTENDING AT ALL
8 = E TERMINATES

FOR SLIDING:

BEFORE BOX COMES FULLY OVER TOY (EVEN JUST OVER), BABY:

1 = GRASPS TOY
2 = TOUCHES TOY
3 = IS INSIDE BOX (EVEN ONE FINGER IN)
4 = TOUCHES EDGE (OR SIDE) OF BOX AS BOX COMES OVER TOY -- NEVER GETS INSIDE BEFORE BOX COMES ON
5 = NEVER ACTUALLY TOUCHES BOX -- HALTS JUST BEFORE IT
6 = ONLY VERY BEGINNINGS OF REACH -- NEVER GETS RIGHT UP TO BOX & TOY
7 = NO REACH
8 = NOT ATTENDING

GOES IN, NO TOY

USE FOR: A) IF BABY REACHES IN FOR TOY, BUT WITHDRAWS HAND WITHOUT TOY FOR NO APPARENT REASON, OR

B) FOR INSTANCES OF RAISING, USE FOR "HOW FAR WAS BABY" WHEN BOX CAME DOWN.

IN BOX

0 = NOT IN BOX
1 = TIPS OF FINGS JUST INSIDE (BEFORE 2ND JOINT)
2 = UP TO KNUCKLE (AT LEAST ONE FING)
3 = UP TO WRIST (OR JUST BARELY BEYOND IT)
4 = PAST WRIST (WRIST-ELBOW)

FROM TOY

0 = NOWHERE NEAR
1 = TOUCHING
2 = 1/4" — 1"
3 = 1" — 3" (MODERATE)
4 = 3" — 4 1/2" (FAR)
5 = > 4 1/2" (VERY FAR)

TRAILING / SLIDING

FOLLOWS WITH:

0 = DOESN'T NOTICE
1 = EYES ONLY
2 = EYES FIRST, THEN HANDS
3 = EYES AND HANDS FOLLOW WITH WHOLE TIME

FOLLOWS TO:

0 = NO FOLLOWING WITH HAND
1 = EDGE OF BOX (AIR)
2 = EDGE OF BOX (TOUCHING)
3 = INSIDE BOX

TOUCH TOY:

0 = NEVER TOUCHES
11 = BEFORE TOY ENTER BOX (MOMENTARILY)
21 = AS TOY ENTERS BOX (MOMENTARILY)
12 = BEFORE TOY ENTERS BOX (MAINTAINS CONTACT)
22 = AS TOY ENTERS BOX (MAINTAINS CONTACT)
3 = AFTER TOY IS IN BOX

CODE E TRAILS AS AN ACT

FOR THIS ACT, CODE GOES IN NO TOY, AIM PROB, AND FINGS FOR BABY

FOR EYES CODE: WHEN TOY RE-ENTERS BOX, DOES BABY SEE IT THROUGH OPENING OR THROUGH ANOTHER SIDE?

IF BABY FOLLOWS: CODE SITE AND HAND FOR FOLLOWS UNDER SAME ACT AS E TRAILS

IT IS THE BABY'S FIRST LANDING THAT COUNTS HERE.

G = GRASPING B = BENT F = FIST
S = STRAIGHT C = CUPPED (OUTER SURFACE OF HAND TOUCHES)

REACT TO F TOUCH

= BABY'S REACTION TO GETTING HIS FINGERS CAUGHT ON AN EDGE, OR PERHAPS JUST BRUSHING THE BOX

THIS CAN BE CODED WHEN THERE IS NO AIM PROBLEM. YOU DO NOT NEED AN AIM PROBLEM FOR THIS CATEGORY TO APPLY.

THERE CAN BE MORE THAN ONE ANSWER HERE PER ACT.

00 = PULLS BACK BEFORE EVER TOUCHING
01 = AT MERE TOUCH OF BOX, BABY RECOILS, WITHDRAWS, OR STOPS
USE THIS FOR SLIGHT BRUSHES OF THE BOX.
02 = FINGERS CAUGHT AT EDGE, BABY RECOILS, WITHDRAWS, OR STOPS

BABY NEITHER WITHDRAWS HAND NOR UNCATCHES FINGERS & GOES IN:

	STRAINS	NO STRAIN
GETS TOY	12	11
NO TOY	14	13

11 = FINGERS CAUGHT ARE NOT A REAL HINDRANCE; THE BABY IS ABLE TO GET TOY EASILY ANYWAY
13 = AN EXAMPLE MIGHT BE THAT THE BABY CAN TOUCH THE TOY WITHOUT STRAINING, BUT CANNOT GRASP IT UNLESS HE STRAINS OR UNCATCHES HIS FINGERS, BUT HE NEVER STRAINS OR UNCATCHES

21 = UNCATCHES FINGERS & PROCEEDS IN (EVEN IF HE GETS CAUGHT AGAIN IN THE PROCESS)

25 = JUST REMAINS PUT

30 = REFLEXIVELY GRASPS BOX

F

Is the baby's FOREARM (wrist to elbow) touching the box?
LOOK FOR THIS ON <u>TOP</u> <u>OPEN</u> TRIALS. VERY IMPORTANT.

FINGS

1 = pointer
2 = index
3 = ring
4 = pinky
5 = thumb
P = palm

OTHER

A = in the air
B = other

For NON-CENTRAL HAND, under FINGS EDGE do not specify FINGS.

