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OBJECT REPRESENTATION AND MEANS/ENDS COORDINATION IN
8-MONTH-OLD INFANTS' SEARCH FOR HIDDEN OBJECTS

A Thesis Presented

by

DANIEL D. MCCALL

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

February 1996

Department of Psychology

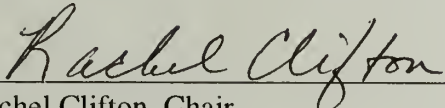
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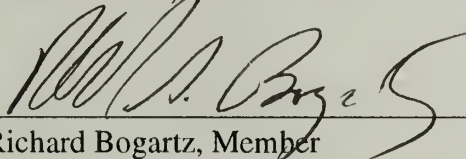
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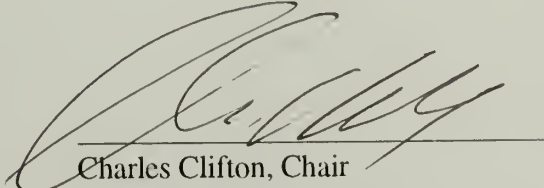
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ABSTRACT

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FEBRUARY 1996

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Although Piaget (1952/1954) may have underestimated the age at which infants achieve object permanence (Baillargeon, 1987), his empirical finding that infants will not reliably search for hidden objects until eight months of age has been widely replicated (Harris, 1987; Willatts, 1984). Although it is generally assumed that when infants lift the cover they do so in order to retrieve the hidden toy, this assumption can be questioned. An infant can, however, "succeed" on the search task without relying on, or acting upon, a representation of the occluded toy. An infant may reach and grasp the cover because he/she finds the cover interesting, thereby fortuitously revealing the occluded toy, and may then initiate a second reach for the (now visible) object. Such an infant would be mistakenly characterized as "searching" for the hidden toy.

The present study avoided such a confound by examining the previously untested ability of infants to search for occluded objects in the dark, so that the act of opening the cover does not reveal the toy. An opaque, plastic cover which opened and closed on a hinge was used to conceal a small toy. A rattle sound, at the location of the toy, was played only when the cover was closed, in order to guide infants' initial reaches in the dark. The sound was terminated upon opening the cover, so that infants who continued to search for the toy could not do so on the basis of any perceptual cues. Thirty eight-month-old infants were trained on the task in the light to ensure that they could successfully retrieve the toy when they could see it, and were then tested in the dark. Half of the infants had some trials in the dark when they had seen no object hidden, and half had some "surprise" trials on which they saw a toy hidden but it was snuck away after the lights were put out.

Reaching for the covered object in the dark was less frequent than the light, although 18 out of 30 infants did succeed in opening the cover and retrieving the toy, without the benefit of perceptual feedback. Frequency of responding in the dark did not differ whether infants had seen an object hidden or not. Further analyses examined the morphology of infants' search on each trial in terms of the number, duration, latency, and accuracy of reaches prior to and subsequent to opening the cover. Infants' search behavior in the dark differed from the light only in a longer latency to

initiate a response in the dark. Infants' responding in the dark did not differ on any of the above measures whether they had see a toy hidden or not.

Infants succeeded in searching for a covered object in the dark, performing a complicated, two-stage means/ends action without the benefit of visual feedback. However, infants searched for an object in the dark just as frequently regardless of whether they had seen one hidden or not. These findings replicate and extend those of Appel and Gratch (1984) who found that under similar training conditions infants would search in the light when no object was hidden. These findings suggest that either a) infants in the dark were simply executing a sequence of search behavior which had been conditioned through training in the light; or b) they were actively searching in the dark with the intention of retrieving a hidden toy, but they either forgot or did not notice from trial to trial whether or not a toy was hidden, and simply searched anyway.

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CHAPTER 1

INTRODUCTION

Literature Review

According to Piaget (1952,1954), one of the most important achievements of the sensorimotor period in infancy is the attainment of the object concept. Simply put, the 'object concept' is the notion that objects in the environment exist independently of one's perceptual or manual interactions with them, and as such forms the basis for developmental achievements beyond the sensorimotor period. An understanding of the spatial, temporal and causal relationships between objects is, according to Piaget, impossible without first coming to understand that objects exist as independent entities.

In Piaget's (1952, 1954) framework, at the core of the object concept lies the notion of object permanence - that objects continue to exist when occluded or otherwise not visible. This understanding of the permanence of objects provides the basis for the reasoning about objects which marks the existence of the object concept, and thus predates the appearance of a complete object concept. For Piaget, infants first became aware of the permanence of objects in sensorimotor stage IV (8-9 months of age), as indicated by their willingness to search for objects which had been occluded. The traditional test of infants' search behavior as employed by Piaget and

others (e.g. Harris, 1987; Willatts, 1984) is as follows: The infant's attention is drawn to an object, which is then placed on a table in front of the infant and within his/her reach. The object is then covered, either by a cloth or rigid cover such as a box, and the infant is given the opportunity to search. Prior to 8 months of age, infants will not remove the cover to retrieve the toy, unless the toy is only partially covered by the barrier. But by 8 months, infants will quickly remove the cover, release it, and reach for and retrieve the toy. Piaget argued that infants of this age have come to represent the object as permanent and retrievable. The failure of younger infants to uncover hidden objects was taken to suggest that they are not yet aware of objects as permanent entities. Prior to the formation of a sense of object permanence, objects are merely pictures for the infant - forms which they can follow, recognize, and act upon, but only when they are in view (cf. Gratch, 1976; Shuberth, 1983).

Recent evidence has called into question Piaget's interpretation of the search data. Studies using a visual habituation/dishabituation paradigm (e.g. Baillargeon, Spelke, & Wasserman, 1985; Baillargeon, 1987; Spelke, Breinlinger, Macomber, & Jacobson, 1992) as well as those employing a reaching-in-the-dark procedure (e.g. Wishart, Bower, Dunkeld, 1978; Clifton, Muir, Ashmead, & Clarkson, 1993) have suggested that infants may have an awareness of objects as permanent much earlier than Piaget believed, and

that infants' failure to search for hidden objects may reflect difficulties in motor coordination rather than the lack of a sense of object permanence.

Baillargeon (1987) describes a typical experiment using the visual habituation/dishabituation paradigm. She habituated 3.5- and 4.5-month-old infants to a screen rotating toward and away from them through a 180° path. She then placed a block behind the screen, and presented one of two trials. In one condition (the 'possible' condition) the screen rotated up to meet and stop at the block. In the other condition (the 'impossible' condition) the screen rotated the original 180°, while an experimenter surreptitiously removed the block. Infants looked longer in this 'impossible' condition than they did in the 'possible' condition, suggesting that they expected the screen to stop when it made contact with the object. Baillargeon therefore suggests that infants as young as 3.5 months of age had an awareness of the presence of the block behind the screen, even though they could not see it.

Several studies have now demonstrated that infants will reach out and retrieve sounding objects in the dark. Wishart et al (1978) and Clifton et al (1993) have indicated that infants as young as 4 months of age will localize a sounding object in the dark, and will accurately reach out and contact it. Clifton, Rochat, Perris, & Litovsky (1991) further investigated whether reaching in the dark was mediated by a representation of the target object. Six and one-half month old infants were trained in the light to reach for a

small and a big object, each of which was producing a different sound.

Infants' reaches were typically differentiated in that they reached for the small object with one hand only, but made a bimanual reach for the larger object. Following the training period, infants were tested with both objects in the dark. Based on sound cues alone, the infants also reached differentially to the small and big object in the dark, suggesting that they represented the objects as permanent entities, even in the absence of visual information.

The visual habituation and reaching data imply that infants show an understanding of the permanence of objects well before they begin to search for hidden objects. However, as Fischer and Bidell (1991) point out, contrary to the thinking of Baillargeon (1987) and Spelke et al (1988), these findings do not necessarily conflict with Piaget's theory of the development of the object concept. Fischer and Bidell conclude that the results found with the habituation paradigm merely indicate that the perception of objects is structured by physical knowledge at an early age. They further argue that the gradual nature of any developmental sequence predicts that given the proper task constraints, it is not surprising that abilities indicative of object permanence appear prior to the ability to search. Similarly, Munakata, McClelland, Johnson and Siegler (1994) suggest that representations of occluded objects may be gradually strengthened with development, such that

younger infants, while able to represent hidden objects, may be unable to use this representation to guide their search behavior.

What, then, is unique about the search task which prevents infants from succeeding until 8 or 9 months of age? Prior to 8 months infants seem to be well aware that objects continue to exist when hidden, yet are unable to incorporate this awareness into a sensorimotor scheme. The search task may impose constraints on infants' ability to plan or perform actions on objects. Piaget (1952) recognized that the ability to search, as a *sensorimotor* adaptation, is constrained as much by the planning and execution of motor behavior as by an awareness of the permanence of objects. Search behavior is unique in that it involves the coordination of multiple actions into a means/ends sequence: the act of removing the cover serves as the means for retrieving the object. Piaget argued that prior to the ability to search, infants are incapable of organizing actions in this manner. He claimed that early infant actions are circular in nature. That is, they are motivated by the immediate perception of the desired object. For Piaget, the emergence of manual search behavior in sensorimotor stage IV was more than simply an indication that the infant had achieved an understanding of object permanence - it was the first evidence of truly intentional action (Piaget, 1952, 1954; Flavell, 1963). The infant for the first time is able to coordinate previously circular reactions into novel sequences to achieve desired goals.

Baillargeon, Graber, DeVos, and Black (1990) likewise suggest that infants prior to 8 or 9 months of age are aware of the operations necessary for searching for a hidden object, but are merely unable to organize the necessary actions into the appropriate sequence. Younger infants are clearly capable of executing the various components of the means/ends task in isolation. They can accurately reach out and grasp objects placed within their reach, and can move objects in a manner comparable to removing covers from hidden objects. Their deficit is in the ability to unite these components into the proper sequence. Baillargeon et al adopt Newell and Simon's (1972) problem solving terminology to explain infants' difficulty with the search task. Success on a task requires a representation in 'problem space' of the various components of the problem, which include the 'initial state' confronting the solver, the 'goal state' - in this case the retrieval of the object, and the 'operators' or actions necessary for achieving the goal state. In the case of a multiple stage problem such as search, there are additional 'intermediate states' on the way to the goal state. The achievement of the goal state creates a stop order which terminates the execution of the sequence. The sequence necessary for success on the search task may therefore be represented as illustrated in Figure 1.

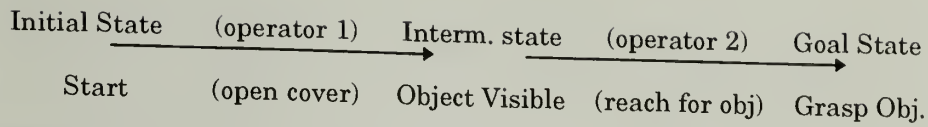


Figure 1 The action sequence necessary for successful retrieval of a hidden object.

Success on the search task represents an advancement over earlier occurring indications of object permanence like the ability to reach for sounding objects in the dark because it implies that infants are able to represent and coordinate the entire sequence of actions, while maintaining the representation of the goal state. The appearance of search behavior therefore implies that the infant has achieved two very significant and related milestones. The searching infant is now (a) able to represent the existence of an occluded object and maintain this representation as a goal of a complicated action, and (b) is capable of joining multiple actions into intentional, goal-directed, means-ends sequences.

Diamond (1991) has similarly suggested that prior to 8 or 9 months of age infants are unable to sequence motor behavior into means/ends actions. She presented physiological and behavioral evidence that implicates regions of the frontal cortex, the supplementary motor area (SMA) and the dorsolateral prefrontal cortex (DPC) in the coordination of sequences of actions. Monkeys with lesions to the SMA had difficulty executing a previously learned sequence of actions, although they could perform the individual components (Halsband, 1982, cited in Diamond, 1991). Adult

monkeys with lesions to the DPC, human infants, and infant monkey show similar patterns of failure on tasks which involve detouring reaches around barriers. Diamond argued that this concordance between the behaviors of adult monkeys with lesions, infant monkeys, and infant humans around 8 months of age suggests that infants' inability to succeed on means/ends tasks is due to the relative immaturity of the DPC and the SMA.

Another reason why younger infants may fail to successfully search for hidden objects concerns the physical demands and methodology of the task. Several authors have argued that as the search task has traditionally employed the use of a cloth or large box to cover the object, it may impose a further constraint on infants' abilities, as they may not see a cloth or large box as graspable and movable (e.g. Willatts, 1984; Rader, Spiro, & Firestone, 1979). This suggests that if one were to simplify the search task, younger infants would succeed. Rader, Spiro, and Firestone (1979) tested infants with small, easily graspable, rigid covers, and found that infants as young as 5 months of age would remove the cover and retrieve the objects. However, their suggestion that infants were truly searching for the toy is questionable, and illustrates a confound which in fact causes problems for all interpretations of infants' search behavior - the target object is available to perception once the cover is removed. As Willatts (1984) points out, early infant search behaviors do not appear 'intentional': infants will make an

initial reach for the cover and remove it, but will then spend a great deal of time playing with the cover before releasing it and retrieving the toy. It may be possible that the infants in the Rader et al study found the cover itself interesting and reached for it, thereby fortuitously revealing the target object. After examining the cover, subjects may have noticed the toy, and made a second reach to retrieve it. It is doubtful that these youngest infants were executing goal-directed, intentional, means-ends action sequences of the type that Piaget described.

Willatts (1984) attempted to overcome this confound by analyzing the amount of time that infants 5, 6, and 7 months of age spent interacting with and looking at the cover versus the toy. He determined that with age, search became more 'intentional', as indicated by the fact that older infants spent less time interacting with the cover than did younger infants. The oldest infants' search behavior was characterized as follows: upon the covering of the object, the infants immediately reached out, removed the cover (while maintaining visual fixation at the position of the object), and immediately made a second reach for the toy (either with the free hand or after releasing the cover). Thus Willatts concluded that the oldest infants searched *for the purpose of* retrieving the object. However, the finding that infants perform actions faster with age is not surprising, and Willatt's conclusion that older infants' search behavior was intentional is unsatisfying. In addition, his

measures may simply reflect the relative attractiveness of the toy versus the cover, which may in itself change with age. Because the hidden object is perceivable immediately upon removal of the cover, success on a search task does not require that the infant represent the hidden object as a goal. Ironically, a young infant who "searches" in the traditional Piagetian paradigm does not in fact need to represent the hidden object, nor does he/she need to execute an intentional means/ends action. An infant who makes two separate, goal-directed reaches - one for the cover and one for newly revealed toy, is difficult to differentiate from the infant who moves the cover as a *means* of getting to the toy - representing the toy as the primary goal of his action all the way through the sequence.

The Present Study

The present study was designed to overcome the confounds of the Piagetian search task in order to examine the representations which underlie infants' search for hidden objects. The present study investigated the search behavior of 8-month-old infants in an effort to address the two conceptual issues presumed to be the basis for success on the task: infants' ability to represent objects as permanent entities, or as goals of complex sequences of actions; and relatedly, their ability to execute multi-stage, means/ends actions.

To determine whether in fact infants are truly searching for the purpose of retrieving an object, it is necessary to show that the hidden object is represented as a goal during the execution of the means. Referring to the problem-solving diagram from Figure 1 (above), purposeful search would require that the infant represent the goal state (object) during the execution of operator 1 (removal of the cover). To investigate whether this is the case, perceptual information regarding the existence of the object was eliminated in the current study by testing the ability of infants to perform the search task in the dark. Testing in the dark required infants to act on the basis of a representation of both the cover and the hidden object, and forced them to execute both components of the means/ends sequence necessary to open the cover and retrieve the object without the benefit of visual feedback. During trials in the dark, an attractive sound was used to allow the infant to localize the covered object, but was terminated upon removal of the cover.

Consequently, the sound provided a cue to the infant that "something is there", and was available to guide their initial reach for the cover (operator 1), but did not provide any information regarding the presence of an object under the cover. In order to retrieve the object after opening the cover (the second operator in the means/ends sequence) infants in the current study were required to reach in silence and darkness. Thus perceptual information regarding the object's location was eliminated, and the successful retrieval of

the object demanded that infants act only on a representation of the occluded object. In addition, testing in the dark permitted the examination of the means/ends nature of infants' action sequences. Success on the search task in the dark required that infants plan and execute a two-step, means/ends action without the benefit of visual feedback about the target object and about their own hands. An infant who "searches" in the light by simply reaching for the cover because he/she finds it interesting, fortuitously revealing the toy, and then reaching for the toy, would not have succeeded in searching for an occluded object in the dark, as he/she would not have vision to guide him/her. In the present study, only a successfully planned and executed, two-step, means/ends action could result in retrieval of the toy.

To test further the assumption that infants uncover objects acting on a representation of the hidden object, two groups of infants were tested. The first group, in addition to being tested with a covered object in the dark, received "no-object" trials in the dark. After showing the infants that no object was hidden, the lights were extinguished and they were given an opportunity to interact with the cover alone. If infants' search behavior is typically mediated by a representation of the occluded object, then this condition should not motivate infants to search. Appel and Gratch (1984) have previously tested 8-month-old infants' search behavior in response to conditions when no toy was present, and reported that infants would refrain

from searching on “no-toy” trials. However, if infants in Appel and Gratch’s study were first given the opportunity to search for a toy and were then presented with a “no-toy” trial, they would then remove the cover and search for the non-existent toy. Appel and Gratch’s results question the intentionality of infants’ search behavior, implying that it is not mediated by the presence or absence of an object (or that, alternatively, infants will search whether or not they remember a toy is available). One-half of the infants in the present study were tested on “no object” trials in the dark to further address the role that the target object plays in guiding infants’ search behavior.

Conversely, a second group of infants was tested in the present study using “surprise” trials. In these trials, infants saw an object being hidden which was surreptitiously removed when the room lights were extinguished. If the object was in fact represented as a goal state for the infant, then it was expected that the retrieval of the object should cause the search behavior to terminate. If, on these “surprise” trials, the infant expected an object to be present but was unable to find it upon removing the cover and reaching for it, he/she should continue searching in the dark, as the goal state would have not yet been achieved.

Infants in the group who received “no object” trials saw that there was no toy present prior to dousing the room lights; whereas infants in the group

who received “surprise” trials saw a toy hidden underneath a cover which was later surreptitiously removed by the experimenter. Thus the resulting situation facing the infants in the two groups was identical - they were presented with a cover in the dark with no toy underneath. Therefore any differences in the behavior of the infants in the two groups on these trials must be due to events prior to the dousing of the room lights - namely, either seeing a toy hidden or not - and would suggest that their representation of the hidden object guided their search behavior.

In addition to appropriately testing infants' representational abilities, the proposed study attempted to simplify the traditional search task to remove potential motoric difficulties while retaining the essential means/ends structure of the task. As indicated above, the search task as traditionally conducted may present the infant with an unnecessarily difficult motor task. The covered object is usually presented on a table in front of the infant, and as such the infant may have difficulty retrieving the cover from the surface of the table. Infants may have difficulty with covers that are made of cloth or are too large to grasp readily. Also, to successfully retrieve a hidden object after removing a cover, infants must either release the cover or reach for the toy with their free hand, requiring a degree of bimanual coordination of which infants may not be capable until later than 8 months of age (Diamond, 1991). The apparatus used in the present study

was designed to overcome these potential difficulties. Covered objects were presented attached to rods which were extended toward the infant, facilitating access to the toy. In addition, the covers were designed to be easily graspable and movable, and a spring-loaded hinge ensured that the cover was easily released by the infant as soon as it was opened.

One final disadvantage of previous methodologies that was addressed in the present study concerns the method of data analysis. With the exception of the study by Willatts (1984), previous observations of infants' search behavior have focused exclusively upon their success or failure in retrieving a hidden object (e.g., Gratch, 1975; Harris, 1987, 19871; Piaget, 1952,1954). A coding scheme which simply observes whether or not an infant retrieves a hidden toy cannot determine if an infant is executing the search actions in a means/ends sequence, nor can it determine for sure if an infant is truly representing the object as the goal of his/her actions. A yes/no coding system fails to differentiate the child who 'unintentionally' retrieves the toy from one who systematically plans his/her actions and executes an intentional means/ends search. A coding system was designed for the present study which attempted to characterize infant behavior beyond a simple success or failure analysis, by examining the morphology of infants' interactions with the object both before and after they opened the cover. To better understand if and how infants use their knowledge of the continued

existence of a hidden object to guide their search, reaches were analyzed in terms of their frequency, duration, latency and accuracy - any of which could potentially reveal what an infant understood about the hidden object, beyond simply coding whether or not the infant retrieved the toy. To examine the sequential, means/ends nature of infants' interactions with hidden objects, search behavior was broken down into its various components - reaches before opening the cover, interactions with the cover, and reaches after opening the cover - and analyzed to address whether or not searching infants do in fact execute actions in means/ends sequences, and whether they can execute a means/ends sequence in the absence of visual information.

CHAPTER 2

METHOD

Subjects

Thirty infants, ranging in age from 32 to 37 weeks old ($M = 34.8$ wks) participated in the current study. Subjects were randomly assigned to one of two groups, the "no-object" group and the "surprise" group, each containing 15 infants. The no-object group contained 9 males and 6 females, of an average 35 weeks old (range = 32-37) and the surprise group contained 7 males and 8 females, averaging 34.7 weeks old (range = 33-36). Subjects were recruited from local birth announcements via a letter (see appendix A) and follow-up telephone call. All subjects were full-term births free of complications and had no colds or ear infections on the day of testing. An additional 13 subjects were tested but were not included in the final sample. Four were eliminated because they failed to search on trials in the light, 8 were eliminated because the session had to be terminated early due to fussiness, and 1 was eliminated due to experimenter error.

Apparatus

Testing was conducted in a two room experimental suite, consisting of an outer reception and equipment room and an inner testing room. The inner testing room was a double-walled, sound deadened chamber which was illuminated by two, 25-watt light bulbs positioned to provide dim, indirect

illumination. An infrared video camera was used to videotape during light and dark trials from directly overhead to facilitate later scoring of reaching behavior. The video signal was passed through a date-time generator to time trial duration and to aid in scoring of the videotapes.

The apparatus consisted of a table, 25 cm high, 150 cm wide, and 20 cm deep (see Figure 2). Attached to the top surface of the table were two aluminum rods, each 1 m in length, at 45° left and right of midline. The rods were attached to the surface of the table with supports which allowed them to slide freely toward and away from the infant. At the end of the rod, facing the infant, a small, attractive toy (Sesame Street "Big Bird" finger puppet, 8 cm x 4 cm, or orange tiger finger puppet, 7.5 cm x 4 cm) was attached with Velcro to allow the infant to remove it. Two different toys were used so that the experimenter could change toys when it was judged that the infant was losing interest in the game. The sound was played by a small speaker attached to the end of the rod just behind the object (see Figure 2). When the rods were fully extended, the object was within reach of the infant (approx. 15 cm away). This distance allowed the infant to easily reach the object, but also required him/her to fully extend his/her arm in a clear reach in order to obtain the object. When retracted away from the infant, the objects were well out of reach, and were pulled behind a curtain attached to the front of the table.

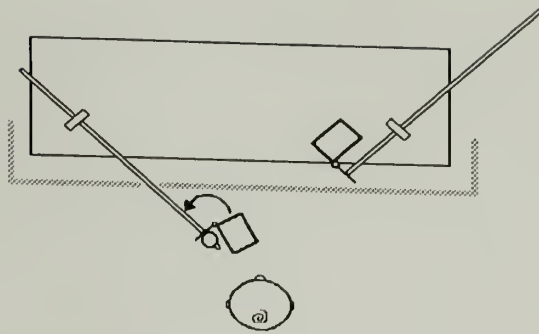


Figure 2 Top-view schematic of the apparatus used in the current experiment.

Also attached to the end of the rod was a cover consisting of a rigid, opaque plastic box, with one side left open to allow for easy grasping. The cover was attached with a hinge on one side to allow it to swing left and right, to cover and uncover the toy. The hinge was placed such that the cover on each side swung toward the center of the apparatus when opened (see Figure 2). A small spring attached to the hinge caused the cover, when moved in the correct direction, to swing fully open and remain open. This ensured that only one successful movement (a lateral swipe) in the correct direction (toward midline) was necessary to open the cover. This design was the result of extensive pilot testing, which determined that infants 5 - 7 months have no difficulty executing the necessary movement to open the cover.

Auditory Stimulus

The stimulus used during all trials was a pre-recorded rattle sound, played back from a reel-to-reel tape deck (Teac) through an amplifier (Onkyo A8170). The output from the amplifier was passed through a speaker switch-box which directed the output to the speaker at the end of each rod. The reel-to-reel tape deck, amplifier, and switch-box were located in the outer room and monitored by a second experimenter so as not to distract the infant during testing. This rattle sound has been used in previous studies with 6-month-old infants (Clifton, Perris, Bullinger, 1991; Perris & Clifton, 1988), and was found to be an attractive and easily localized sound. The sound was amplified to a comfortable level, and measured 59-60 dBA with a B&K sound level meter (on the "fast" setting) placed at the location of the infant's head.

Procedure

Each session required two experimenters. The primary experimenter interacted with the infant in the inner testing room and presented the trials. The second experimenter remained in the outer equipment room. This second experimenter monitored the audio and video equipment, timed the trials, switched speakers as necessary, and instructed the primary experimenter over headphones, giving trial type and duration information. The second experimenter also viewed the trials over a video monitor, and provided critical information during the dark trials, informing the primary

experimenter when the object was in position and monitoring infant behavior in the dark.

Infants were seated on their parent's lap in front of the apparatus. Parents were instructed to hold their infant securely at the waist, centered on their lap and facing forward, to allow for a full range of movement. They were further instructed to refrain from interacting with their infant during the testing, unless the infant became visibly upset during the procedure. Parents were asked to wear a set of headphones, over which they heard the same rattle sound heard by their infant. This was done in order to mask the location of the object in the dark, to prevent them from unintentionally cueing their infant.

Testing began with "demonstration" and "warm-up" trials, which were identical for both groups of infants. Subjects were first presented with one "demonstration" trial on each side: The experimenter knelt on the floor next to the infant, attracted the infant's attention to the toy, covered it, then grasped the cover and swung it open in a clearly visible manner. The modeling sequence was repeated two more times. The object was then covered again, and advanced toward the infant and left within reach for 20 seconds. The behavior was then modeled on the opposite side. Pilot testing indicated that the youngest infants tested (5.5 months) were capable of learning via observation of this type. Although infants in the pilot work who

did not see the appropriate behavior modeled were still eventually able to open the cover, they began to do so later in the session than infants who saw the behavior modeled. By modeling the behavior, we were able to shorten the session, an important consideration in working with young infants.

During the demonstration and all subsequent trials, the rattle sound was used to indicate when the cover was in position. The second (outside) experimenter activated the sound when the cover was closed, and terminated the sound as soon as the cover was opened - either by the first experimenter (i.e. during the demonstration trials), or by the infant.

After the demonstration trials, the experimenter stepped behind the apparatus, opposite the infant, to conduct the remainder of the testing. The infant was first presented with 4 covered-object trials, in the light, to serve as a "warm-up": The experimenter attracted the infant's attention, attached the object to the rod, closed the cover (while the second experimenter began the sound playback), and advanced the object to within reach of the infant. The infant was then given 20 seconds to interact with the object, after which the object was withdrawn out of view, behind the curtain, and the next trial was begun. As the ability of infants to perform this task was essential before the experimental manipulations could be carried out, any infant who failed to successfully uncover the object at least once on each side was not included in the final sample. As a warm-up, these trials were intended to familiarize the

infant with the situation before dark trials were presented, and to determine that the infant was willing and able to perform the task in the light. The presentation of these trials therefore remained flexible: if at the end of the four trials an infant had successfully reached on only one side, then a fifth trial was presented on the opposite side.

The side of the first trial presentation was counterbalanced for both groups as follows: one-half of the infants were presented a demonstration trial on the left first, then the right, and were then presented with 4 warm-up trials in the order left-right-right-left; the other half of the infants were presented a demonstration trial on the right first, then the left, and had 4 warm-up trials in the order right-left-left-right. This was done to control for any potential side bias.

Upon successful completion of these preliminary trials, test trials were started. Test trials for each group of infants consisted of 6 blocks of 3 trial types each, for a total of 18 test trials. The block design was to ensure that infants who failed to complete all 18 trials still contributed data to each of the conditions, and did not need to be eliminated from the study. Each subject was required to complete (i.e. not get fussy during) at least four blocks (twelve trials) to be included in the final sample. As detailed below, one group of infants (the “no-object” group) received, in each block, a covered-light trial, a covered-dark trial, and a no-object covered trial. The other

group (the "surprise" group) also received a covered-light trial and a covered-dark trial, but had a "surprise" no-object trial.

1. A covered-object light trial (all infants): The procedure was identical to the "warm-up" trials: the experimenter attracted the infant's attention, attached the object in full view of the infant, swung the cover over the object (while the outside experimenter started the sound), and advanced the object until it was within reach of the infant. This trial type was repeated once in each block in order to refresh the infant's memory about the task, and to refrain from presenting all trials in the dark, as infants would have gotten distressed during prolonged darkness.

2. A covered-object dark trial (all infants): The experimenter attracted the infant's attention, attached the object, and closed the cover (while the outside experimenter started the sound). He then doused the room lights (by depressing a foot pedal which switched the room lights off and switched on an infrared light source) and advanced the (now covered) object until it was within reach of the infant, as indicated over headphones by the second experimenter viewing the infrared video image in the outer equipment room.

3. A no-object covered dark trial (for the "no object" group): The experimenter attracted the infant's attention, swung the cover closed (outside experimenter started the sound), extinguished the room lights, and advanced the closed cover until it was within reach.

4. A "surprise" no-object covered dark trial (for the "surprise" group):
The experimenter attracted the infant's attention, attached the object to the end of the rod, and swung the cover closed (while the sound was started). The experimenter then extinguished the room lights, quickly removed the object, and advanced the (now empty) cover toward the infant until it was within reach.

All trials lasted for a period of 20 s, timed from the moment the object was within reach of the infant (as identified by the outside experimenter) after which the object and cover were retracted behind the curtain and the lights were turned on.

The order of presentation of the test trials was determined in the following manner. Six blocks of the three trial types (light, dark, and surprise or no object, depending upon the group) were created, with the order of the three trial types within each block randomized. These six blocks were shuffled to create a different protocol for each subject. Once the order of trials was chosen, a side of presentation was assigned to each trial in each protocol according to the following restrictions: from block to block, a given trial type could not be repeated on the same side; and across the entire session, no side could be presented more than twice in a row (two sample protocols, one for a subject in the surprise group and one for a subject in the no object group, are presented in Appendix B). These narrow criteria were

chosen to ensure that infants' behaviors would not become stereotyped to one particular side of the apparatus, and to ensure that the task would be variable enough to maintain infants' interest through an uncommonly long session (2 demo trials, 4 warm-up trials, and 18 test trials).

Data Scoring

Videotapes were scored by two independent observers. A primary scorer coded all of the data, and a secondary scorer coded 11 of the 30 subjects to check the reliability of the scoring system. All videotape coding was facilitated by a Visual Basic computer program which ensured consistency in coding, caught recording errors, and entered all data into a file for future analyses. Raters coded each of the completed test trials (up to 18) as detailed below.

First, raters identified the trial onset time. To ensure that all infants' behavior was coded for precisely twenty seconds, it was necessary for raters to identify the starting point of each trial. Trial onset was defined as the point at which the object stopped its advance toward the infant, and was taken from the date/time stamp on the video image. Occasionally, an infant would lean forward to intercept the object as it approached. In this case, trial onset was defined as the point at which the infant intercepted the approaching toy.

Once the trial onset was identified, the trial end was simply calculated as trial onset + 20 s. However, during testing, if an infant removed the toy from its Velcro attachment to the apparatus, the trial was terminated. If this happened prior to the calculated 20 s endpoint, the rater noted the time, and this became the trial end.

Next, the rater identified if and when the infant opened the cover, again noting the time from the time stamp on the video image. The time of opening the cover was taken as the moment that the infant *started* to open the cover. Occasionally, an infant would get the cover partially open, release it, and it would shut again (because the cover had not been opened far enough for the springed hinge to swing the cover away). This did not count as opening the cover, as the sound was not terminated and the infant did not have access to the covered object. Only if the infant succeeded in opening the cover far enough to gain access to the toy was he/she scored as successfully opening the cover.

Once the rater had identified the trial onset, endpoint, and time of opening the cover, he/she returned to the beginning of the trial to code the infant's reaching behavior for the duration of the trial. A template which had been drawn on clear film was placed over the image on the video screen, dividing the overhead image of the 180° reaching space in front of the infant

into regions (see Figure 3). To enable the coding of infants' reaching accuracy, the reaching space was divided into the following four regions:

1.) The target area - defined as the region occupied by the covered object when it was advanced to within reach of the infant.

2.) The non-target area - the same sized region as the target area on the opposite side of midline, indicating the position that would be occupied by the opposite side covered-object, if it had been in position.

3.) The target hemifield - the 90° region surrounding but not including the target area.

4.) The non-target hemifield - the 90° region surrounding but not including the non-target area.

With the template in Fig. 3 in place on the video screen, the rater watched the videotape of the trial and evaluated each arm movement to first determine if it was a reach. Reaches were defined as extensions of the arm away from the body in the direction of the apparatus. To be considered as a reach for this analysis, some part of the infant's hand had to cross the semi-circular dashed line on the template, thereby entering one of the regions. Incidental arm movements - those that resulted as part of a torso movement, a turn toward the parent, or a counterbalance for a change in posture - were not counted as reaches, even if they did cross into a region on the template.

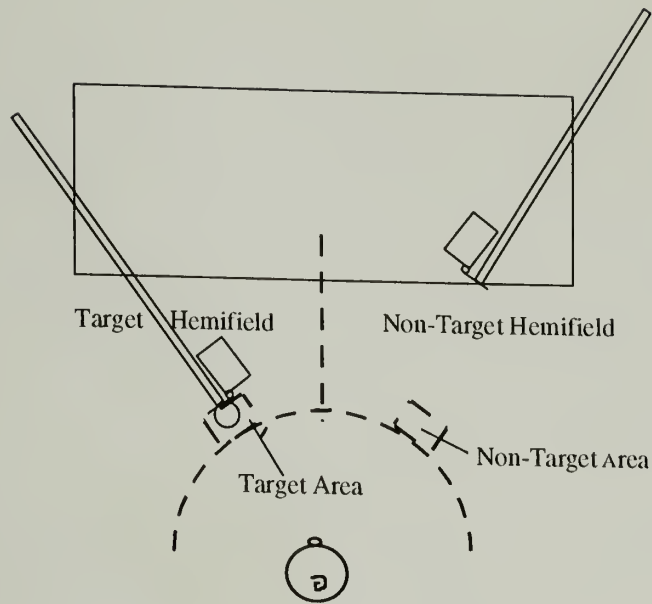


Figure 3 An overhead view of the apparatus with the video scoring template

Once an arm movement was identified as a reach, the rater coded the hand used as left, right or bimanual. Bimanual reaches were defined as those on which both hands entered the same template region within .5 s of each other. If the infant reached with two hands simultaneously, but into two different template regions, the reaches were coded independently.

Next, the region that the reach entered was coded, along with the time that the reach entered the region. The region was coded as the template region in which the reach terminated, regardless of whether or not the hand passed through another region en route. The time that the reach entered a

region was taken from the time stamp on the video image at the moment that any part of the hand touched the line on the template demarking the region.

The time the hand left the region - the endpoint of the reach - was also coded. This permitted the coding program to calculate the duration of time that the hand spent in the region. The time the hand left the region was coded as the moment that no part of the hand remained within the boundaries of the region on the template. Most frequently, this resulted from the infant retracting his/her hand back across the semi-circular border on the template. Occasionally, however, infants would make repetitive "batting" motions (usually at the target object) bringing the hand rapidly into and out of the region on the template. Rather than code each individual "bat" as a reach, the entire sequence of batting was coded as one reach, until the infant paused with his/her hand out of the region for at least 3 video frames (.1 s), at which point the reach was considered terminated. On rare occasions, an infant would extend his/her hand into one region, pause, then move laterally into another region, without retracting behind the semi-circular border. These lateral movements were coded as separate reaches as long as the infant paused between movements for at least 3 video frames (.1 s). If the pause was for less than 3 frames, the entire movement was treated as one reach, terminating in the final region entered.

Finally, if the reach was into the target area, the rater judged whether or not the hand made contact - either with the closed cover, or if it had already been opened, the object underneath the cover.

Coding continued in the same manner for each arm movement until the end of the trial - either 20 s after the trial onset time or when the infant removed the toy from the apparatus, whichever came first - and proceeded through each trial in the session. (See Appendix C for the complete videotape coding instructions).

Reliabilities

Inter-observer reliabilities were computed for all of the items rated from the videotapes, across the eleven subjects which were scored by the two raters. Percentage of agreement between the two raters was calculated as follows:

$$\% \text{ agreements} = \frac{\# \text{ agreements}}{\# \text{ agreements} + \# \text{ disagreements}} \times 100$$

For all of the continuous, time-based measures, an agreement was counted when the judgments of the two raters differed by no more than .25 s. The percentage of agreements for each of the measures is presented in Table 1. The coding procedure produced high levels of agreement, ranging from 90% for identifying reaches, to 100% for determining whether contact was made.

Table 1
Inter-observer reliabilities

Measure	Criterion for agreement	% agreement
Identifying trials on which a reach occurred	yes/no	99.2 %
Trial onset time	$\pm .25$ s	95.9
Time of opening cover	$\pm .25$ s	93.4
Identifying that a reach occurs	yes/no	90.0
Region of reach	yes/no	99.7
Time into region	$\pm .25$ s	97.4
Time out of region	$\pm .25$ s	96.0
Hand used	yes/no	100
Contact	yes/no	100

Data Reduction

Infants' responses on each trial were divided into the three principal components of the task - reaches prior to opening the cover, the action of opening the cover (if the infant succeeded in opening the cover) and reaches subsequent to opening the cover. In this way, comparison could be made between the two groups and between trial types in terms of a) the quality of their initial responses to the hidden object, b) their relative success at

opening the cover, and c) their responses after they open the cover. Each stage of the response can reveal something different about what the infant understood about both the existence (or absence) of the hidden object as well as the actions necessary to retrieve it. For instance, an infant who is deliberately searching for a hidden object may have fewer reaches for the closed cover, may open the cover more quickly, or may be more likely to reach out in the darkness after he/she opens the cover than an infant who knows nothing about a hidden object. Dividing the response into behavior prior to and after opening the cover is critical because the action of opening the cover, in addition to being the intermediary stage in a means/ends sequence, was the point at which the sound was terminated. Thus reaches after opening the cover must be treated differently from those prior to opening the cover. With this in mind, several different dependent variables were drawn from the raw reaching data. Table 2 presents all of the variables for each subdivision of the task. The number and duration of reaching measures presented in the table are self-explanatory. Accuracy of reaching was computed separately for each trial as the proportion of the total reaches which went into each region on the scoring template (target area (TA), target hemifield (TH), non-target area (NTA), and non-target hemifield (NTH)). The latency to initial response was calculated as the duration of time between the trial onset and the infant's first reach. Latency to open the cover is the time

between the initial response and the time that the cover was open. Latency to make a reach after opening the cover is the duration of time between opening the cover and making another reach.