For HAND DOING THE ACT,

Do NOT code:
1) when hand is on box, other than at an open edge or inside opening
2) when act ends on aim problem so that the coding of aim prob tells us all we need to know

Code:
1) when hand is at an open edge, or inside opening, & the act does NOT end on an aim problem
2) when hand is NOT on the box

AIM PROBLEMS

1ST DIGIT=
SIDE

FRONT = 0
LEFT = 1
RIGHT = 2
BACK = 3
TOP = 4
CORNER 1 = 5
FT EDGE = 6
LT EDGE = 7

2ND DIGIT=DIRECTION
OF ERROR

UP (TOO HIGH) = 1
DOWN (TOO LOW) = 2
LEFT = 3
RIGHT = 4
SHORT = 5
LONG = 6
LOW & SHORT = 7
LOW & LEFT = 8
HIGH & LEFT = 9
RIGHT & SHORT = 0

3RD DIGIT=
SPECIFIC PLACE

4TH DIGIT=

FINGERS IRRELEVANT = 0
FINGERS BEFORE 2ND JOINT = 1
FINGERS AFTER 2ND JOINT = 2
WRIST OR BEYOND = 3
FINGERS NEVER TOUCH ANYTHING = 4

0111= AIMED FOR F SIDE, BUT WENT TOO HIGH & HIT FT EDGE (FINGERS BEFORE 2ND
0112= " " " " " " " " " " " " " PAST 2ND)
0120= " " " " " " " " " " UNDERSIDE OF TOP
0143= " " " " " " " " " " CORNER 2 (CENTER OF PALM)
0133= " " " " " " " " " " CORNER 1 (CENTER OF PALM)
0152= " " " " " " " " " " TOP

0211= " " " " " " " LOW, " " EDGE OF TABLE (BEFORE 2ND
0220= " " " " " " " " " WENT UNDER TABLE
0232= " " " " " " " " " HIT TABLETOP

0331= " " " " " " " FAR TO LEFT, & HIT CORNER 1
0342= " " " " " " " " " " " " LEFT SIDE
0360= " " " " " " " " " " " MISSES BOX ALTOGETHER
0371= " " " " " " " " " " " HITS LT EDGE
0381= " " " " " " " " " " " HITS LF EDGE
0320= " " " " " " " " " " HITS INSIDE OF LEFT

0420 = aimed for F side, but went too far to RIGHT, caught under RU edge
0441= 0411 = aimed for F side, but went too far RIGHT, & hits RIGHT side
0460 = " " " " " " " " " " misses box altogether
0471 = " " " " " " " " " " hits RT edge
0412 = " " " " " " " " " " hits RF edge
0432 = " " " " " " " " " " hits inside of R side

0560 = " " " " " " " " SHORT, & misses box altogether
0582 = " " " " " " " " " " hits FT

0952 = " " " " " " " HIGH & LEFT, hits CORNER 1

1152 = on LEFT side, aimed too HIGH, hit CORNER 1
1112 = " " " " " " " TOP [hit LT edge]
1122 = " " " " " " " LT edge
1130 = " " " " " " misses box altogether
1160 = " " " " " " hits underside of top
1173 = " " " " " " " FT

1241 = " " " " " LOW " TABLETOP
1252 = " " " " " " " front EDGE OF TABLE

1432 = " " " " " far right, hit TOP of box
1411 = " " " " " " " hit TOP of box
1452 = " " " " " " " " CORNER 1
1421= 1462 – " " " " " " " " LF edge
1472 = " " " " " " " " FT edge

1512 = " " " " " SHORT, fingers went outside F side
1521 = " " " " " " " hit LF edge
1531 = " " " " " " " " LT edge
1550 = " " " " " " " hit tabletop
1542 = " " " " " " " " inside of F

1640= 1360 = " " " " " far LEFT, misses box altogether
1331 = " " " " " " " hits LT

1631= 1611 = " " " " " " BACK, hits LB edge
(Carey: 1613 = overshoot long to LEFT)
1623 = " " " " " " " went around B side
1661 = " " " " " " " hits INSIDE of BACK side
1652 = " " " " " " " " LB + LT

DO NOT USE 1631, 1632, 1630
or
1641, 1642, 1640

1072 = on left side, aimed too SHORT & RIGHT, hit FT
1043 = " " " " " " " " hit FRONT side
1022 = " " " " " " " " hit LF edge

2163 = aimed for RIGHT, went too HIGH, hits TOP of box
2147 = " " " " " " hit underside of TOP
2112=2171 = " " " " " " finger caught on RT edge

2240 = " " " " " LOW, went under table
2252 = " " " " " " hits front EDGE of TABLE
2312 = " " " " " far LEFT, hit top
2322 = " " " " " " " hit RF edge [corner 2]
2332 = " " " " " " " hit FT
2422 = " " " " " far RIGHT, hits inside of R side
2412 = " " " " " " " hit RF
2572 = " " " " " SHORT, hit RT edge
2511 = " " " " " " " FRONT side
2522 = " " " " " " " RF edge
2532 = " " " " " " " FT
2612 = " " " " " far BACK, hit RB edge
2633 = " " " " " LONG, hit TABLETOP
2912 = " " " " " HIGH & LEFT, hits RT

4252 = on TOP OPEN, aimed too LOW, hits RF
4240 = " " " " " " hit underside of TOP
4233 = " " " " " " hit FT
4222 = " " " " " " hit Corner 2
4273 = " " " " " " hit RT edge
4280 = " " " " " " went under table
4261 = " " " " " " hit LT
4342 = " " " " " far to LEFT, & got caught on LT edge
4471 = " " " " " " " RIGHT," " " " RT edge
4393 = " " " " " " " " hit R side [Carey: 4293]
4510 = " " " " " SHORT, & hit TABLETOP [Carey: FT]
4610 = " " " " " LONG, & hits BOTTOM of box

4660 = on TOP OPEN, aimed too LONG, misses box altogether
4642 = " " " " " " hits LT
4712 = " " " " " LOW & SHORT, hit CORNER 1
4732 = " " " " " " " " hit FT edge
4012 = " " " " " far RIGHT & SHORT, hit CORNER 2
4521 = " " " " " SHORT, hit FT edge

5510 = aimed for CORNER 1, too SHORT, hit TABLETOP

6220 = aimed for FT edge, too low, hits F edge of table
6270 = " " " " " " " RF
6551 " " " " " SHORT to grasp it, hits FT, fingers slide off
6564 = " " " " " " misses box
6512 = " " " " " " hit FT and F
6210 = " " " " " LOW, went under table
6364 = " " " " " far LEFT, misses box
6721 = " " " " " LOW & SHORT, hit FRONT
7240 = " " LT " " ", hits L side
7411 = " " " " " far RIGHT, hit TOP
8173 = " " RF " " HIGH, hit RT
8252 = " " " " " LOW, hit front edge of table

8523 = aimed for RF edge, too SHORT, hand cupped at RF, F
9452 = " " LF " " LOW, hits edge of table
9422 = " " LF (to grasp), too far to R, hits LF with edge of hand

APPENDIX F

SITES

001 - 008 corners:
see sheet with diagram

010 - 029 Sides/Edges:
010
011- F (front)
012- T (top)
013- L (left)
014- R (right)
015- FT = TF
016- LT = TL
017- LF = FL
018- RF = FR
019- U (under) or bottom
020- B (back)
021- LT + RT
022
023- RT = TR
024- LB = BL
025- RB = BR
026- BT = TB
027- FU = UF
028- LU = UL
029

030 - 049
031- LF + RF
032- both sides (L + R)
033- F + R
034- F + T
039- R + T
040- box flipped over
041- F + L
042- RT + LF
043- R + L
044- LB + RF
045- R + FT
046- corners 1 + 2

047- LT + FT

048- L + T

049- L + 2

050 - 059

050- Away

051- Away to E

052- Away to L

055- Away to R

060 - 069

060- far left of box

065- toy not in box

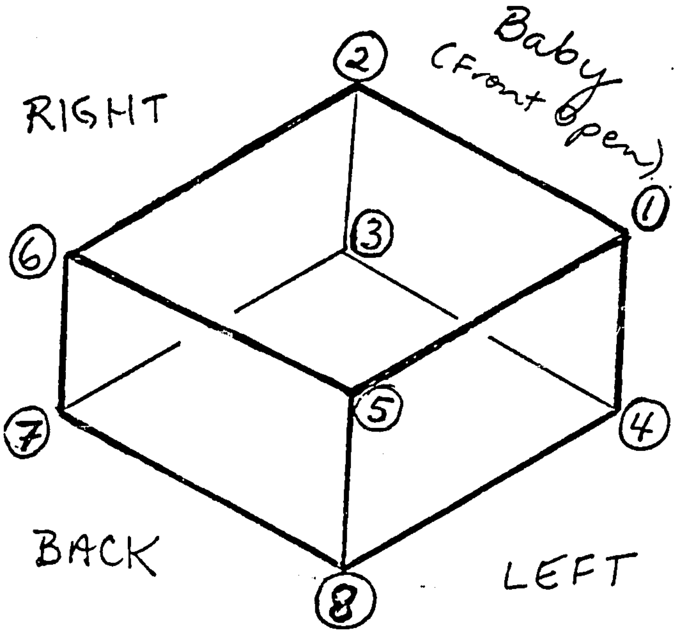
070 - 099

070- tabletop

071- table edge

075- air

080- E hand



APPENDIX G

ACT CODES

001 - 009 : Reaches, Hits, Touches, Points, Scratches

001 - 019 : Reaches for Toy

001 R parallel to box
002 R (pts.,scratch)
003 R to where toy was when E trailed
004 R,exerts force
005 begins (as if to) R, but nothing
006 starts to go in, but stops
008 opens,closes hand in air (grasping)
009 R (fings. 1,5)
010 R
011 R aborted
012 R (touches box)
013 R (hits)
014 R (slides)
015 R (toy not in box)
016 R (searching, hovers)
017 R (tests)
018 R (scratches)
019 R (pushes)

020 - 029 : Hits box

020 Hits
021 Hits aborted
022 Hits (R)
023 Hits (table)
024 Hits lightly
025 Hits (tries turn)
026 Hits (scratches,reaching)
027 Hits (toy out)
028 Touches (tries turn)
029 Wipes box

030 - 039 : Touches box

030 Touches
031 Touches aborted
032 Touches (R)
033 Touches lightly
034 Touches (grasps)
035 Touches (pts)
036 Touches table (R)
037 Touches (tries R or turn)
038 Wipes table
039 Touches (inhib turn)

040 -049 : Points at toy

ACT CODES

040 Pts.
041 Pts. aborted
042 Pts. (R)
045 Pts. at opening
044 Pts. (scratching, R)
047 Pts. (grasps)
048 Pts. (scratches)
049 R (pts.)