Table 2
Dependent variables drawn from the videotape scoring

<hr/> <u>Prior to opening cover</u> <hr/>
number of reaches
duration of time spent reaching
accuracy of reaches (template region)
latency to initial response
<hr/> <u>Action of opening cover</u> <hr/>
latency to open cover
<hr/> <u>After opening cover</u> <hr/>
number of reaches
duration of time spent reaching
accuracy of reaches
latency to reach

The number of trials presented to infants could vary (from 4-6 of each trial type, due to the blocked design), as could the number of trials on which infants responded. For this reason, each of the dependent variables was averaged across trials, to yield a single value for each subject on each trial type.

CHAPTER 3

RESULTS

The present study had two main objectives. The first was to examine if and how 8-month-old infants' searching for hidden objects is dependent upon a representation of the occluded objects. Put another way, does the fact that an infant moves a cover and retrieves a toy reveal anything about what that infant understands about the hidden object? The second, related, objective was to examine infants' ability to combine multiple actions into meaningful, means/ends sequences. Each of these objectives will be addressed separately below. Basic descriptive information about individual subjects' responses will be presented first.

Response data for each infant on every test trial is graphically represented in Appendix D. Individual infants' responses were highly variable from trial to trial. Infants were usually successful at opening the cover and retrieving the toy on all of the light trials (because those who were unsuccessful were eliminated from the study - see Method section). They also performed the search task in the dark, although not as often. Table 3 presents the number of trials on which individual infants responded by a) reaching at all, b) reaching and opening the cover, and c) reaching, opening the cover, and making one or more reaches after opening the cover. Infants

Table 3 Number of trials on which individual subjects responded with each stage of search

Subject #	# of 3-Trial Blocks Presented	Light Trials			Dark Trials			Surprise or No Object Trials		
		Reach at all	Open cover	Reach after open	Reach at all	Open cover	Reach after open	Reach at all	Open cover	Reach after open
No Object Group	1	6	6	5	2	2	0	4	2	1
	5	5	4	4	4	3	3	5	5	5
	8	4	4	3	3	2	1	3	2	2
	9	6	5	4	4	4	3	6	5	5
	14	4	4	3	1	0	0	2	2	1
	16	4	4	4	1	0	0	0	0	0
	24	6	6	6	4	4	2	4	3	3
	26	6	6	6	0	0	0	0	0	0
	27	5	5	5	2	2	1	2	1	1
	30	6	6	6	5	4	3	4	3	2
	32	6	6	5	1	1	1	2	1	0
	35	4	2	2	0	0	0	1	1	1
	40	4	4	3	1	1	1	4	2	1
	41	4	2	2	4	2	1	3	3	3
	43	4	2	1	0	0	0	0	0	0
Surprise Group	3	4	4	2	4	1	1	3	1	0
	6	4	2	2	2	0	0	0	0	0
	11	6	6	4	6	4	2	6	6	3
	12	6	4	3	6	5	3	5	3	1
	13	5	5	2	3	2	1	2	0	0
	15	4	4	4	4	3	3	2	1	1
	19	4	4	4	2	2	1	3	3	2
	20	4	2	1	2	0	0	4	1	1
	25	4	4	4	4	3	2	4	4	3
	31	4	2	2	4	1	1	4	2	1
	33	4	3	3	1	0	0	3	0	0
	34	4	2	2	0	0	0	0	0	0
	37	5	5	4	1	1	0	0	0	0
	39	6	6	6	2	6	6	1	0	0
	42	4	1	3	3	0	2	3	1	0

did not universally succeed or fail on the search task in the dark. Most infants that succeeded in opening the cover and making a subsequent reach on trials in the dark also had trials on which they either failed to respond altogether, reached but failed to open the cover, or reached and opened the cover but failed to make a subsequent reach.

Object Representation

Infants' representation of the occluded object as well as the actions necessary for retrieving the object are examined in two ways. One is by comparing search behavior on the light and dark trials. In the dark, infants did not have the benefit of vision to guide their interactions with the cover and the concealed toy. Thus, if they execute the search behavior in the dark in a manner similar to the light trials, then it could be concluded that their actions are motivated by their representation of the occluded object. The second way that infants' representations are examined is by comparing responses of the two groups of infants. The two groups of infants (hereafter referred to as the "surprise" group and the "no-object" group) received identical covered-object test trials on the light and dark conditions. The third trial type differed for the two groups. The surprise group saw an object hidden underneath the cover, the sound started, the lights put out, and the object taken away. The no-object group saw the cover closed without an object underneath, the sound started, and the lights put out. Once the lights

were extinguished, the experience for the two groups was identical - they had a sounding cover with no object underneath. For this reason, the analyses of variance conducted below analyze trial type as a within-subjects factor with three levels - the light (test trials, not the demonstration or warm-up trials), dark, and the third trial type - which for the surprise group was a surprise trial and the no-object group was a no-object trial. If infants were searching for the purpose of retrieving the occluded object, we would expect to find few within-subjects trial type differences, as their behavior in the light and dark trials should be similar. This is especially relevant for their behavior after opening the cover, when the sound had been terminated. Likewise, if infant's search behavior was mediated by events prior to the lights going out (i.e., seeing an object or no object), than we would expect the ANOVAs below to find significant main effects of group, or perhaps a significant trial type X group interaction. Any difference in responding between the two groups on the third (surprise/no-object) trial type would suggest that the presence or absence of an object under the cover influenced their search behavior in the dark.

Likelihood of Response

Figure 4 presents the means of the individual subject frequency data in Table 3. Since subjects differed on the number of trials they were presented, Fig. 4 presents the means as the proportions of trials on which

subjects a) reached at all; b) opened the cover; and c) reached after opening the cover.

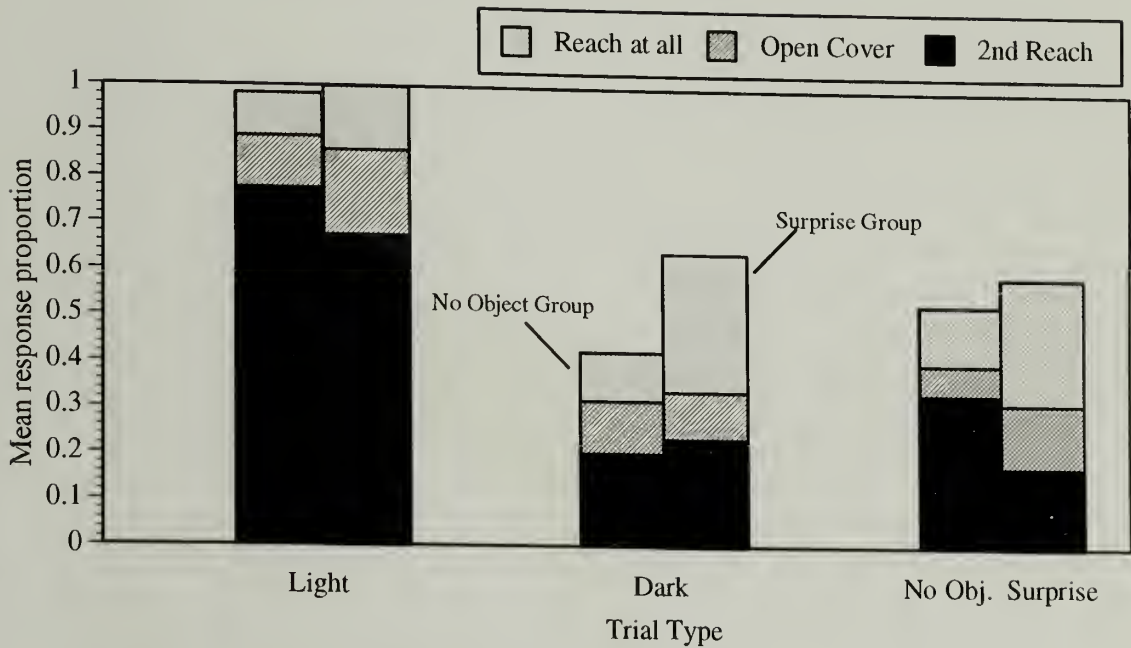


Figure 4 Average proportion of trials on which subjects performed each portion of search task.

Proportion scores were transformed using an $\arcsin\sqrt{\quad}$ transformation, in order to normalize the distribution. A 2(group) X 3(trial type) analysis of variance¹, with group as a between subjects factor and trial type as a within subjects factor was conducted on the transformed proportion of trials on which infants made at least an initial reach. There was no significant main

¹ These and all subsequent ANOVAs to be reported were first conducted using a larger, 2 (group) X 2 (gender) X 2 (side of first presentation) X 3 (trial type) model, and revealed no main effects of gender or side of first presentation, on any of the dependent variables tested. The smaller, 2(group) X 3(trial type) model has therefore been used throughout.

effect of trial type and no main effect of group, and no interaction. A follow-up contrast comparing the performance of the two groups on the surprise/no-object trial type was not significant. Dependent samples t-tests (collapsing across both conditions) revealed that infants were significantly more likely to reach in the light relative to the dark [$t(29) = 6.83, p < .001$] and in the light relative to the surprise/no object [$t(29) = 6.26, p < .001$] trials. This finding is not surprising, given that it has previously been reported that infants reach less frequently for sounding objects in the dark than they do in the light (Clifton, Rochat, Robin, and Berthier, 1994; Perris and Clifton, 1988).

Since the two trial types that were presented in the dark (the dark, object trial, and the surprise or no-object trial - depending upon the group) differed only in terms of the presence or absence of the object, each infant's score on the dark, object trial can be considered a baseline performance, against which the surprise/no-object performance can be compared. A difference score was calculated between the two trial types. An independent samples t-test on these difference scores, with group (surprise or no object) as the independent variable was not significant. Seeing an object being hidden under the cover or not seeing one hidden did not influence infants' likelihood of making an initial response.

A 2 (group) X 3(trial type) ANOVA conducted on the proportion of trials on which infants opened the cover revealed a significant effect of trial

type [$F(2,56) = 6.059, p < .01$] but no effect of group and no interaction. Follow-up comparisons revealed that this effect was due to the greater likelihood of opening the cover on the light relative to the dark trials [$t(29) = 6.83, p < .001$] and the surprise/no-object trials [$t(29) = 6.27, p < .001$]. With the benefit of vision, infants were more likely to successfully open the cover. A contrast between the two groups' performance on the surprise/no-object trials was not significant. Difference scores were again calculated between the dark and surprise/no-object trials, and an independent samples t-test using these scores was again not significant. Infants were just as likely to open the cover in the dark whether they had seen an object hidden under it or not.

A final 2 X 3 ANOVA was conducted on the proportion of trials on which infants made one or more reaches subsequent to opening the cover. Again, there was a significant main effect of trial type [$F(2,56) = 5.51, p < .01$] due to the greater likelihood of response on the light relative to the dark trials [$t(29) = 9.85, p < .001$], and the surprise/no-object trials [$t(29) = 7.42, p < .001$]. A contrast of the two groups' performance on the surprise/no-object trial type was again not significant, nor was a t-test on the dark - surprise/no-object difference scores. Infants in both groups were equally likely to reach out in the dark after they had opened the cover, regardless of whether they had seen an object hidden or not. Nevertheless, the fact that

infants succeeded at all in opening the cover and making a follow-up reach in the dark (after the sound had stopped) suggests that they were searching for the purpose of finding the object.

The presence or absence of an object underneath the cover did not seem to influence infants' likelihood of responding in the dark. Not only were infants in the two groups equally likely to reach out in the dark for the (sounding) cover, they were just as likely to open the cover and reach once the cover had been opened and the sound shut off. As an analysis of infants' *likelihood* of responding, the above does not address the quality of infants' responses - it is simply a measure of relative success or failure at each stage of the task. Given that infants respond just as often whether a toy is hidden or not, how might the nature of those responses differ in terms of the dependent variables drawn from the videotape coding - the number of reaches and their duration, accuracy and latency?

As shown in Table 3, an individual infant could respond differently in the dark from trial to trial - opening the cover and reaching for the toy on one trial, then failing to reach at all, then reaching but not opening the cover, etc. This variability in responding could reflect differences in how the infant was representing the task from trial to trial, but it could also be due to motivational changes, differences in attention prior to the lights going out, interactions with the mother between trials, emotional state, or any of a

number of immeasurable factors. It would therefore be mistaken to characterize such an infant as universally succeeding or failing on the task. For this reason, analyses for each of the dependent variables below are presented first for all trials, and then for the subset of trials on which infants succeeded at each stage of the task by reaching one or more times, opening the cover, and reaching one or more times after the cover was open. These latter trials were unique because, in making a reach after opening the cover, when the sound was off, infants could be assumed to be acting on some representation. Trials on which infants simply reach, or even reach and open the cover, but fail to reach subsequently suggest that the situation is represented differently than trials on which infants do reach after opening the cover. Prior to opening the cover, infants have the benefit of sound in the dark to guide their behavior, yet a reach in the dark after opening the cover is done in silence and presumably reflects a different level of understanding on the part of the infant. Analyses done separately on this subset of the trials may be a more accurate reflection of infants' representational abilities. Analyses are presented separately for each stage of the response - before and after opening the cover. In all cases, analyses exclude trials on which infants fail to respond at all. Since the previous analyses of infants' likelihood of responding has shown that the two groups do not differ in the proportion of trials on which they respond, then including such "no response" trials here by

averaging in zeroes would be redundant. Rather, these analyses are intended to describe the nature of infants' search behavior *given* that they search.

Excluding no-response trials in some cases eliminates entire infants - those who fail to respond on any trial of a particular type. On dark trials, 4 infants failed to make even an initial response on any trial and as a result those 4 plus 8 additional infants did not contribute data to the analyses of reaches after opening the cover (those additional 8 did reach at first, but failed to open the cover and make a subsequent reach on any trial). This leaves 9 infants of the 15 infants in each group who responded after opening the cover on at least one trial in the dark. On the surprise/no-object trials, 6 infants (3 in each group) failed to reach on any trial, and they plus an additional 6 infants (1 from the no-obj. group, 5 from the surprise group) did not contribute data to the analyses after opening the cover, leaving 11 infants in the no-object group and 7 infants in the surprise group.

Reaches Prior to Opening the Cover

The results above, while showing that infants in the two groups do not differ in their willingness to reach out, overlook potential qualitative differences between infants' responses. The analyses below attempt to characterize these initial responses to the closed cover.

Number of Reaches

Figure 5 presents the mean number of reaches prior to opening the cover per trial. Means were computed for each trial type by totaling the number of reaches on each trial, and averaging across trials to yield a single score for each subject. The means in Fig. 5 were calculated on these scores.

All Trials. A 2 (group) X 3 (trial type) ANOVA showed no main effects and no interaction. A follow-up contrast comparing the performance of the two groups on the surprise/no-object trials was not significant, nor was an independent samples t-test on differences scores between the dark and surprise/no object trials with group (surprise or no-object) as the independent factor. Infants in both groups, on all trial types on which they made at least one response, did not differ in the number of reaches they made prior to opening the cover.

Reach-Open-Reach Trials Only. The same tests again revealed no significant differences between any of the trial types nor between the two groups of infants.

The lack of differences here may be partly due to the fact that this analysis looks at only those infants who responded, and the averages did not deviate much from the minimum response of 1 reach. These results do, however, show two things. One, infants' initial reaching for a covered object does not differ from the light to the dark. If infants in the dark were simply

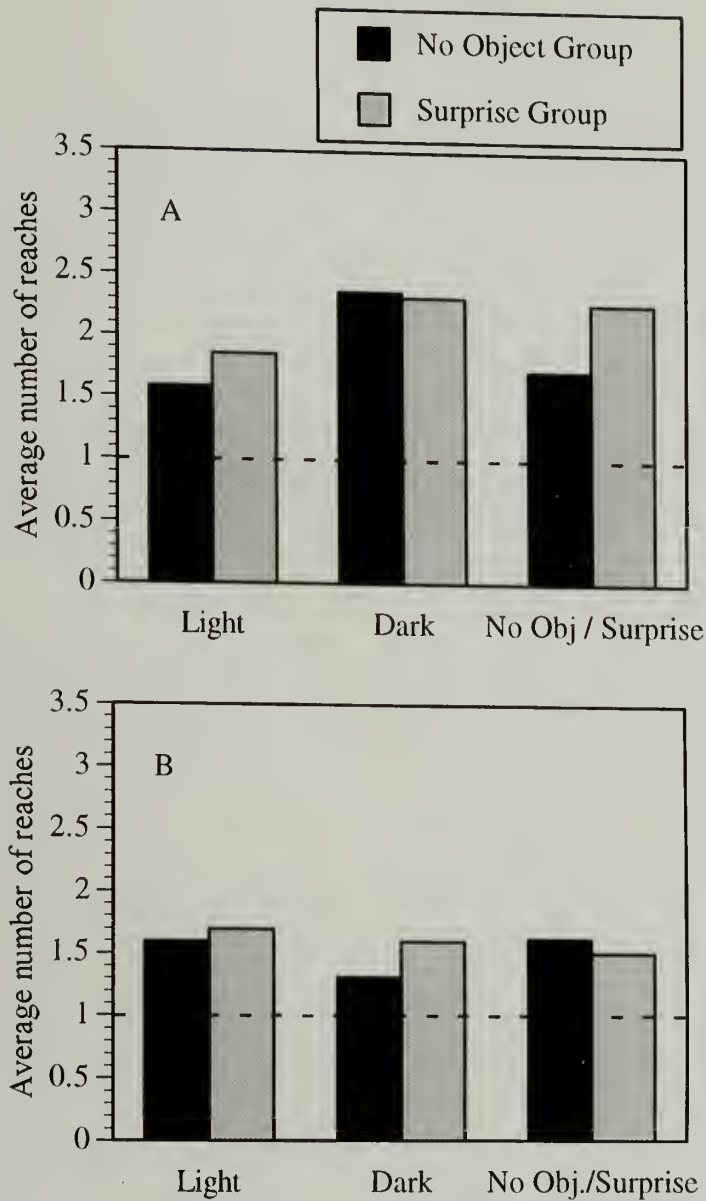


Figure 5 Mean number of reaches prior to opening the cover. Data is presented for all trials (A) and for the subset of trials on which infants reached-opened the cover-and-reached again (B). Note: Since no response trials were excluded, the dashed line indicates a minimum response.

reaching for the sound or reaching randomly, we might have expected that they would have reached more frequently than infants in the light, who were reaching in order to open the cover. Secondly, infants reached just as frequently for the sounding cover in the dark whether they had seen a toy hidden underneath the cover or not. Seeing an object hidden or not prior to the lights going out did not seem to influence the number of infants' reaches prior to opening the cover.

Duration of Reaching

An infant can make one, long-duration reach or several very brief ones. The number of reaches made is therefore considered independently from their duration, as each describes the quality of infants' responses in a unique manner. The durations presented here are the total duration of time spent reaching prior to opening the cover. Figure 6 presents the mean duration of reaching by condition and trial type for all trials on which infants responded (A) as well as the subset of trials on which infants made one or more reaches, opened the cover, and made one or more subsequent reaches (B).

All Trials. A 2 X 3 ANOVA showed no main effects and no interaction. A follow-up contrast on the surprise/no-object trial type and an independent samples t-test on the 2 groups' difference scores between the dark and

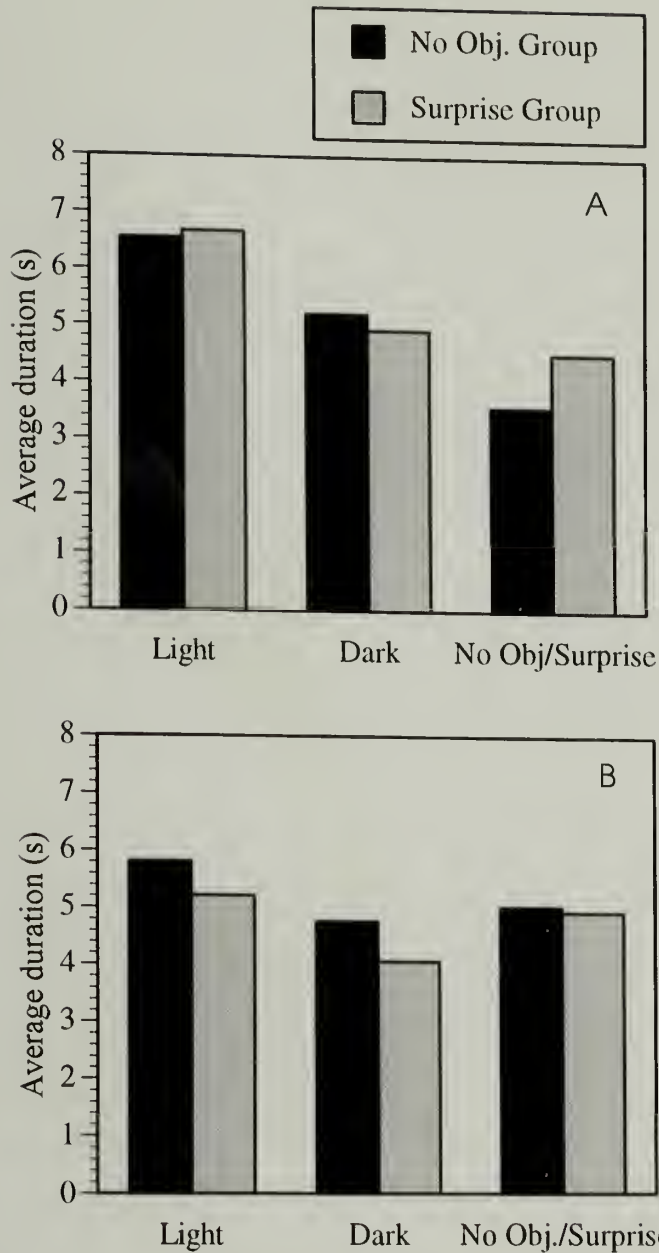


Figure 6 Mean duration of reaching prior to opening the cover. Data is presented for all trials (A) and for the subset of trials on which infants reached-opened the cover-and reached again (B).

surprise/no-object trials were not significant. Seeing an object hidden or not did not influence the duration of time spent reaching.

Reach-Open-Reach Trials Only. The same tests conducted on the subset of the trials on which infants reached, opened the cover, and made at least one more reach revealed no significant differences between any of the trial types or conditions. Prior to opening the cover, the average duration of time that infants spent reaching was similar for the light and dark trials. Also, like the number analyses above, duration of reaching prior to opening the cover was not affected by the presence or absence of an object under the cover.

Latency to Make a First Response

Figure 7 depicts the average latencies to make an initial response, by group and trial type, for all trials (panel A) and the reach-open-reach subset (panel B). Analyses had similar patterns of results, regardless of whether all trials were considered or only the subset. 2 (group) X 3 (trial type) ANOVAs showed a marginally significant main effect of trial type [all trials, $F(2,38) = 2.99, p < .10$; subset, $F(2, 24) = 3.09, p < .10$] and no interaction. Infants reached sooner in the light than they did on the dark trials [all trials, $t(24) = -7.31, p < .001$; subset, $t(17) = -3.65, p < .01$] and the surprise/no object trials [all trials, $t(21) = -5.3, p < .001$; subset, $t(17) = -2.27, p < .05$]. A contrast of the two groups' performance on the surprise/no-object trials, and an

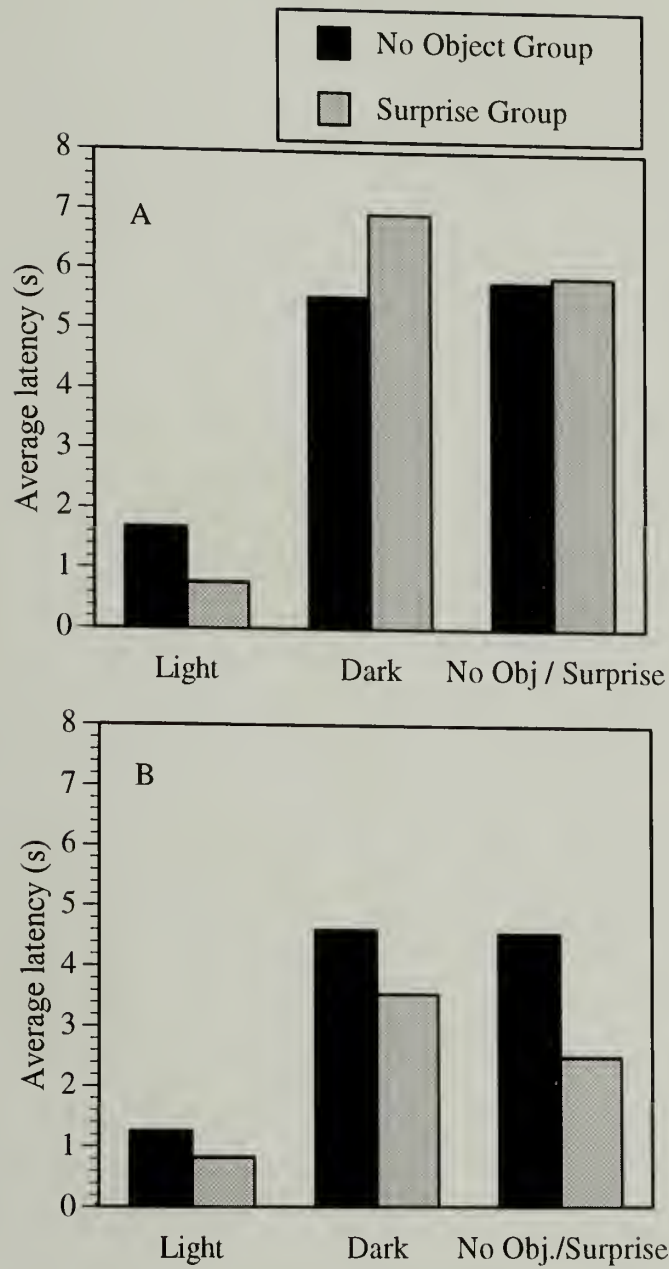


Figure 7 Mean latency to make an initial response, presented for all trials on which infants responded (A) and the subset of trials on which infants reached, opened the cover, and reached again (B).

independent samples t-tests on the dark - surprise/no object difference scores were not significant. Not surprisingly, infants were quicker to reach in the light than in either of the dark conditions. Infants frequently intercepted the advancing covered object in the light, contacting it before it stopped moving toward them, while in the dark they may have had to adjust to the change in room illumination before getting a reach organized. In addition, infants had to use sound localization to guide the accuracy of their reaches in the dark, while in the light they had the benefit of vision of the cover. In the dark, there was again no difference between the two groups on the critical third trial type (surprise/ no-object), again suggesting that the presence or absence of an object under the cover did little to influence infant's initial response.

Accuracy of Reaches

Figure 8 presents the mean proportions of reaches which entered each region of the reaching space defined by the scoring template (target area - TA, target hemifield - TH, non-target area - NTA, and non-target hemifield, NTH). Proportion scores were transformed using an arcsin $\sqrt{\quad}$ transformation, in order to normalize the distribution. A 2 (group) X 3 (trial type) ANOVA on the (transformed) proportion of reaches into the target area found a significant main effect of trial type [$F(2,42) = 11.85, p < .001$]. Infants were less accurate in the dark conditions than in the light [Light vs. Dark, $t(25) = 5.59, p < .001$; Light vs. Surprise/ No Obj., $t(23) = 6.00, p < .001$], but the

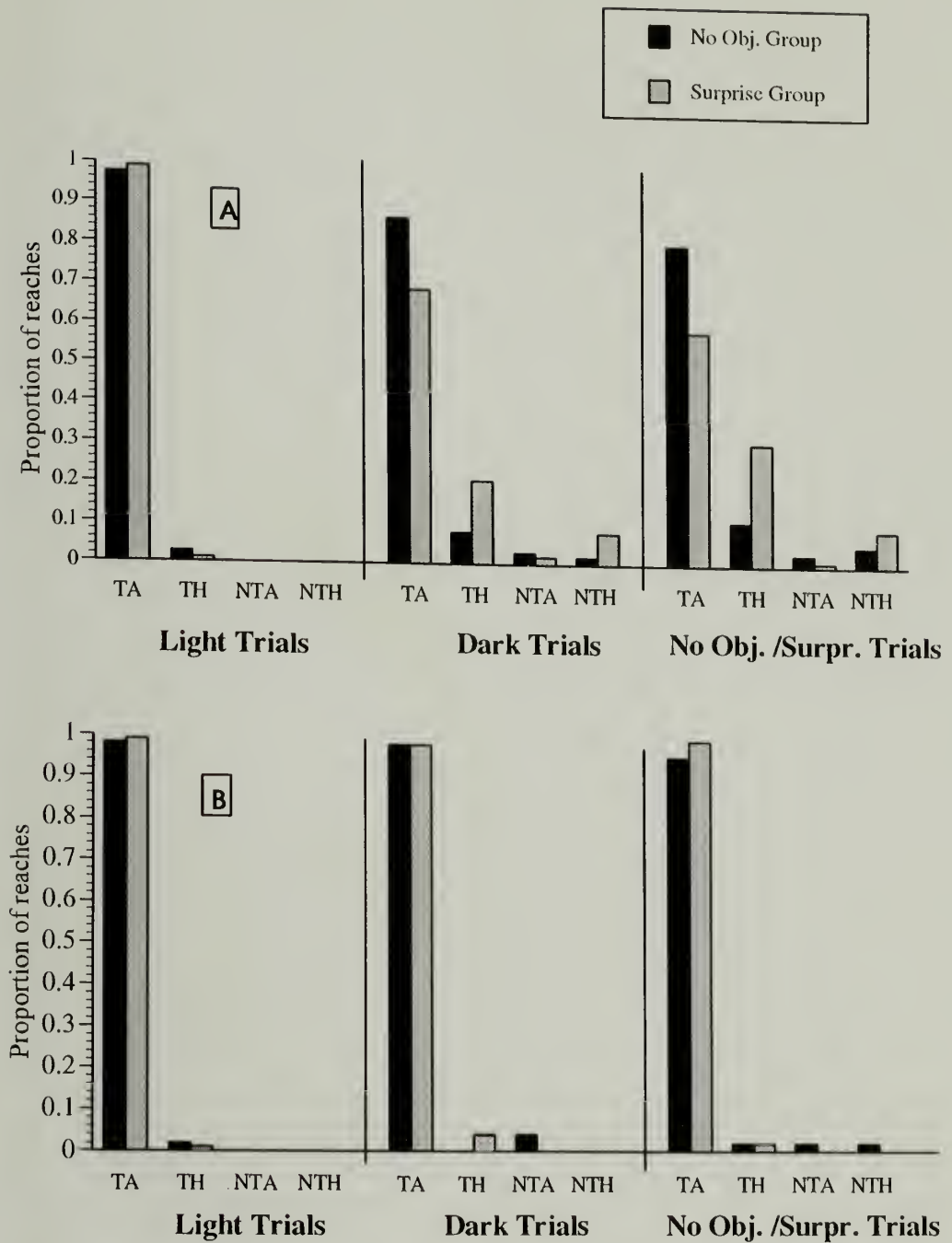


Figure 8 Proportions of reaches prior to opening the cover that entered each region in the reaching space, presented for all trials (A) and the subset of trials on which infant reached, opened the cover, and reached again (B).

majority of reaches were still to the target area. Figure 8 (B) shows the accuracy of reaches prior to opening the cover on the reach-open-reach subset of trials. The same ANOVA on the transformed proportion of reaches to the target area found no significant main effects and no interaction. The distribution of reaches in the two dark conditions is similar to the light condition, in that almost all reaches are into the target area. But, since this is the subset of trials on which infants succeeded in opening the cover, then their first reaches had to be accurate (or else they wouldn't have found the cover in the dark).

Summary of Performance Prior to Opening Cover

Infants' reaching prior to opening the cover in the dark differed from their reaching in the light only in that they were slower to initiate a reach and they were slightly less accurate. And, for the subset of trials on which infants opened the cover and followed with at least one reach, their performance in the light and dark differed only in that they were slower to initiate a reach. Thus, judging from their performance on this first phase of the search task, infants' searching in the dark parallels search in the light.

Infants' reaching behavior prior to opening the cover was unaffected by the experience of seeing an object hidden or not. Reaches in the surprise and no-object groups did not differ in number, duration, latency or accuracy.

Reaches After Opening the Cover

The period after the cover is open is a critical one, especially on trials in the dark. At this point in the trial, the sound is terminated, and infants' reaches must be guided solely by their representation of the location and/or the existence of a hidden object. In the light, infants' reaching after opening the cover can be motivated by their perception of the toy. They lose this advantage in the dark, and any reaching after they open the cover, in the silent darkness, suggests that they are searching for the purpose of retrieving the hidden object. Since infants do succeed in retrieving the toy on the dark trials (although less frequently than in the light), the qualitative comparisons in terms of number, duration, latency, and accuracy become critical in determining the relationship between infants' searching in the light and dark.

It was hypothesized that if infants' search behavior was in some way mediated by a representation of the occluded object, then infants in the surprise group, after opening the cover in the dark and searching for the object, should continue searching after they fail to find the expected object. Infants in the no-object group, if they manage to open the cover in the dark on the no-object trial, should have no reason to reach out and continue searching. The results presented previously (Fig. 4) show, however, that infants in the two groups were equally likely to reach out, open the cover,

and make one or more subsequent reaches in the dark, whether or not there was a toy present. The following analyses look beyond the simple proportions of trials measure presented previously, and examine the nature of infants responses in terms of the same dependent variables (number, duration, latency, accuracy) tested above. The division of data used when examining reaches prior to opening the cover - into all trials and the reach-open-reach subset - is obviously irrelevant here, as this analysis includes only infants who do respond after they open the cover.

Number of reaches

The number of reaches, along with the duration of reaching (presented below) reflects the infants' perseverance at retrieving the toy once the cover has been opened. Figure 9 presents the average number of reaches per trial after opening the cover, again not including trials on which no response was made (the dashed line in Fig. 9 marks the minimum response of 1 reach). A 2(group) X 3(trial type) ANOVA found no main effects and no interaction. On average, regardless of whether infants were searching in the light or the dark, they made the same number of reaches per trial after opening the cover. An independent samples t-test on the dark - surprise/no object difference scores, with group as the independent factor, was not significant. Thus, the number of reaches infants made after opening the cover did not depend on their seeing an object in the light, nor prior to trial onset.

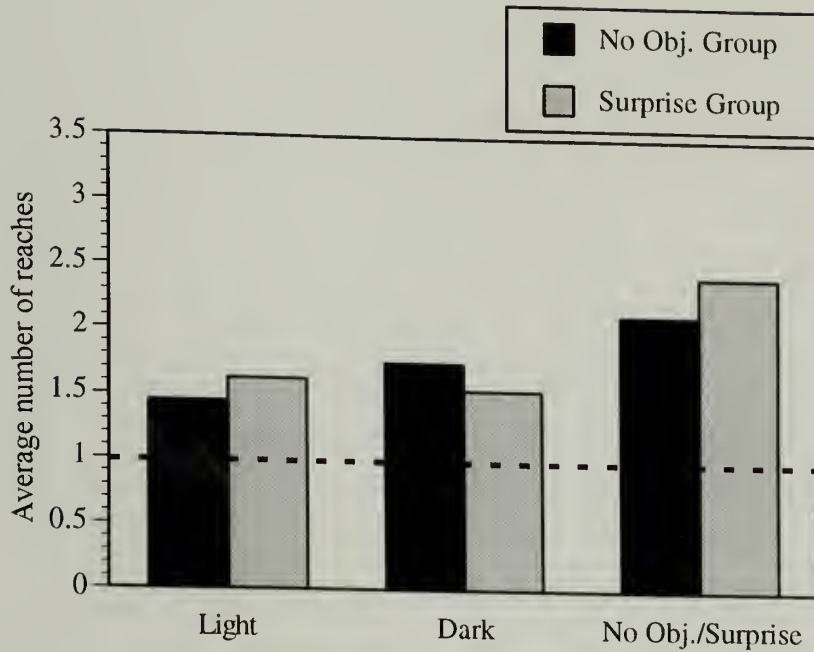


Figure 9 The average number of reaches after opening the cover, by trial type and condition.

Duration of Reaching

The average duration of reaching after opening the cover is presented in Figure 10. Again, the same ANOVA and subsequent comparisons failed to show any significant differences between the groups and trial types. The duration of reaching did not differ between the light and dark trial types. Even though infants could see the object in the light and had no perceptual information about it in the dark, they spent a comparable amount of time reaching in both conditions. The lack of any main effect of group, and the lack of any interaction implies that the duration of infants' reaching subsequent to opening the cover in the dark was not dependent upon their having seen an object hidden underneath the cover or not.

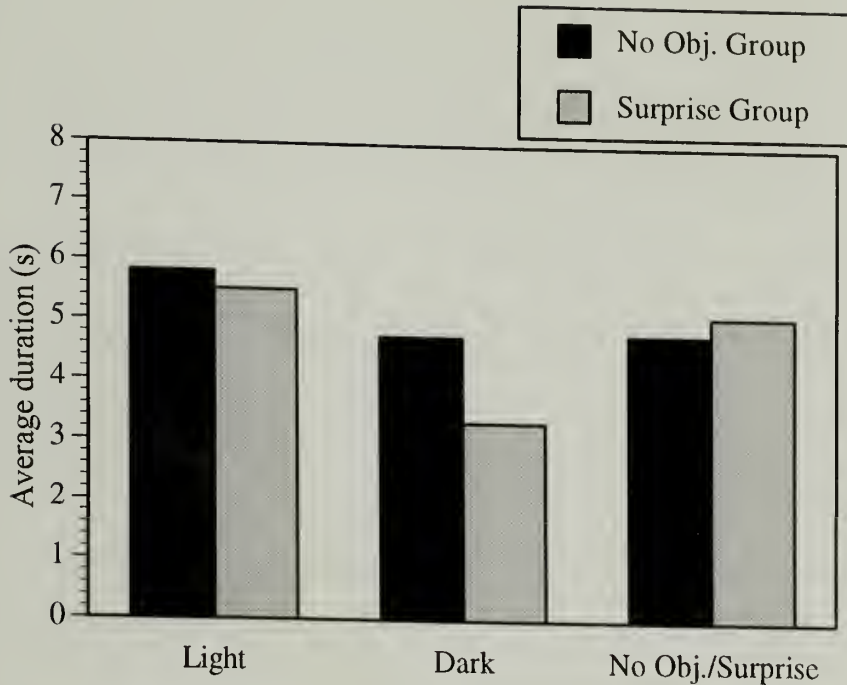


Figure 10 Average duration of reaching after opening the cover, by trial type and condition.