050 - 059 : Scratches box

050 Scratches
051 Scratches aborted
052 Scratches (R)

060 - 069 : Goes inside box (for toy)

060 Goes in
061 Goes in, withdraws
062 Tries to go in
063 Starts in while box up, closed side

070 - 079 : Goes to opening

070 Goes to opening
071 Goes to opening, followed E hand
072 R, stops, never enters tho at open
073 Goes to box, doesnt touch
075 Goes to table, to side of box

080 - 084 Grasps Toy

080 Grasps toy
081 Tries grasp toy, box mvt prevents
082 Goes to opening, doesnt try enter
083 Touches toy
084 Pulls toy out a bit

085 - 089 Grasps Box

085 Grasps box (R)
086 R, exerts force (try turn)
087 Tries to R or turn
089 Touches box, en route

090 - 099 Reaches in & gets toy; Retrieves toy

090 Retrieves toy
091 Tries 2-handed, but both wont fit
092 Conts. reach and retrieves
093 Ignores box, tries 2-handed retrieval
095 2-handed retrieval
096 Tries to get toy out closed side

ACT CODES

097 R, pushes toy out

110 - 159 Tests side, Pokes side, Slides hand along side, Runs hand along surface

110 - 119 Tests Side

110 Tests side
111 Tests side (R)
112 Tests side (slides)

120 - 129 Pokes Side

120 Pokes side

130 - 139 Slides Hand Along Side

130 Slides hand along side
131 Slides (testing)
132 Starts to slide, inhibits

140 - 149 Runs Hand Along Surface of Box

140 Runs hand along box
141 Goes along edge
142 Goes along edge, en route

150 - 159 Strokes Box

150 Strokes side of box

200 - 399 : Means-End Behavior -- Raises, Turns, Pulls, Pushes, Tilts, Tips,
Tips, or Lifts Box

200 Holds box in place while R

210 - 219 Raises box

210 Raises box
211 Raises F of box
212 Raises Rt. of box
213 Raises L of box
215 While box up, grasps & raises more
216 Raises slightly

220 -229 Turns box

220 Turns box
221 Grasps box & turns
222 Box turns
223 Box turns slightly
224 Turns box wrong direction
225 Turns/raises
226 Turns as if to discard
227 Turns box further

ACT CODES

228 Turns box slightly
229 Grasps & turns slightly

230 - 239 Pulls box/ Pulls box toward self

230 Pulls box
231 Pulls/grasps
232 Pulls further
233 Helps other hand pull
237 R, pulls
238 Pulls box slightly

240 - 249 Pushes box/ Pushes box away from self

240 Pushes box
241 Pushes, raises
242 Pushes, turns
243 Pushes box slightly
245 Pushes (R)
246 Pushes box, as if to discard
247 Pushes & lifts
249 Pushes & pulls

250 -259 Tips Box

250 Tips box
251 Grasps & tips
252 Tips & pulls
253 Tips further

260 -269 Raises or Lifts Box

260 Raise or lift
261 Raise/lift/turn

270 - 279 Moves box

270 Moves box
271 Moves box, flips over, toy out
272 Moves box as if to discard
273 Pulls & turns

280 - 289 Tilts box

280 Tilts box

290 - 299 Lifts box/Lifts box off toy

290 Lifts bx
291 Pulls & lifts box
292 Lifts box partially off toy
293 Lifts & turns
298 Lifts & tilts

ACT CODES

300 - 309 Exerts force on the box

300 Exerts force
301 Exerts force, grasps box
302 Exerts force, tries R or turn
306 Exerts force to R or to raise self

310 - 319 Tries to Raise Box

310 Tries to raise box
311 Tries to raise F of box
312 Tries to raise Rt. of box
313 Tries to raise L of box
314 Grasps, exerts force (tries raise?)
315 While bx up, tries: grasp, raise more
316 Tries to raise slightly

320 - 329 Tries to Turn Box

320 Tries to turn box
321 Tries to grasp box & turn
324 Tries to turn box wrong direction
325 Tries: turns/raises
326 Tries to turn as if to discard
327 Tries to turn box further
328 Tries to turn box slightly
329 Tries to grasp & turn slightly

330 - 339 Tries to Pull Box Toward Self

330 Tries to pull box
331 Grasps & tries to pull
332 Tries to pull farther
333 Tries to help other hand pull
334 Tries to pull or raise
335 Tries to pull or tilt
336 Tries to pull box or raise self
338 Tries to pull box slightly
339 Tries to turn or pull

340 - 349 Tries to Push Box Away from Self

340 Tries to push box
341 Tries: pushes, raises
342 Tries: pushes, turns
343 Tries to push box slightly
346 Tries to push box, as if to discard
347 Tries: pushes & lifts
349 Tries: pushes & pulls

350 - 359 Tries to Tip Box

350 Tries to tip box

ACT CODES

351 Tries to grasp & tip
352 Tries to tip & pull
353 Tries to tip further

360 - 369 Tries to Raise or Lift Box

360 Tries to raise or lift
361 Tries: raise/lift/turn

370 - 379 Tries to Move Box

370 Tries to move box
372 Tries to move box as if to discard
373 Tries: Pull & turn
375Tries: pull box or raise self

380 - 389 Tries to Tilt Box

380 Tries to tilt box

390 - 399 Tries to Lift Box
390Tries to lift box
391 Tries: pulls & lifts box
391 Tries to raise/lift F
392 Tries to lift box partially off toy
393 Tries: lifts & turns
398 Tries: lifts & tilts

400 - 499 : Experimenter Trails Toy, Exp. Slides Box; Baby Follows

410 -419 Trails

410 E trails
411 Trails & squeaks
412 Trails halfway

420 - 429 Slides

420 E slides box
421 E begins trial by sliding box
422 E slides box halfway

430 -439 Show & Change

430 E turns box & returns it

490 - 499 Follows

490 Follows
491 Tries to follow (hands held)
492 Follows out, but not back
493 Begins R as box comes over toy

ACT CODES

500 - 599 : Other Acts by Experimenter

500 E moves toy toward baby
501 E moves box
502 E puts baby's hand in box
503 E replaces box over toy
504 E picks toy out of box, holds it in air
508 E holds toy up; increases graspable area
509 E moves toy back to original position

510 - 519 Exp Touches Toy in Box (Exp's Hand Inside Box)