Latency to Reach

The latency to reach after opening the cover was measured as the interval in seconds between the opening of the cover and the next reach. Average latencies are presented in Figure 11. The same 2(group) X 3(trial type) ANOVA failed to find significance for any of the main effects or the interaction. Regardless of whether infants could see the newly uncovered object or not, they took just as long to make a reach. If, in the dark, infants had simply been reaching for the sound and had managed to get the cover open, they would not have made a reach into the silent darkness, and would not have done it as quickly as they had in the light. The independent samples t-test on the dark - surprise/no object difference scores was not

significant, suggesting that their latency to respond after opening the cover was unaffected by their having seen an object hidden or not prior to the lights going out.

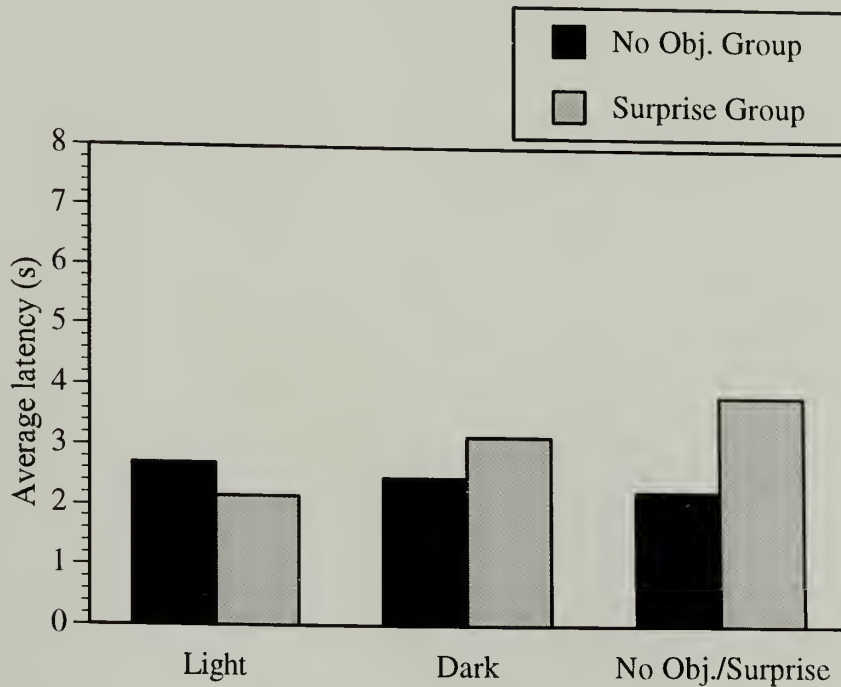


Figure 11 Average latency to reach after opening the cover, by trial type and condition.

Accuracy

The proportion of reaches to each region in the reaching space is presented in Figure 12. A 2 (group) X 3 (trial type) ANOVA on the transformed ($\arcsin\sqrt{}$) proportion of reaches into the target area found no significant main effects and no interaction. After opening the cover, in the dark, with no sound to guide them, infants in both groups reached back to the target area quite frequently, whether there was an object there (surprise

group, $M=.80$; no-object group, $M=.79$) or not (surprise group, $M=.81$, no-object group, $M=.78$). This high degree of accuracy in the dark, with no sound identifying the object's location, indicates that infants remembered the object's position after they had uncovered it, and lends further support to the notion that they were not simply reaching based on perceptual cues, but were actively searching for the hidden object.

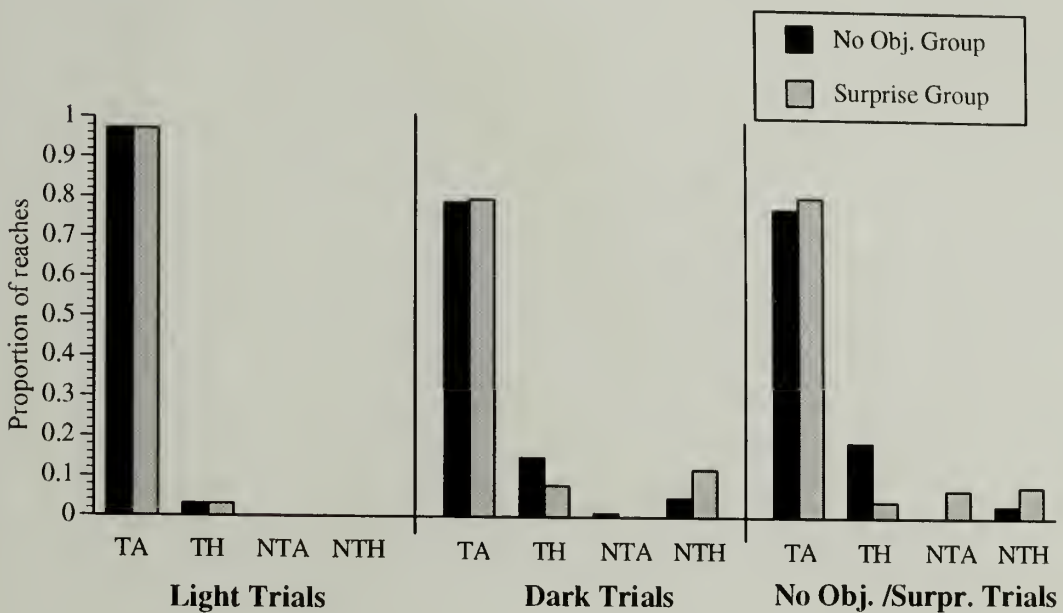


Figure 12 Proportion of reaches after opening the cover that entered each region in the reaching space.

Object Representation - Summary

Although infants searched for the hidden object in the dark on fewer trials than they did in the light, their behavior when they did was quite similar to their search behavior in the light. Aside from starting the reach-

open-reach sequence later in the dark than in the light, there were no differences between infants' search behavior for a hidden object in the light and their search behavior in the dark. Light and dark search behavior was similar in terms of the number and duration of reaching before and after opening the cover, as well as the accuracy of reaches before and after opening. Of critical importance is the parallel behavior on light and dark trials after the cover was open, when the sound had been terminated. In the light, infants had sight of the object to motivate their reach and guide its accuracy, but in the dark they had to reach based solely on their representation of the occluded object. Yet reaches after opening the cover were not different between the light and dark trials, in terms of their number, duration, latency, and accuracy. Table 4 summarizes the results of the various analyses of variance.

Infants' representation of the hidden object, however, may not have been wholly accurate. The lack of any group differences and the failure to find any trial type X group interactions suggests that infants' search behavior was not influenced by their having seen an object hidden underneath the cover or not. First, infants in both groups just as frequently reached out, opened the cover, and reached again on all trials where no object was present. In addition, reaching behavior on the dark and surprise/no-object trials did not differ between the two groups on any of the measures

Table 4 Summary of F-statistics from analyses of variance on the reach-open-reach subset of trials

	Group main effect (df=1,12)	Trial type main effect (df=2,24)	Trial type X Group (df=2,24)
<i>Reaches prior to opening cover</i>			
Number	.978	.525	.637
Duration	.029	.155	.122
Accuracy	1.920	.016	.169
Latency	2.711	3.090 (p<.10)	.783
<i>Reaches after opening cover</i>			
Number	.269	.539	.520
Duration	.019	1.281	.939
Accuracy	.279	.036	.364
Latency	1.305	1.393	.762

used here. Prior to opening the cover, infants in both groups did not differ in the number, duration, latency and accuracy of their reaches for the closed cover in the dark. After opening the cover on dark trials, those infants that made at least one reach did not differ in the two measures of the perseverance of search - frequency and duration of reaching, nor did they differ in terms of the latency and accuracy of their reaches. Reaches in the dark after opening the cover were quite accurate, as infants in both groups reached back to the target area on approximately 80 percent of their reaches.

Means/Ends Coordination

The analyses of infants' search behavior presented above suggest that their behavior in the dark did not seem to be influenced by having seen an object hidden or not. However, the fact that infants opened the cover and subsequently reached in the dark at all shows that they successfully combined the three different components of the task (reach, open and reach) into a sequence which they could execute in the absence of any visual feedback. Using only these trials on which infants reached, opened the cover, and reached again, the present section examines the data from the previous section in terms of the sequencing and timing of infant's interactions with the apparatus before and after they open the cover.

Figure 13 again presents the average number of reaches, but shows both the reaches before and after opening the cover on the same graph. The average number of reaches are highly consistent across trials in both the light and the dark, both before and after opening the cover. The average number of reaches after opening the cover on the surprise/no object trials was slightly but not significantly higher than the rest (surprise, $M=2.43$; no-object, $M=2.13$), which were all under 2. On average, infants did not make a great number of reaches when performing the task. This suggests that their behavior was a tightly controlled, efficient action which was similar to how they performed the action in the light.

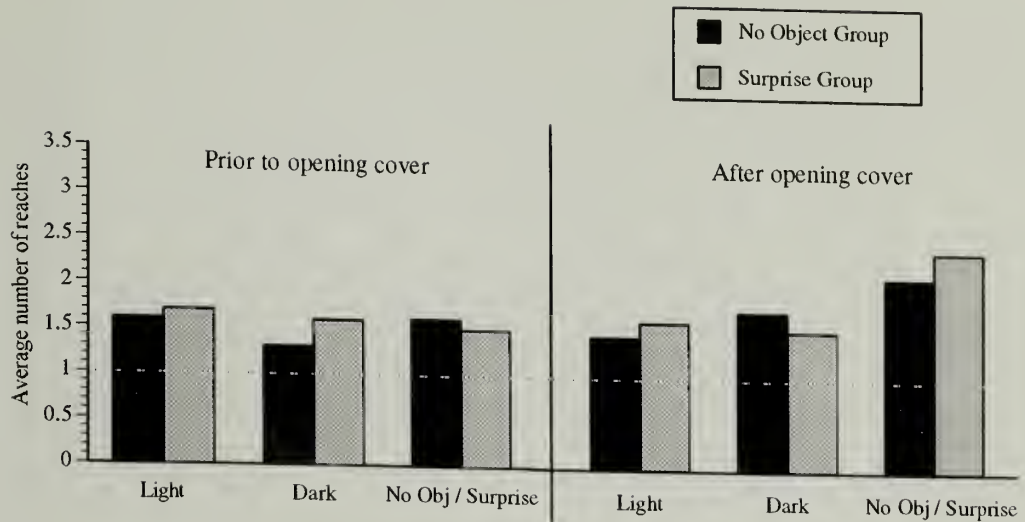


Figure 13 Average number of reaches before and after opening the cover.

Figure 14 presents the duration of reaching data before and after opening the cover. Again, the means across each of the trial types, before and after opening the cover, are quite similar, and there are no significant differences between the means (as reported previously). On average, infants spend the same amount of time reaching in the light before (overall $M=5.4$) and after (overall $M=5.6$) opening the cover. This pattern is similar for the dark (overall, before $M=4.1$; after $M=4.0$) and surprise/no object (before $M=4.3$; after $M=4.9$) trials.

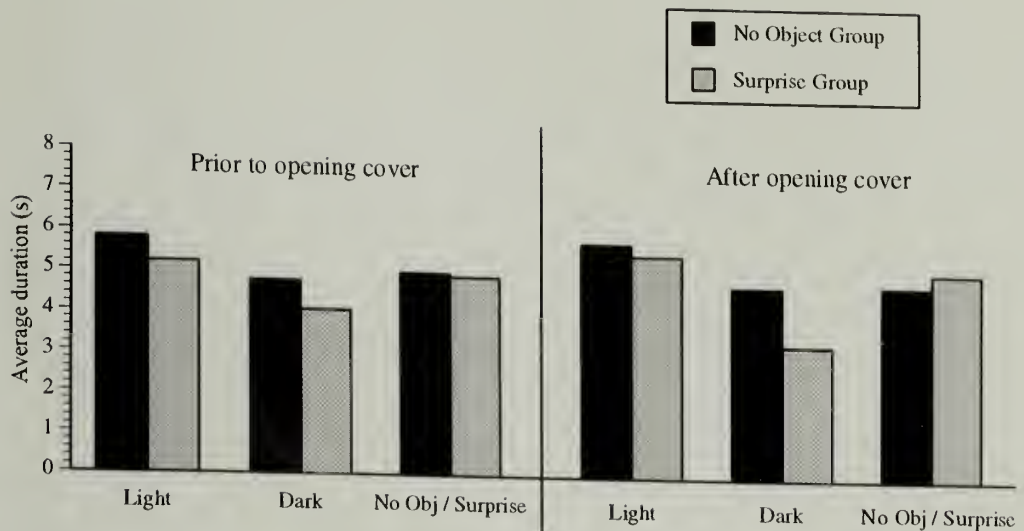


Figure 14 Average duration of reaching before and after opening the cover.

The latency data, plotted as a series of timelines in Figure 15, help to paint a clearer picture of infants' execution of the complex, two-stage action sequence in the light and dark. While on average infants started the sequence of actions later in the dark than they did in the light [as reported previously, light vs. dark $t(17) = 3.65, p < .01$; light vs. surp/no obj. $t(17) = 2.27, p < .05$], the pattern of response after that is quite similar across the different trial types. Once the sequence is initiated, infants, on average, execute the reach-open-reach pattern with remarkable consistency across the various trial types and conditions, and all within the first 10 seconds of the trial.

Although infants were less likely to complete the two-stage task in the dark than they were in the light (as reported above), their behavior when

they did was quite similar to the light trials. The frequency and duration of reaching as well as the timing of reaches before and after opening the cover were all consistent across all of the trial types.

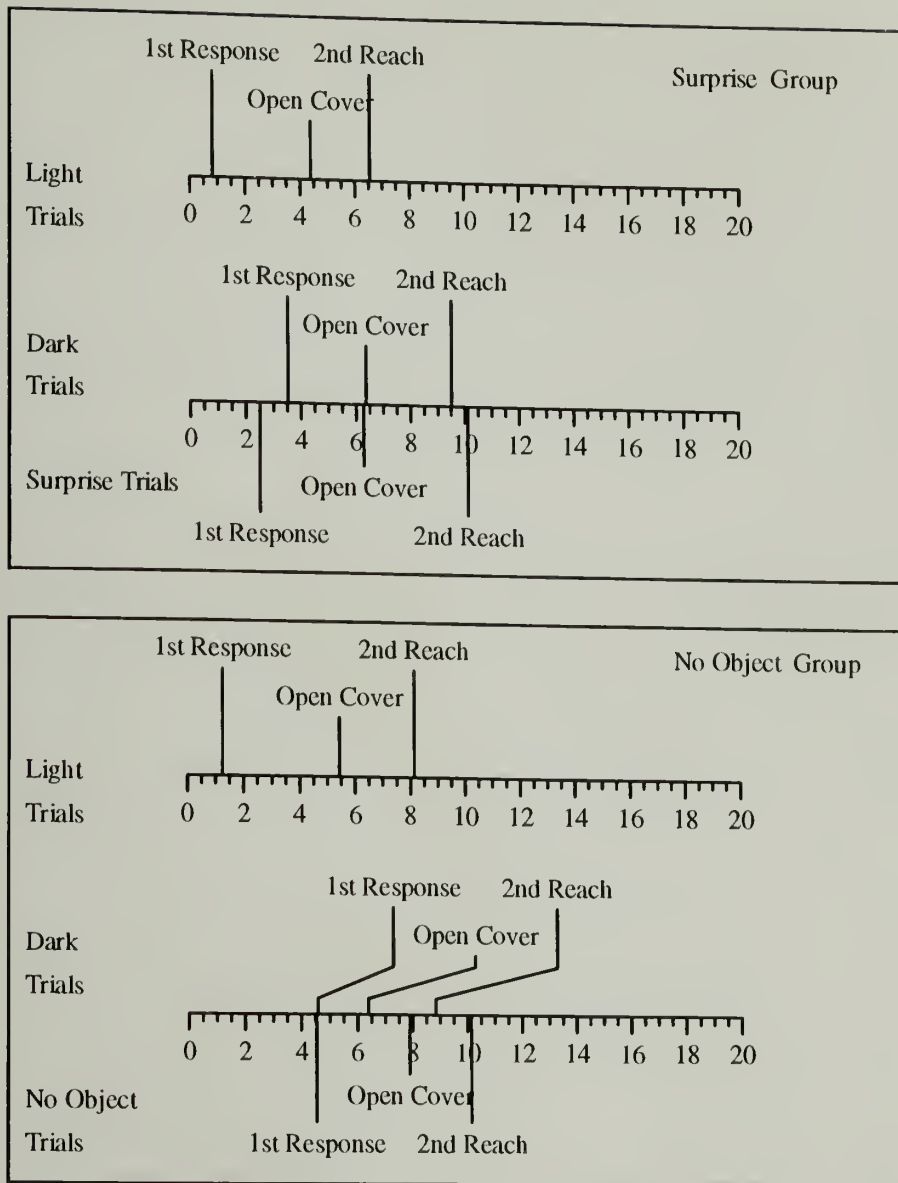


Figure 15 Average latencies for each trial type, presented in timeline form. Each timeline spans the twenty seconds of the trial, and illustrates at which point during the course of the trial, on average, infants made an initial response, opened the cover, and made a reach after opening the cover.

CHAPTER 4

DISCUSSION

The purposes of the current study were twofold. The first was to investigate whether the search behavior shown by 8-month-old infants can be considered to be evidence of their supposedly newfound ability to combine actions into meaningful, goal-directed, means/ends sequences rather than a series of consecutive but independent, perceptually driven actions. To address this question, the current study evaluated the previously untested ability of infants to execute the search action in the dark. The second, related objective of the current study was to examine if and how a hidden object is represented as the goal of infants' search behavior. To examine this, two groups of infants were compared on their response to a trial in the dark where they either a) saw an object hidden under the cover which was taken away after the lights were put out, or b) saw that no object had been hidden before the lights were put out.

Regarding the first objective, whether infants who search are truly executing actions in a means/ends sequence, the results of the present study suggest that they are. Infants were successful at performing a complex, multi-stage action in the dark. Although they were less likely to perform the search behavior in the dark than in the light, they nonetheless succeeded in reaching out accurately, opening the cover, and making a second reach, in

silence and darkness, for the hidden toy. This second reach, after opening the cover, is critical. Infants executed this, the second operator of the means/ends sequence, in the absence of any perceptual information, suggesting that they were searching for the purpose of retrieving the toy. However, the fact that they executed the behavior is, by itself, not entirely convincing. But the manner in which they executed the component actions of the search behavior in the dark closely paralleled their behavior in the light. In spite of the dramatic perceptual differences between the light and dark conditions, infants' reaching and searching behavior was similar across the two conditions, in terms of the average number, duration, and accuracy of reaches both before and after opening the cover. Likewise, reaching behavior within trials was remarkably symmetrical. That is, the number, duration, and accuracy of reaches were not different before and after opening the cover. Infants were not simply reaching in the dark for the sounding cover, getting it open, and then making a large number of long duration reaches in order to maximize their chances of finding something in the dark. Rather, they executed the behavior like they did in the light - showing a systematic well-controlled pattern of reach-open-reach in their search for the toy.

Infants seemed to be executing the search behavior as a multi-stage, goal-directed, means/ends action. The fact that they reached out for the object in the dark after the cover was open and the sound was off implies that

they were in fact searching for the purpose of retrieving a represented object, executing the second operator in a means/ends sequence. But just how accurate was their representation of the occluded object? The Infants in the two groups showed similar patterns of search regardless of whether they had a) seen a toy hidden underneath the cover which was then removed, or b) seen the cover closed with no toy underneath. Not only did they complete the two stages of the task just as frequently in both of the dark conditions, but the morphology of their search behavior was similar across all the trial types. With no object present under the cover, the number, duration, accuracy and latency of their reaching before and after opening the cover was quite similar to their behavior with an object under the cover. Infants' behavior was not affected by seeing or not seeing the toy just before the lights went out.

We therefore have two apparently contradictory findings in the present study. The failure to find any differences in the qualitative measures of infants' search between the light and dark conditions, including the fact that infants in the dark made a reach for the object after opening the cover, suggests that they searched for the purpose of retrieving it. On the other hand, seeing an object placed under the cover or not prior to the lights going out did not seem to influence infants' search behavior. The two findings do not contradict one another, however, but merely address different questions. Infants' ability to perform the multi-stage search behavior in the dark

suggests that they were searching for the purpose of retrieving the object. Armed with the ability and willingness to search for hidden objects in the dark, they searched whether or not they had seen a toy hidden prior to the lights going out. There are several possible reasons why we failed to find any differences between the two groups of infants, and why infants in the no-object group did not refrain from searching when they had seen that no toy had been placed under the cover.

First, we must consider the possibility that, because we gave the infants extensive practice in the light before we presented any dark trials, that they were simply conditioned to make the search response in the dark. Is it possible that infants were simply conditioned in the light to open the cover and make a second reach for the object, and were simply executing a conditioned (albeit complex) behavior in response to the sound in the dark? This explanation must be seriously considered in light of the morphological similarity in search behavior across the various trial types. On average, reaches did not differ in terms of their number, duration, latency, and accuracy on any of the trial types presented (with the exception that reaches were initiated sooner in the light), and as such the results of the present study do not definitively counter the argument that infants' search behavior was simply a conditioned response. Prior to searching in the dark, infants had a great deal of experience in the light, including two demonstration

trials, and at least four warm-up trials, all of which had an object hidden under the cover. Thus infants who searched on these six trials were rewarded by finding the object. These six trials could have been sufficient to establish an association between search behavior and reward, such that search behavior would continue in the same manner in the dark. However, while not analyzed in the current study, the individual subject data presented in Appendix D illustrate that infants' strategies for solving the search task varied from trial to trial: an infant might open the cover and reach for the object with the same hand, or might open the cover with one hand and reach for the object with the other, or might hold the cover open with one hand while retrieving the toy with the other. To some extent this strategic variability extended to their behavior in the dark. Further, infants did not simply execute the behavior as it was modeled for them, nor did they discover and repeat actions which may have succeeded in retrieving the toy - they frequently craned their heads around the cover as they opened it in order to look behind it. They bent their bodies to the side so that they could look into the open side of the cover while they reached across and pulled the cover open with their contralateral hand. It is this implementation and variation of strategies for solving the search task which suggests that infants were not simply conditioned to execute the two stages of the search behavior, but were actively and intentionally searching for a toy. Nevertheless, the

findings of current study do not definitively rule out an explanation that infants' search behavior was conditioned, and future studies must attempt to address this issue further.

Another alternative explanation for the current results is that infants may have accurately represented the presence or absence of the toy under the cover, but it might not have influenced their behavior because it simply might not have mattered to them. The toy may not have been the goal of their actions in the first place, or the goal of their actions may have varied from trial to trial, depending upon whether they had seen a toy hidden or not. They might have been reaching to get the toy when it was there, but were satisfied with touching the Velcro on the apparatus when they knew there was no toy. It is unlikely that the toy was not the goal of their actions. In the light and dark (object) trials, their interest in the apparatus was terminated once they removed the toy. If they succeeded in removing the toy from its Velcro attachment to the apparatus, they pulled back from the apparatus and manipulated the toy. It is equally unlikely that the goal of their actions varied from trial to trial, because of the performance of the infants in the surprise group. On the surprise trials, we were building up an expectation that there was an object underneath the cover, but sneaked the toy away. There was no reason for the goal of their actions to change, and when they reached, opened the cover, and reached again, their expectations

would have been violated, and their behavior would have differed from the infants in the no-object group. This result did not obtain.

The lack of any significant differences between the responses of infants in the two groups, rather than simply reflecting a conditioned response or shifting goals on the part of the infant, suggests that they were uncertain about the presence or absence of the toy underneath the cover. There are several reasons why they might have been uncertain about the existence of the toy. They might have failed to encode whether or not the toy was hidden prior to the lights going out, due to a lack of attention or memory storage deficits. Conversely, they might have had difficulty remembering whether or not the toy was there on that particular trial, because it had been there on previous trials. Infants made their initial response later in the dark than they did in the light - perhaps they had simply forgotten whether or not they had seen a toy hidden by the time they began their reaching. Alternatively, infants are accustomed to seeing objects appear and disappear unpredictably - bottles and toys are taken away and disappear from view, yet return from time to time. Perhaps they were not sure whether or not the toy was there because they understand that objects' appearances and disappearances are often unpredictable.

In any event, it is likely that the lack of any group differences reflected infants' uncertainty about the objects' presence underneath the cover. Yet

faced with this ambiguity, they still searched in a manner similar to their search behavior in the light. Infants seemed to forget whether or not they saw a toy hidden, but searched anyway, possibly because they had had success by searching in the light.

The findings in the current study replicate those of a study by Appel and Gratch (1984) which investigated infants' search behavior in the light when no toy was hidden. In that study, infants refrained from searching if "no-toy" trials were presented first, but *would* search on "no-toy" trials if they had been tested on trials with a toy first. Similarly, in the current study, we gave infants a great deal of experience reaching in the light (2 demonstration trials and 4 warm-up trials) before we ever tested them in the dark without an object. They may have reached on the no-object trials because they had had a great deal of success at retrieving the hidden toy by the time they were tested with no object under the cover. A future study could address this issue, by testing a group of infants who never see a toy underneath the cover but get the same training at opening the cover, and are then tested in the dark with a toy under the cover. Appel and Gratch's results with infants searching in the light would suggest that infants would refrain from searching in this situation.

Why does experience with searching for an object lead infants to fail to differentiate between trials on which a toy is present and trials with no toy?

In many ways, this response pattern is a preservative error, much like the A-not-B preservative error which is also made by infants of 8 months (See Wellman, Cross, and Bartsch, 1986, for a meta-analysis). In the A-not-B task, which was first devised by Piaget (1952, 1954) infants are given repeated experience searching for an object hidden in one location (A). After several trials, the object is hidden in a new location (B) in plain view of the infant, yet the infant searches for the object back at location A. Often, a delay is instilled between the hiding at location B and the initiation of search, by restraining or distracting the infant. The response to the shift to the new location varies with the delay, depending upon the age at which infants are tested on the task (Wellman et al, 1986). At 8 months of age, if infants are allowed to search as soon as the object is hidden at location B, they perform at chance, searching with equal probability at A and B. But with as little as a three second delay, they search consistently at location A, making the error. At ten months, infants will search correctly at B with no delay, but will make the error if a 5 s delay is inserted between hiding and retrieval.

The way that infants were tested in the current study may have induced a preservative error similar to the A-not-B error. Infants were given enough experience so that they were consistently searching for the hidden object (our "A" in the A-not-B error), and were then tested with no object

hidden (our "B"). The pattern of searching continued, just as the pattern of searching at A continues on the A-not-B task. And, because in the current study we covered the object, doused the room lights, and then advanced the object to within reach of the infant, all of which took several seconds to accomplish, we instilled a delay between the hiding and searching portions of the trial. Much like a 3 second delay makes 8-month-olds search reliably to location A in the A-not-B task, our delay made them search regardless of the presence or absence of a toy under the cover. This suggests that, with development, infants' responses to the various dark conditions in the present study should change in a way that parallels the change in response on the A-not-B problem, and that by 12 or 13 months of age, when infants no longer make the A-not-B error, they should show different patterns of behavior to the various conditions in the present experiment. Indeed, Appel and Gratch (1984) found that 8-month-old infants would search in the light on "no-toy" trials if they had had prior experience searching for a toy, but by 12-months infants would refrain from searching on "no-toy" trials regardless of their experience on earlier trials. Future studies could address these developmental changes in the context of the stimulus conditions of the present experiment, examining more precisely how changes in infants' understanding about hidden objects (as well as their understanding of their own ability to retrieve them) informs their search behavior.

Summary

It was proposed that infants could successfully retrieve a hidden object in the light without having to execute a means/ends action per se, but by executing two independent actions - one for the visible cover and one for the newly visible toy once the cover is moved. However, if we accept that infants' search behavior in the dark was intentional and goal-directed, and not simply a conditioned response, then infants' ability to retrieve the hidden object in the dark suggests that they can in fact organize actions into a sequence for the purpose of retrieving a hidden object. In order to retrieve the hidden object in the dark, infants had to be able to reach accurately, open the cover, and reach accurately again, motivated solely by their representation of the occluded object. Infants' success on this task suggests that they can, with varying degrees of consistency, represent the occluded object as the goal of a complex, multi-stage motor behavior.

However, infants were just as likely to search in the dark whether they had seen a toy hidden or not prior to the lights going out, and the morphological characteristics of their search did not differ between trials with and without a toy. This pattern of responding is akin to search behavior on the A-not-B task, on which infants of this age show a preservation of response to a particular location, whether or not a toy is hidden there. It was suggested that infants' search behavior under the current paradigm would

change in parallel with developmental changes in infants' preservation errors on the A-not-B task.

APPENDIX A
LETTER TO PARENTS

Dear Parents:

As part of an ongoing project in infant perception, we are studying how young infants respond to sounds they hear around them. We learned about the birth of your infant from the birth announcements in the newspaper at the time, and we are now writing to you to describe our project and invite you and your infant to participate.

You have probably noticed that your baby is very interested in reaching for objects, particularly those that make sounds. In this study we will present a colorful toy to the baby, which will be attached to a small speaker producing sound, allowing him or her to reach and get the toy. The toy will then be hidden behind a small cover, to test if the child will remove the cover to retrieve the hidden toy. On some of the trials, we will turn the room lights off, and see if the baby can reach correctly for the toy when it cannot be seen.

Throughout the test session, your infant's behavior will be videotaped for later scoring of reaching behavior. During the entire session, your infant will be seated on your lap. There are no discomforts or risks involved in this study. In fact, we hope that the visit will be very pleasant for both you and your infant. We will be happy to show you the videotape after the session and to discuss with you the findings of this study as well as other studies of infant perception. At the end of the session, your child will receive a small gift of appreciation.

Participation in this study involves one visit of approximately 45 minutes, to Tobin Hall, room 651 at the University of Massachusetts in Amherst. We are including a map, for your convenience, showing you where on the campus you can park nearby our building, and will be happy to meet you by your car and escort you into our laboratory.

Our study depends mostly on parents' help and participation, and we will be extremely grateful if you will be able to help us out. We will be calling you within the next few days, to answer any questions and ask if you would like to make an appointment. However, if you have received this letter and would like to contact us, to learn more about our study or to arrange an appointment quickly, please feel free to do so. We have very flexible schedules, including weekends, to accommodate the needs of parents. Please feel free to call Dan McCall at 586-1135 or Rachel Clifton at 545-2655. Thank you very much for your consideration of our project.

APPENDIX B

SAMPLE PROTOCOL FOR TESTING

Subject Name: _____, _____ Subject #: _____
 Date of Birth: ____/____/____ Test Date: ____/____/____
 Birth Weight: ____ lbs. ____ oz. Full Term? Y/N: ____ weeks early/late
 Video # ____ Locations: _____ - _____ Experimenters: ____/____

Demonstration Trials:

	<u>Speaker</u>	<u>Contact?</u>	<u>Comments</u>
D1)	1	_____	_____
D2)	2	_____	_____

Warm-up Trials

T1)	1	_____	_____
T2)	2	_____	_____
T3)	2	_____	_____
T4)	1	_____	_____

Test Trials

	<u>Speaker</u>	<u>Condition</u>	<u>Light/Dark</u>	<u>Comments</u>
1)	1	no obj.	dark	_____
2)	2	obj.	light	_____
3)	1	obj.	dark	_____
4)	1	obj.	light	_____
5)	2	no obj.	dark	_____
6)	2	obj.	dark	_____
7)	1	obj.	light	_____
8)	2	obj.	dark	_____
9)	2	no obj.	dark	_____
10)	1	no obj.	dark	_____
11)	1	obj.	dark	_____
12)	2	obj.	light	_____
13)	1	obj.	dark	_____
14)	2	no obj.	dark	_____
15)	1	obj.	light	_____
16)	2	obj.	dark	_____
17)	2	obj.	light	_____
18)	1	no obj.	dark	_____

APPENDIX C

INSTRUCTIONS FOR COMPUTER SCORING

To get into the program:

After turning on the computer you should see the `c:>` prompt. Type 'win' to get into Windows. Once in Windows, double-click on the folder named BabyApps, then double-click again on the "Scoring" icon. You should then see the first window of the program open, asking for subject information.

Subject Info:

Enter the subject's name and number (enter the subject's real number, not the number in parentheses), and click on the appropriate condition and scorer name. When all of the information is correct, click on "OK". After confirming what you entered, you will see the scoring screen.

Some general things about the program:

There are two forms to the program. The scoring page you are looking at now, and a spreadsheet which holds all of the data as you score. You can change back and forth between the two by clicking on "view" in the menu bar at the top of the screen, and selecting "spreadsheet" or "scoring form".

Scoring Form: This is where all of the data will be entered initially, as you progress from reach to reach and trial to trial. Once information is entered on this screen and you click on "Enter" or "Next Trial", you cannot change it. To change data from a previous reach or trial you will need to go to the spreadsheet.

Spreadsheet: Everytime you hit "Enter" or "Next Trial" on the scoring form, data is entered here, in a new line for every reach. If you need to edit data in the spreadsheet (eg. if you find a mistake after you've entered the data from the scoring form) just double-click on the cell you need to change, and an editing screen will appear.

SAVE YOUR WORK OFTEN! If the computer or the program crashes and you haven't saved your work, it's gone forever. To save, click on "file" on the menu bar at the top of the screen (on either the scoring form or the spreadsheet) and click on "save". It is probably good practice to save after every trial.

SCORING A VIDEO

Once the tape is cued up for this subject and the subject info is filled out, you should see the scoring form. The scoring form has two parts. The top part is the trial information. Once this area is filled out the bottom part will appear, which is used for scoring reaches throughout the trial. You must therefore begin by filling in the trial information.

- 1.) Click on the appropriate buttons for **Trial type** and **side** of presentation. This information can be found on the subject's protocol form from the day of testing, located in the subject's folder.
- 2.) Fill in the **Time toy is in position**. This is the start of the trial. Watch the videotape for the point where the object stops its initial advance toward the infant. Often the toy will be advanced, stopped, adjusted, and moved again. We want to record the time that the toy

stopped the first time as it approached the subject. If the infant leans forward and touches the object as it is still approaching, then record the time of contact in this box. This becomes the new starting time.

*****When entering times into the program, put minutes in the 'min.' box, hit enter, and put seconds and hundredths in the 'sec.' box (eg. 35.97) *****

3.) The **End of Trial** time will be calculated and filled in automatically (it simply adds 20 sec. to the start time). However, if the infant removes the toy during the course of the trial, you will need to change the **end of trial** time to the moment that the toy is removed from the apparatus - the trial ends when the toy is removed.

4.) The **Time cover is opened** has already been scored in a previous pass. Enter the time from the previous scoring in this box. If the infant did not open the cover during the trial, enter 00:00. However, you will need to double-check the previous scoring as follows, because our criteria have changed.

a.) The cover only counts as 'open' if we can see the toy (big-bird or the tiger) from above. Therefore, if the cover is only opened partway and sticks. This may count as open if we can see the toy.

b.) If the cover is opened as in (a) and then closed again - we will still count it as cover-open. This is different from our previous scoring and will need to be checked. If this occurs, make a note in the comments. However, if the cover is opened, closed, then opened again, second opening is the one we are interested in.

c.) Once you have determined by (a) and (b) that the cover has in fact been opened, roll the videotape backwards until just before the cover is opened. Now roll it forward until you see the cover just begin its movement open. This is the time to enter in the scoring form.

Once you are satisfied with all of the trial information, click on "OK". If you have made any mistakes at this point, the program will let you know and you can go back and change them. Otherwise, the bottom half of the scoring form should appear so that you can begin to score reaches.

The Template

Now that you've got the trial onset determined and all the other trial info filled in, find the clear template and attach it to the monitor with tape such that one of the two boxes completely encloses the cover on the apparatus. This template will be used for scoring reaches, as it defines the regions that the infant may reach into. Remember that the object's position may be adjusted after the trial begins. If that happens, the template must be moved along with it, so that it always fits over the apparatus.

The template divides the reaching space into four areas:

- 1.) **The target area:** the region enclosed by the template box that encloses the object.
- 2.) **Non-Target area:** the same box on the opposite side of the apparatus.
- 3.) **Target hemifield:** The side of the screen that contains the object (does not include the target area).
- 4.) **Non-Target hemifield:** The side of the screen the does not contain the object (does not include the non-target area).

What is a reach?

Begin by watching the trial all of the way through in real time once or twice to get a sense of what the baby is doing. Then go back to the beginning of the trial and watch for arm movements. You will need to look at every arm movement the baby makes and determine whether or not it is a reach. If it is, you will score it here, then go on to the next arm movement. To be scored as a reach, the arm movement in question must satisfy the following:

- 1.) Reaches are extensions of the arm away from the body in the direction of the apparatus. Usually, (but not always) you can see the elbow angle change, indicating a reach.
- 2.) A reach must cross the dashed line on the template to be considered for this analysis.
- 3.) A reach cannot be an incidental movement (ie. part of a torso movement, a result of a turn toward the parent, or extended as a counterbalance for a reaching hand).

You will likely encounter some of the following special cases while you are scoring:

Batting: repetitive, quick arm movements, with no pause in between movements.

This usually involves hitting the object (the infant literally “bats” at it). But could potentially happen in an area where there is no object to hit.

Note that this is different from “flapping” which is when the infant has his hands at his side and is flapping them like wings. Flapping is not a reach (see (2) above). Batting will be scored as all part of the **same reach**. The reach should be considered to begin with the first batting motion and terminate with the last. The reach (batting) ends when the hand pauses for 3 video frames (~.10 sec.) out of the reaching area. Thus, if the infant is batting, pulls back his or her hand, pauses for 3 frames, and bats again, this is a new reach.