510 E touches toy
511 E squeaks toy
512 E moves toy (hand inside)
513 E pts. in opening, squeaks toy
514 E touches toy quick & brief
515 E moves toy to edge of opening
516 E taps toy (part of toy out
517 E taps toy (in box)
518 E moves toy deeper in box
519 E moves toy slightly from Front wall, then back
520 - 529 Exp Moves Toy (Hand Outsdie; Moves Toy by Moving Box)

520 E moves toy (by moving box)
521 E jostles toy in box (out)
522 E moves toy (by moving box)
523 E moves box & toy toward baby (out)
525 E makes noise w/box to get atten.
526 E uses box to move toy toward baby

530 - 539 Exp Points in Opening/ Pokes Finger in Opening

530 E pts. in opening
531 E pts. at babys L hand
532 E taps babys L hand

540 - 549 Exp Goes to Opening (no pointing, not inside)

540 E goes to opening

550 E moves toy partly out
551E moves toy toward opening
552E moves box back slightly
553 E moves toy away from F wall
554 E moves toy back to F wall
555 E replaecs toy back in box
556 E moves b slightly, toy nearer open
557 E moves b so toy at edge of opening
558 E moves b closer to baby
559 E moves b slightly, toy nearer open

ACT CODES

560 E raises ht. of toy in box (T open)
561 E moves toy slightly in & out of opening

570 - 579 E turns box; Misc.

570 E turns box
571 E turns box slightly
572 E straightens box (returns box to its original position)
573 E tries to straighten box
575 E lowers box
576 E tuns box so toy much out
578 E moves b to R or L so S can see in

580 - 589 Experimenter Raises Box

580 E raises box
581 E raises F
582 E raises R
583 E raises L
584 E raises box further
585 E tips box
586 E holds b up after S raises it
587 E raises box quickly/slightly
590 E terminates trial

600 - 639 : Grasps Edge

600 Grasps Edge
601 Tries to grasp edge
610 Touches box, grasps edge
615 Grasps (R)
620 Grasps edge lightly
630 Aborted R for edge

650 Pts. at mirror
680 Withdraws hand from box
681 Takes hand off toy, stays in box
692 Box too close, touches box, accident
694 Supports self on box
695 Touches E hand
696 Fingers tape
697 Baby resists (as E tries straighten)
698 Conts. previous act
699 Trial not on tape

700 - 799 : Eyes, Torso, or Mouth

710 Leans & looks
711 Leans further & looks
712 Starts to lean & look, stops self
713 Leans slightly & looks
714 Leans back, throws self back
715 Raises self to look thru T

ACT CODES

716 Leans & looks at opening
717 Tries to raise self to look thru T
718 Leans slightly & looks at opening
719 Leans forward
720 Looks at toy
721 Peeks in opening
722 Looks at opening
723 Looks bet. E & toy in box
724 Looks in open (doesnt see toy)
725 Turns head to look at toy
726 Leans to side
727 Leans to side & looks in F
728 Looks at own hand
729 Looks at box

730 - 757 Interrupts

730 Rocks body
731 Rubs eyes
732 Bounces
738 Fusses
739 Cries
740 Goes back in frustration
741 Starts to cry
742 Looks away & voc.s
750 Looks away
751 Looks at E
752 Turns & looks away
753 Looks away & cries
754 Looks up & fusses
755Closed & fussing
756 Closed & crying
757 Starts to turn away

758 Turns back to box
759 Looks where toy last seen
760 Mouths box
761 Goes for toy w/mouth
762 Reaches for toy w/mouth
770 Brings mouth down to box
771 Leans down, mouth open
772 Brings mouth near box, as if for toy
780 Pushes table away
781 Pushes self away from table

800 - 899 Miscellaneous

800 Pushes toy back in box
810 Mother repositions baby
811 Mother restrains baby
815 Toy falls on floor
816 Toy rolls partiallly out
817 Toy flies out

ACT CODES

818 Toy rolls in box, to edge
820 Pushes toy out of reach
822 Pushes toy deeper in box
830 Accidentally touches & moves toy
831 Hand goes in by accident
840 Hand to R of box
841 Hits E hand
850 Raises & lowers hand (what to do?)
860 Toy & box move
861 Toy comes partially out
862 Moves toy
870 Pushes box to L
871 Accidentally pushes box down

APPENDIX H

Baby's First Name ________________ Visit # ______

END OF TRIAL ______.

TIME - Length of trial: ___ min. ____ sec. n/a

LIKE TOY 3 - Baby's level of interest in toy: 0 1 2 3

LIKE TOY 4 - Evidence upon which your rating was based:

Watches toy attentively	A	P	E	n/a
Smiles	A	P	E	n/a
Vocalizes	A	P	E	n/a
Maintains interest re:play	A	P	E	n/a
Reluctant to relinquish	A	P	E	n/a

INTO GAME - Pleasure in SUCCESS,ITSELF A P E n/a

APPLAUSE - Baby's reaction to applause: (Can check 2 ans.s)

NONE OBVIOUS ENJOYMENT IMITATION n/a

DO W/ TOY - What does the baby do with toy once he gets it out?

- __ Transfers it to other hand
- __ Two handed grasp
- __ Mouths it
- __ Shows it to E or P
- __ Studies it
- __ Loses interest in it
- __ Shakes it
- __ Squeaks it
- __ Bangs it
- __ Drops it
- __ Throws it down

E MOVE BOX - What does E do with box once trial is over?

- __ Moves it out of baby's reach
- __ Moves it back, but not completely out of reach
- __ Doesn't move it __ Pushes it closer to baby

DO W/ BOX - What does baby do with the box once the trial is over? (Number in order of occurrence.)