Lateral Movements: occur when the infant reaches into one region on the screen, pauses for 3 video frames, and then moves the hand sideways into a new region on the screen. If the hand does not pause for at least 3 frames, then both movements are part of the same reach.

If a reach is either a batting or lateral movement, make a note in the comments section of the form.

Once you've determined that a given arm movement is in fact a reach, you need to enter the data for that reach into the scoring form as follows:

1.) Hand of Reach:

Click on Left, Right, or Bimanual. (Remember to consider the Infant's left or right, not yours)

Bimanual reaches occur when the two hands arrive at the same template region within .5 sec. of each other. If one hand reaches and the other follows, but later than .5 seconds, they should be scored as separate reaches. Likewise, if the two hands reach into two different regions on the screen, they should be scored as separate reaches

Often, the infant will reach out with one hand, and while keeping it extended, reach out with the second hand (but later than .5 sec.). If this happens, score both as separate reaches. You will need to completely score the first hand, then rewind the tape and score the second hand.

2.) **Region of Reach:**

Click on Target Area, Target Hemifield, Non-Target Area, and Non-Target Hemifield (as specified above, under Template)

The hand counts as entering a particular region only if it is the area in which the reach terminates. For instance, a reach into the Non-Target Hemifield may pass through the Non-Target Area, but we would not say the reach was into the Non-Target area.

If the infant is **batting**, the hand may enter more than one region (eg. if he is batting from left to right to hit a toy, his hand will enter the target area and the target hemifield). However, since we consider batting to be all part of the same reach (see above), the region of the reach should be the region that the first batting motion enters (usually the target area).

3.) **Time in to region:**

Once you have determined the region of the reach, record the time that the hand entered that particular region. The hand counts as entering a particular region when the fingertips first touch the line surrounding that particular region. For bimanual reaches, where this time may be up to .5 second different for the two hands, enter the time that the first of the two hands enters the region.

4.) **Time out of region:**

Enter the time that the last of the fingertips exits the region. For bimanual reaches, you will need to enter a different time for each of the hands (as the scoring form indicates).

If the trial ends while the hand is still in a particular region, then enter the trial end time here.

5.) **Contact?:**

Click here if the hand made contact with the cover or toy on this particular reach. Of course this is only relevant for reaches into the target area, and therefore this option does not appear on the scoring form for all other reaches.

6.) **Comments**

Use the comments section of the form frequently. If there is anything unusual about the reach, make a note of it. Also be sure to make a note if a reach is part of a batting sequence or a lateral movement, as this will help in later analysis of the data.

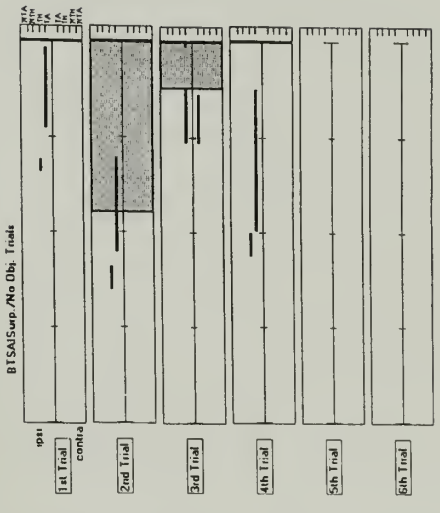
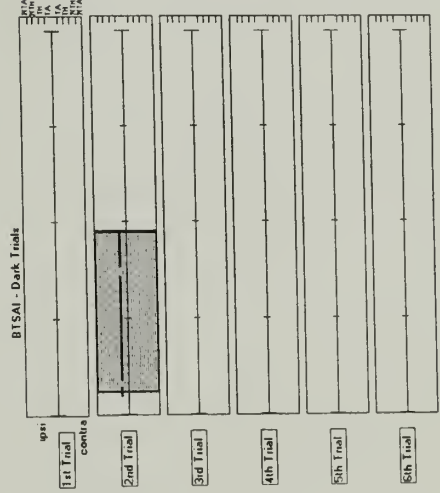
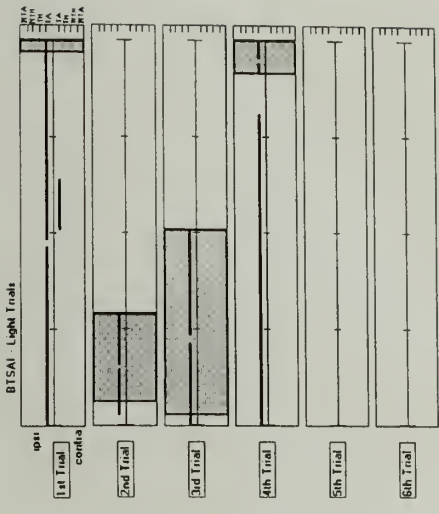
Also, on a separate sheet of paper, make a note of any questions you might have about particular reaches or trials that are not answered by these instructions. Make a note of the subject name, trial number and videotape locations as well, so that we can find it easily when we need to discuss it. Also make a note on the separate page if the program does anything that you don't understand.

APPENDIX D

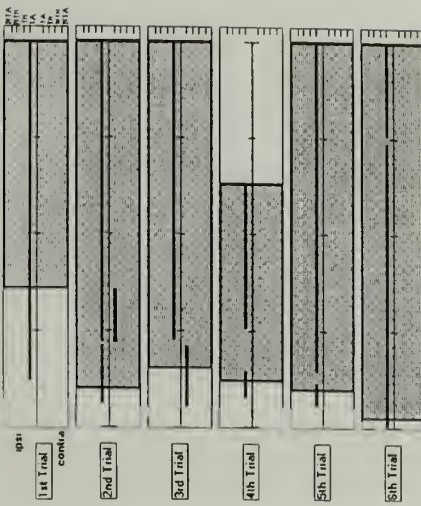
INDIVIDUAL SUBJECT DATA

Appendix D presents the individual subject data on each trial in a graphical representation which simultaneously displays handedness, reach number and duration, time of opening the cover, and the time that the toy was removed (where applicable).

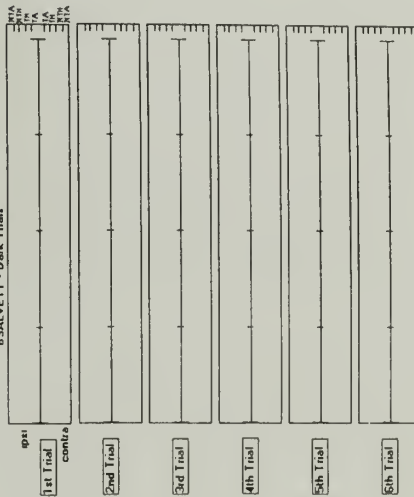
The plots can be read as timelines, from left to right, spanning the entire twenty seconds of each trial. If the infant opened the cover on the trial, the timeline is intercepted by a vertical bar at the time of opening, and the remainder of the timeline is shaded, indicating that the cover had been open (and the sound shut off). If the shaded area ends before the rightmost point on the timeline (20 s), this indicates that the infant removed the toy from the velcro before the end of the 20 s. Individual reaches are represented as horizontal bars, with those made by the hand ipsilateral to the presented object above the line and those contralateral to the object below the line. Duration of each reach is indicated by the length of the bar along the timeline. Accuracy of each reach is indicated by its proximity to the timeline. Those directly above and below the line are reaches into the target area (TA), the next above and below those are reaches into the target hemifield (TH), then the non-target hemifield (NTH), and finally the non-target area (NTA). The first 15 subjects comprise the no-object group, the second 15 comprise the surprise group.



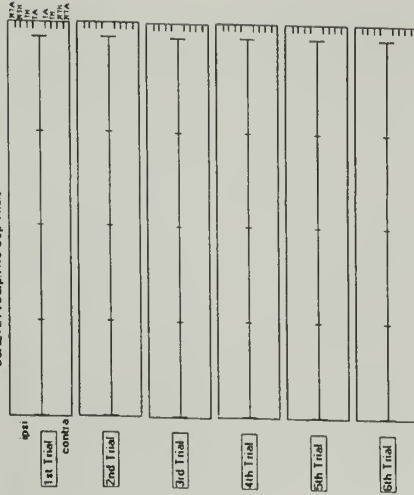
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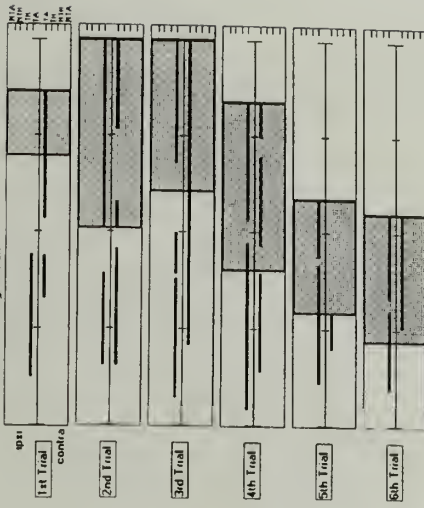
BSALVETT - Dark Trials



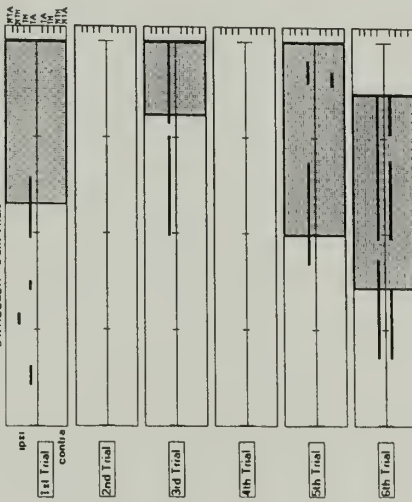
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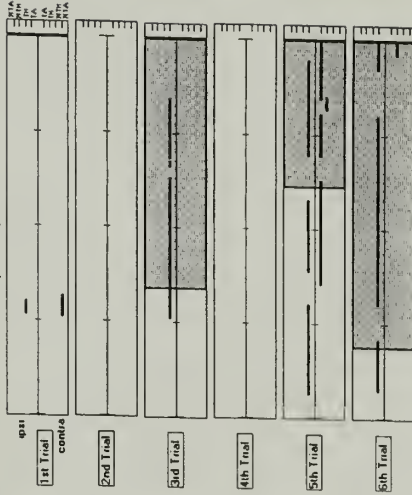
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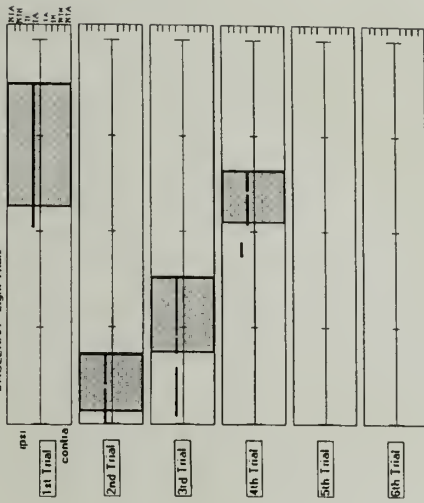
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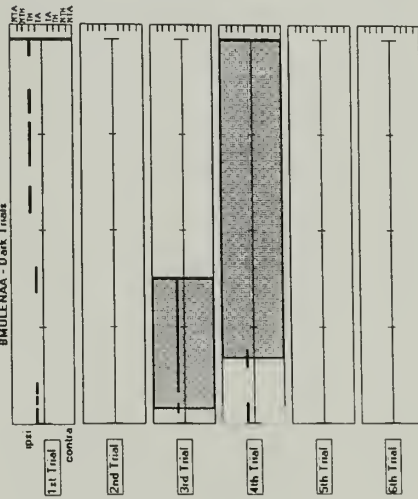
BWHEELERSup / No Obj. Trials



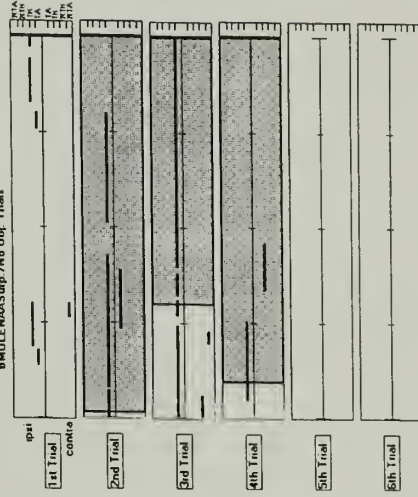
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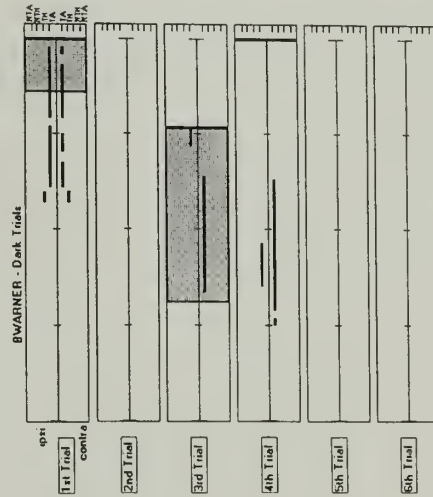
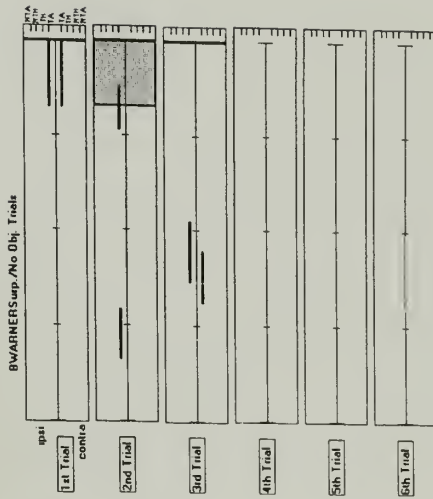
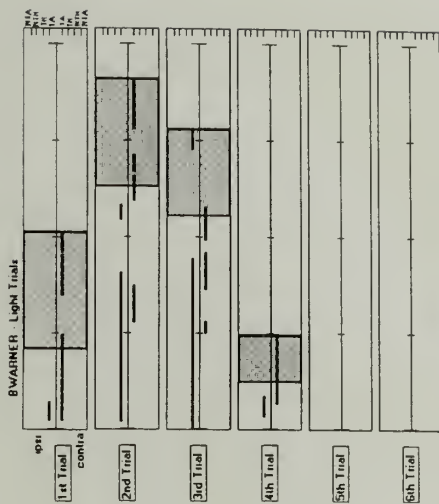


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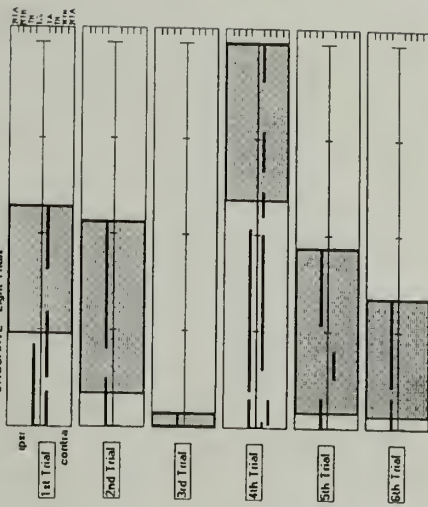


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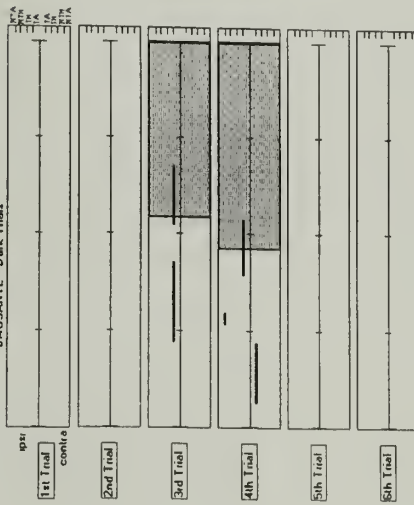




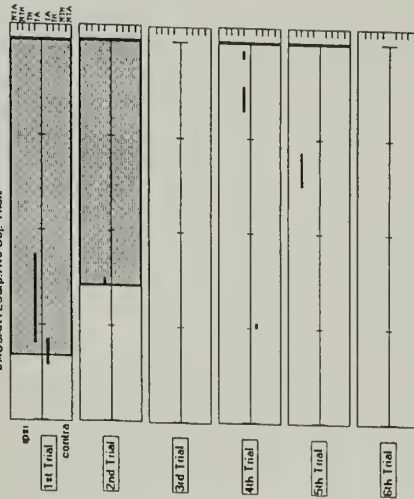
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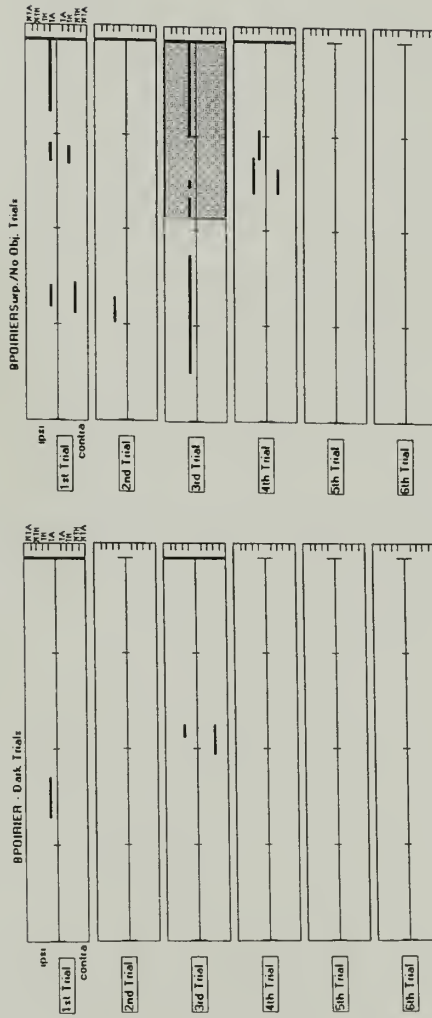
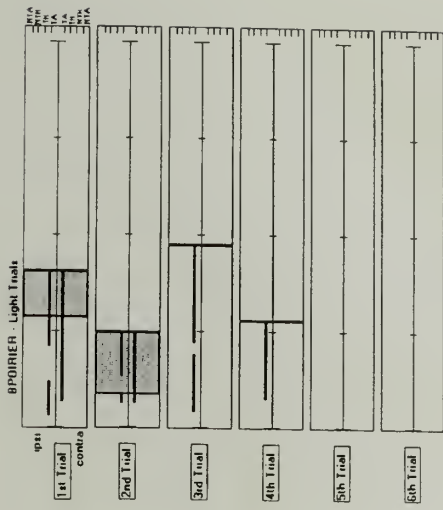


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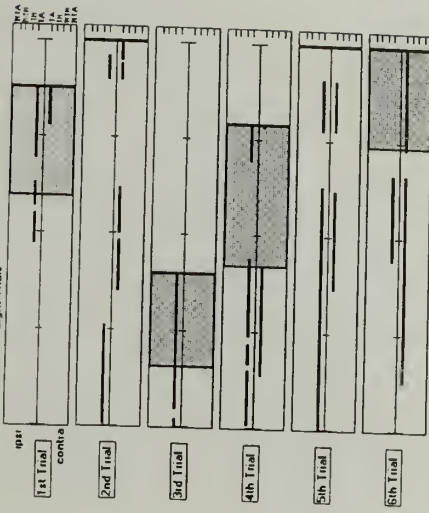


BMUSANTE Sup. No Obj. Trials

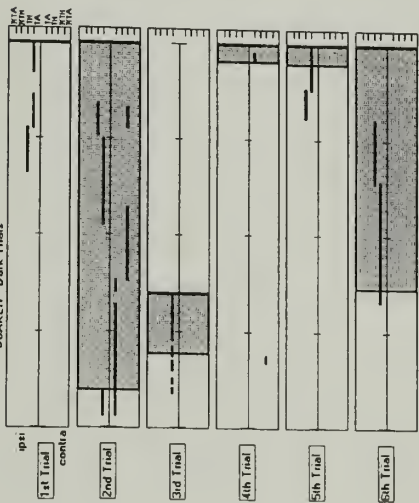




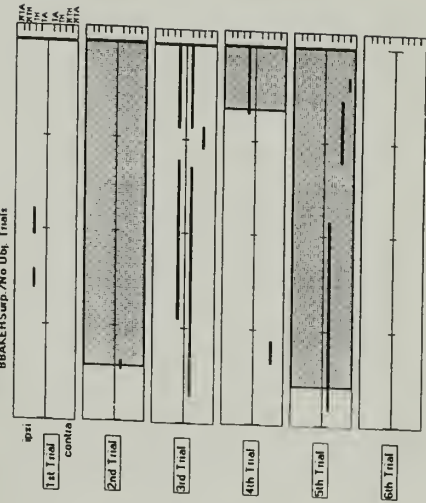
BBAKER - Light Trials



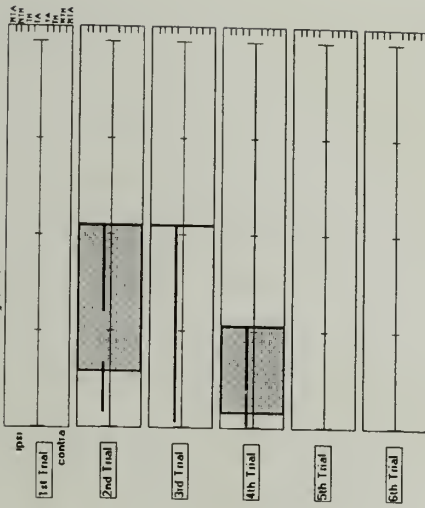
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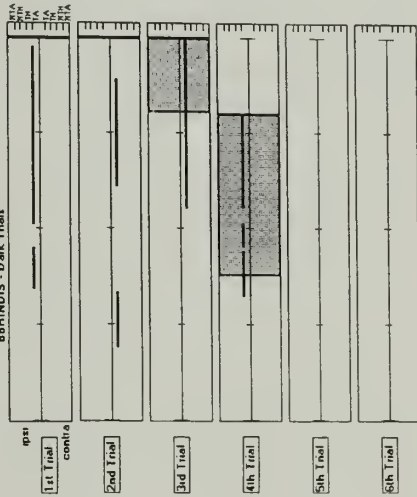
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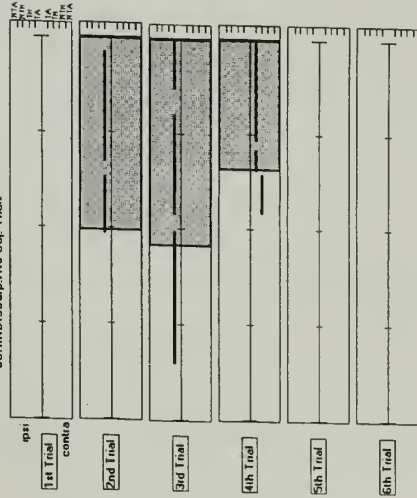
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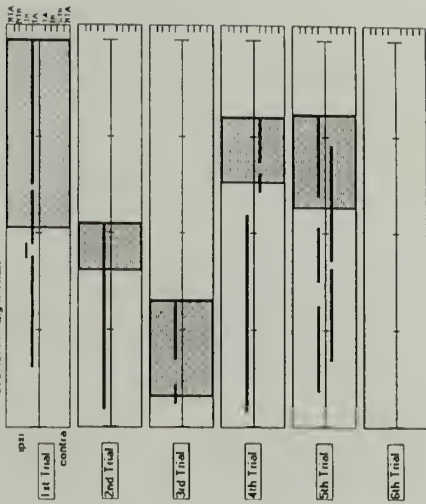
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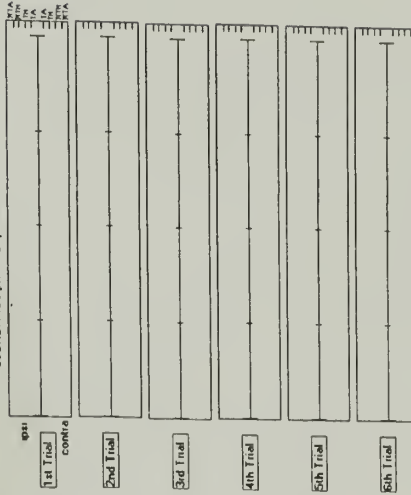
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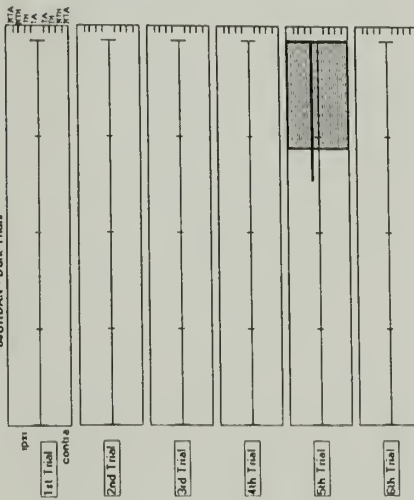
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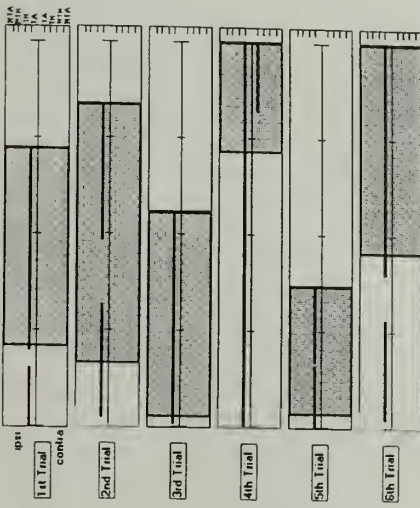
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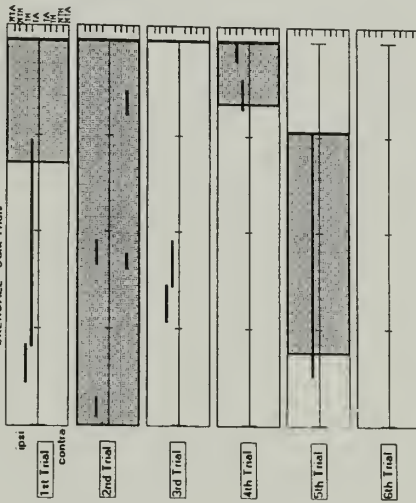
BJORDAN - Dark Trials



BKENDALL - Light Trials

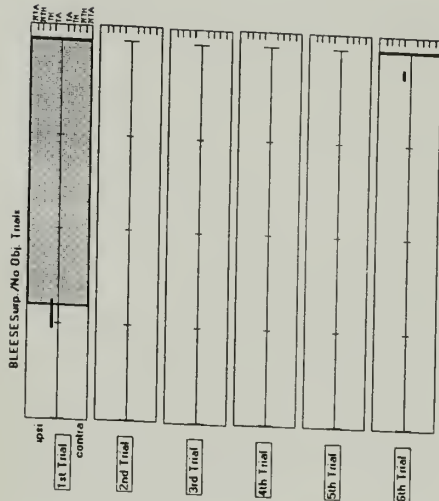
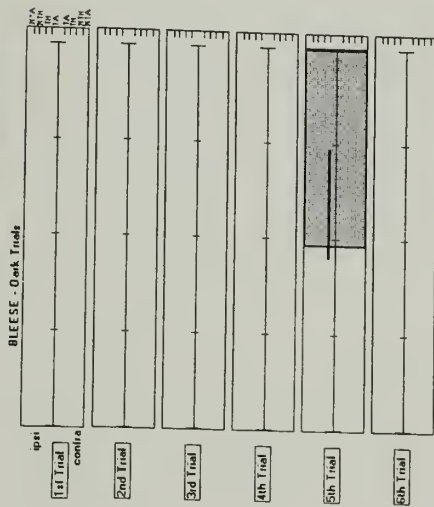
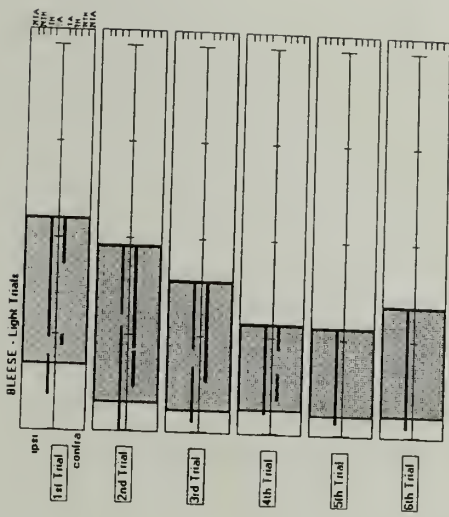


BKENDALL - Dark Trials

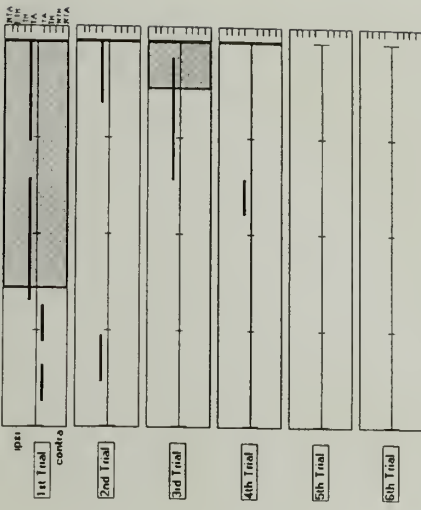


BKENDALLsup./No Obs. Trials

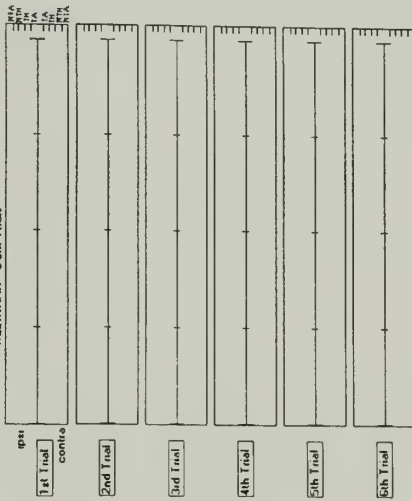




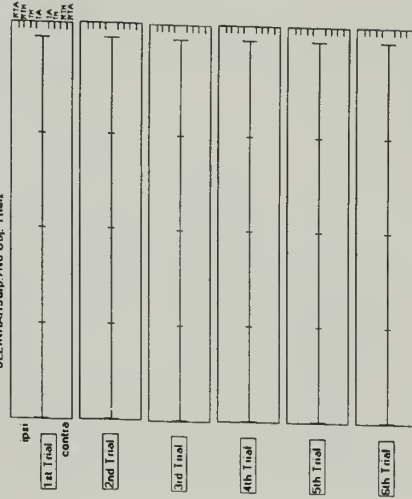
BLENNHAR - Light Trials

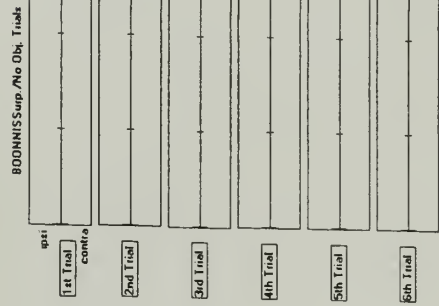
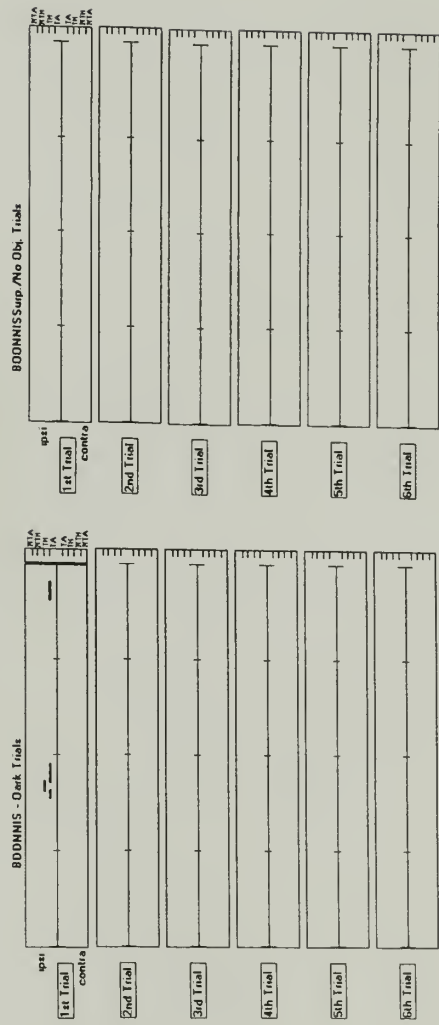
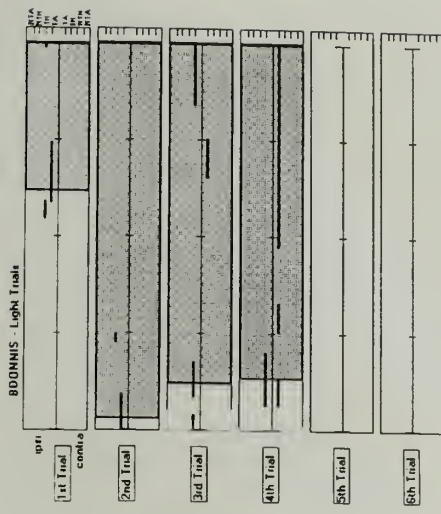


BLENNHAR - Dark Trials

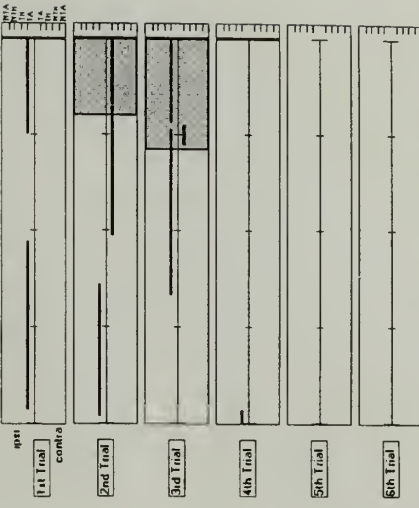


BLENNHAR Supp./No Obj. Trials

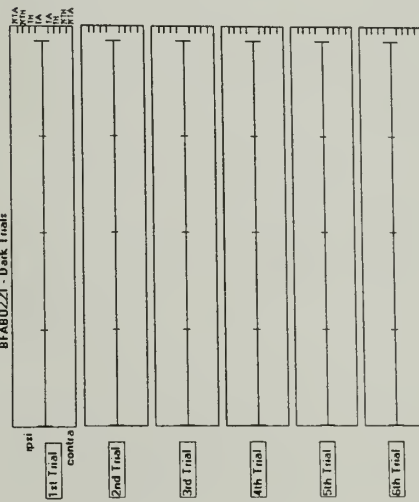




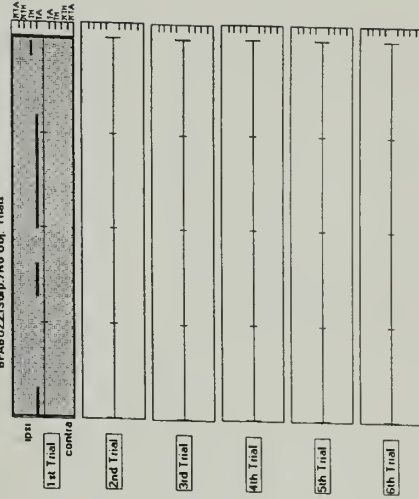
BFABDZZI - Light Trials



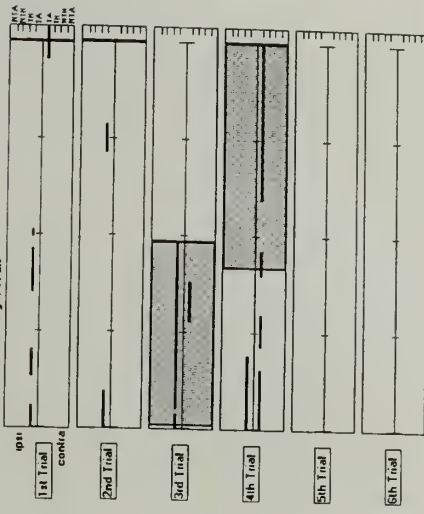
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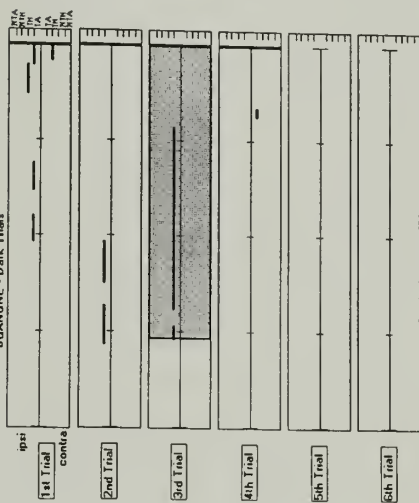
BFABDZZI Sup./No Obj. Trials



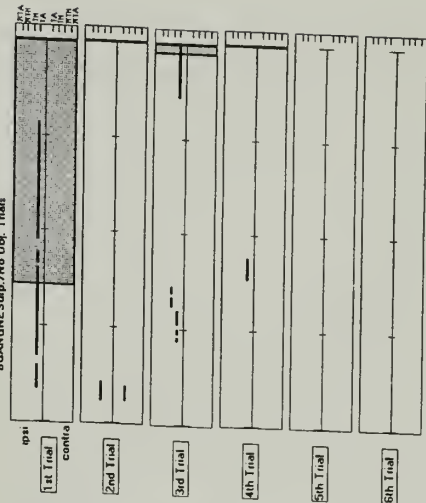
BGANGNE - Light Trials



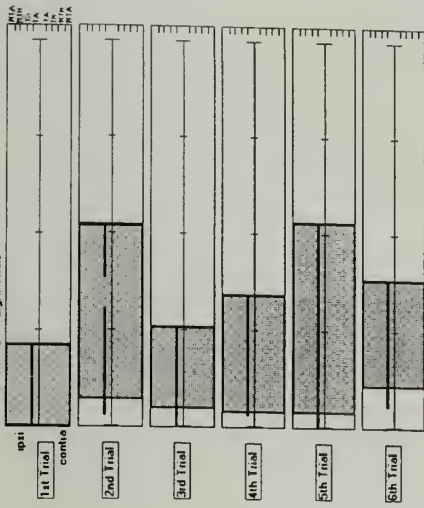
BGANGNE - Dark Trials