- __ Strains for it w/ toy in hand
- __ Strains for it (empty hand)
- __ Out of reach
- __ Stares at it
- __ Mouths it __ Turns it
- __ Grasps opening & glances in
- __ Reaches (w/ toy)
- __ Reaches (empty)
- __ Picks it up
- __ In reach, nothing
- __ Puts hand in it
- __ Throws it on floor
- __ Bangs it

BOX TOY - What does the baby do with toy & box? (No. in order.)

- __ Puts toy deep inside box
- __ Puts toy just inside box
- __ Puts toy just <u>outside</u> box
- __ Puts toy <u>on</u> box
- __ Looks as if will put toy in opening (grabs box, looks in opening), but never puts toy in
- __ Looks back & forth between box & toy
- __ Goes back to start position
- __ Nothing
- __ Bangs together
- __ Retrieves toy

GIVE ME - E asks for toy w/ outstretched hand. Baby's response =

GIVES TOY NO RESPONSE REFUSES n/a

Coder ______

BEGINNING OF TRIAL ____

LIKE TOY 1 - Baby's level of interest in toy: 0 1 2 3

LIKE TOY 2 - Evidence upon which your rating was based:

Waves hands or bounces	A	P	E	n/a
Smiles	A	P	E	n/a
Vocalizes	A	P	E	n/a
Tries to grab toy	A	P	E	n/a
Chooses it over other toys	A	P	E	n/a
watches toy attentively	A	P	E	n/a

H START - Where do the baby's hands start?

1. WIDE TO SIDE 2. TO SIDE

3. IN FRONT OF OPENING 4. IN OPENING

5. UNDER TABLE

BOX TABLE - How close is front edge of box to front edge of table?

7. extending over 0. right at edge

1. 1/4" - 1 1/2" 2. 1 1/2 - 3" from edge

4. 3 - 4 1/2" 5. > 4 1/2" from edge

TOY REACH - How close is toy to baby? 1. x is Almost touching

2. Extremely close 3. Very close

4. Easily within reach

5. Barely within reach 5. Out of reach

BOX L-R - Is the box directly in front of the baby? YES

Slightly to R	Far to R	Very far to R
Slightly to L	Far to L	Very far to L

TOY SITE - Furthest extent of toy:

FORWARD ____, BACK ____, R ____, L ____, UP ____

E HAND - Where are E's hands on the box? NOT TOUCHING

SIDES: __ ( ), __ ( ), __ ( )

EDGES: __ ( ), __ ( ), __ ( )

CORNERS: __ __ __

P HAND - Where is the parent touching the box? NOWHERE

SIDES: __ ( ), __ ( ), __ ( )

EDGES: __ ( ), __ ( ), __ ( )

CORNERS: __ __ __

REFLEX - Does baby continue grasping or sucking parent's finger?

__1. GRASP __2. SUCK __3. NO

Instructions for BEGINNING OF TRIAL (OBJECT RETRIEVAL)

LIKE TOY 1

0 = No interest. Baby does not want toy at all & will not take it if it is presented.
1 = Low interest. Baby is uninterested or bored with toy, but will pick it up if there is nothing else to do.
2 = Interested in toy.
3 = High interest. Baby loves the toy & wants it very much. Very high motivation to get that toy. Use this VERY conservatively.

If any answer to LIKE TOY 2 = EXTREME, then LIKE TOY 1 = 3 unless you see a good reason why not.

LIKE TOY 2

ONLY record evidence that occurred at the beginning of THIS TRIAL. IGNORE evidence from the end of the last trial.

ONLY code a behavior if it is done IN RESPONSE to the TOY. Do not code any of these behaviors if they are not in respone to the toy. A smile to the Experimenter, for example, does not count.

A = Absent P = Present E = Extreme n/a = not applicable.
Reserve E for truly extreme instances. Use it conservatively.

If the baby is allowed to play with the toy, and so the toy is presented once before the play & again before it is hidden, use BOTH presentations of the toy in answering the questions under, "When the toy is presented."

Do NOT code EYES WIDEN unless the baby is looking AT the toy. Do not code EYES WIDEN if that is only part of smiling or putting the toy in the mouth.

ANY vocalization that indicates that the baby wants the toy gets coded under VOCALIZES HAPPILY.

For TRIES TO GRAB TOY use n/a if baby's hands are held and the baby is moving (especially if his hands are moving). That is, if there is evidence that the baby might have tried to grab the toy. If the baby's hands are held and he remains still, the answer here is NO.

If baby's hands are held during presentation of toy, unless his hands are still, BANGS TABLE = n/a.

CHOOSES IT OVER OTHER TOYS: If no other toys present, write n/a. If, when a new toy is presented, he stares fixedly at that toy, ignoring the toy still in his hand, then CHOOSES b PRESENT for this new toy.

WATCHES TOY ATTENTIVELY must be present at least 50% of the time the toy is visible for this to be PRESENT.

H START

3. In Front of Opening
Use this if the baby's hands are held directly in front of the box, REGARDLESS of where the opening is. In other words, this category really equals IN FRONT OF BOX.

BOX TABLE

Use the box (one is 6", the other 4 1/2") to help estimate this.

TOY REACH

Refers to how close TOY is to baby, NOT how close BOX is.

2. Extremely close = box is so close it would be difficult for the baby to reach through the front (the baby would need to back up or push the box away in order to reach in) -- use this criterion REGARDLESS of whether or not it is the front that is in fact open.

3. Very close = box is so close that the baby (from his initial position with his hands held) cannot look through the front. Use this REGARDLESS of whether or not the front is in fact open. ASK if you are unsure; this must be PRACTICED with one person simulating the baby.

BOX L-R

Far = edge of box is at baby's midline.

TOY SITE

SO = slightly over (toy extends < 1/2: over edge of box)
MO = much over (toy extends ≥ 1/2: out of box)

Use the grids provided. (Example on next page with outline of bumblebee rattle superimposed on it.) The grid is the same size as the floor of the shallower box, 6" x 6". (The inner area, 2 boxes in from each side, is the same size as the deeper box, 4 1/2" x 4 1/2".) Place the toy on the grid as it appears in the box and then simply note its farthest extent front, back, left and by noting the number of the farthest box forward, the farthest back, etc. which the toy reaches. The boxes are numbered 1 - 13 from front to back and 1 - 13 from right to left (judged from the baby's position).

E HAND

CODE ALL SIDES THAT E TOUCHES AT ALL.
Do NOT code an edge without coding at least one of its adjacent sides, unless the Exp. is really only touching that edge.

1 = E is covering less than half its surface
2 = E is covering more than half its surface

REFLEX

Look especially during period when baby's hands are held and just as they are released. Is he grasping parent's finger? Is he sucking parent's finger?

Instructions for END OF TRIAL (OBJECT RETRIEVAL)

TIME: LENGTH OF TRIAL

Time from when hands are released to the 1st touch that leads to retrieval (even if the baby drops the toy in trying to get it out). That is, babies who are clumsy and have difficulty grasping the toy are not to be penalized for this: length of trial is to the beginning of the grasp even if it takes several seconds before the baby gets a firm hold on the toy.

LIKE TOY 3

This is based ONLY on the time from when the baby gets the toy out of the box to when E takes the toy away.

LIKE TOY 4

RELUCTANT TO RELINQUISH - if the baby is <u>not</u> holding the toy & he shows no distress to E taking the toy, the answer here is <u>n/a</u>. If he shows distress or reluctance, whether he is holding the toy or not, this is PRESENT.

INTO GAME

This is PRESENT if, when the baby removes the toy from the box:

1) he doesn't look at the toy initially, but instead smiles, looking up. i.e., indicates that his pleasure is not solely, or particularly, in having a toy, or
2) he holds the toy up triumphantly, or
3) during the play afterward, he puts the toy on the box and shows 1) or 2) after retrieving the toy.

APPLAUSE

If there is NO applause, the answer here is n/a, not none.

DO W/ TOY

Skip it.

MOVE BOX

If Experimenter does not move the box for several seconds (i.e., gives the baby time to have done something with it), then even if E moves the box, this movement doesn't count.

DO W/ BOX

The difference between <u>STRAINS</u> & <u>REACHES</u> is only in how far the baby had to reach for the box.

<u>W/ TOY</u> vs. <u>EMPTY</u>: refers to the HAND THE BABY REACHES WITH. Thus, if the baby is holding the toy in his left hand, & reaches for the box with his right hand, code: REACHES (<u>EMPTY</u>).

Code <u>everything</u> the baby does with the box. Number these in order.

BOX TOY

If, on any trial, interesting things happen here so that you cannot FULLY capture what has happened, make a note on a separate piece of paper. Someone else will go over this play period coding it in depth.

GIVE ME

Code this n/a, UNLESS E asks for toy
AND
E extends her hand for it.
If EITHER of these is not present, write n/a.

APPENDIX I

Baby's First Name ______________ Visit # ____

MOVEMENT / CHANGE

OVERLAP ACT __ ___ MOMENTARY ___
E HAND - SIDES: __ ( ), __ ( ), __ ( ) CORNERS: __ __ __
EDGES: __ ( ), __ ( ), __ ( ) N/A
P HAND - SIDES: __ ( ), __ ( ), __ ( ) CORNERS: __ __ __
EDGES: __ ( ), __ ( ), __ ( ) N/A
ORIENT - RB R RF F LF L LB B N/A
BOX TABLE - 7 0 1 2 4 5 N/A
BOX L-R - YES RIGHT: Slightly Far Very Far
LEFT: Slightly Far Very Far N/A
TOY SITE - F ___, B ___, R ___, L ___, UP ___. N/A
MOVED BY - EXPERIMENTER BABY N/A
SEE INSIDE - 1 2 3 4 5 N/A

MOVEMENT / CHANGE

OVERLAP ACT __ ___ MOMENTARY ___
E HAND - SIDES: __ ( ), __ ( ), __ ( ) CORNERS: __ __ __
EDGES: __ ( ), __ ( ), __ ( ) N/A
P HAND - SIDES: __ ( ), __ ( ), __ ( ) CORNERS: __ __ __
EDGES: __ ( ), __ ( ), __ ( ) N/A
ORIENT - RB R RF F LF L LB B N/A
BOX TABLE - 7 0 1 2 4 5 N/A
BOX L-R - YES RIGHT: Slightly Far Very Far
LEFT: Slightly Far Very Far N/A
TOY SITE - F ___, B ___, R ___, L ___, UP ___. N/A
MOVED BY - EXPERIMENTER BABY N/A
SEE INSIDE - 1 2 3 4 5 N/A

MOVEMENT / CHANGE

OVERLAP ACT __ ___ MOMENTARY ___
E HAND - SIDES: __ ( ), __ ( ), __ ( ) CORNERS: __ __ __
EDGES: __ ( ), __ ( ), __ ( ) N/A
P HAND - SIDES: __ ( ), __ ( ), __ ( ) CORNERS: __ __ __
EDGES: __ ( ), __ ( ), __ ( ) N/A
ORIENT - RB R RF F LF L LB B N/A
BOX TABLE - 7 0 1 2 4 5 N/A
BOX L-R - YES RIGHT: Slightly Far Very Far
LEFT: Slightly Far Very Far N/A
TOY SITE - F ___, B ___, R ___, L ___, UP ___. N/A
MOVED BY - EXPERIMENTER BABY N/A
SEE INSIDE - 1 2 3 4 5 N/A

Coder ____ Trial # ____

TRAILING / SLIDING / PUSHING

OVERLAP ACT T/S SPEED FOLLOWS W/: 0 1 2 3
__ ___ ___ ___ FOLLOWS TO: 0 1 2 3
TOUCHES TOY: 0 11 12 21 22 3

OVERLAP ACT T/S SPEED FOLLOWS W/: 0 1 2 3
__ ___ ___ ___ FOLLOWS TO: 0 1 2 3
TOUCHES TOY: 0 11 12 21 22 3

OVERLAP ACT T/S SPEED FOLLOWS W/: 0 1 2 3
__ ___ ___ ___ FOLLOWS TO: 0 1 2 3
TOUCHES TOY: 0 11 12 21 22 3

OVERLAP ACT T/S SPEED FOLLOWS W/: 0 1 2 3
__ ___ ___ ___ FOLLOWS TO: 0 1 2 3
TOUCHES TOY: 0 11 12 21 22 3

OVERLAP ACT T/S SPEED FOLLOWS W/: 0 1 2 3
__ ___ ___ ___ FOLLOWS TO: 0 1 2 3
TOUCHES TOY: 0 11 12 21 22 3

MOVEMENT / CHANGE

OVERLAP ACT __ ___ MOMENTARY ___
E HAND - SIDES: __ ( ), __ ( ), __ ( ) CORNERS: __ __ __
EDGES: __ ( ), __ ( ), __ ( ) N/A
P HAND - SIDES: __ ( ), __ ( ), __ ( ) CORNERS: __ __ __
EDGES: __ ( ), __ ( ), __ ( ) N/A
ORIENT - RB R RF F LF L LB B N/A
BOX TABLE - 7 0 1 2 4 5 N/A
BOX L-R - YES RIGHT: Slightly Far Very Far
LEFT: Slightly Far Very Far N/A
TOY SITE - F ___, B ___, R ___, L ___, UP ___. N/A
MOVED BY - EXPERIMENTER BABY N/A
SEE INSIDE - 1 2 3 4 5 N/A

Instructions for MOVEMENT/CHANGE (OBJECT RETRIEVAL)

LOOK FOR:

1) movement of BABY left-right (will get recorded under BOX L-R)
2) movements of the BOX
3) movement of E's hand (or Parent's hand) such that additional parts of the box are now covered.

If Adele codes with you, coder = 8.

I. OVERLAP

If a m'v't/change occurs between 2 acts, e.g. between acts 3 & 4, write: after A3.

II. MOMENTARY

A) If the change you are recording is momentary, put a check mark here.

B) If more than one change occurs during the same act, but at least one is momentary & at least one is permanent, USE 2 BOXES - one for the momentary change(s) & one for the other changes.

C) Suppose you had recorded:

during Act 5, momentary change, orientation of box = LF

then during Act 7, the baby again moves the box so that its orientation is LF

You would NOT write n/a for ORIENT for Act 7, but you would again record the change.

That is, it is assumed that after any momentary change, the box is back in its starting position - all movement/changes are judged from that starting position, not by anything recorded under the last momentary change.

When a change is not momentary, that is the benchmark against which all future changes are judged, not the start position.

III. GENERAL COMMENTS

A) Use n/a for any item where there was NO change during the Act you are dealing with. That is, do not answer any item except to indicate a CHANGE.

B) If the box moves as the baby reaches in & gets the toy (the last act of the trial) do not record this change. E will often aid the baby once the baby essentially has the toy - don't bother with this.

C) Look at the other coder's answers under EFFECT. His indications of BOX MOVED (BM) should help you identify during what act a movement has occurred.

IV. E HAND

A) When there is a change here, indicate every place E's hand is, not just the the additional place(s).

B) Do not record it when E removes a hand from a side or from the box altogether, but only when E touches any additional side of the box.

C) Remember when there is an addition, record every place BOTH of E's hands are.

V. ORIENT

This always refers to where the OPENING is EXCEPT for TOP OPEN, judge this by the orientation of the open back. (I like to turn the box upside down so that it is clear where this opening is).

(V. ORIENT cont'd)

Thus, if the trial starts out:

box: TOP OPEN

and the box gets moves:

TOP OPEN, ORIENT = LB,

If box moves - toy site often changes, even though the box itself has not moved. If box moves entirely <u>off</u> toy, the only two things that would get coded here are: TOY SITE & BOX L-R or BOX TABLE.

APPENDIX J

SIDE PREFERENCES

Baby's Name ______________________ Date __________ Time __________

TRIAL ______

LOOK FIRST - Which object did the baby look at FIRST? ____

LEFT RIGHT

LOOK TOTAL - Did the baby see BOTH objects? ____

YES ONLY LEFT ONLY RIGHT

POSITION - Were both objects placed an equal distance from the baby's midline? Was the object on the baby's right as accessible to his/her right hand as the object on the left was to his/her left hand? ____

YES LEFT CLOSER RIGHT CLOSER

START - Did s/he start out with one hand further forward, or more ready to reach, than the other? ____

NO LEFT RIGHT

APPROACH - Were both objects moved toward the baby at the same pace? ____

YES LEFT FASTER RIGHT FASTER

MANUAL CUE - Did the experimenter tap, shake, or gesture in any way with one of the objects more than with the other? ____

NO LEFT RIGHT

HAND - Which hand(s) did the baby reach with? ____

LEFT RIGHT

BOTH, AT ONCE BOTH, LEFT 1st BOTH, RIGHT 1st

REACH - Which object did the baby touch first? ____

BOTH LEFT RIGHT

VACILLATION - ____

__ Clear, immediate preference.

__ Hesitated a moment or more & looked at both.

__ Started to go for one, but ended up touching the other first.

OBJECT - Which object was used? ____

COMMENTS: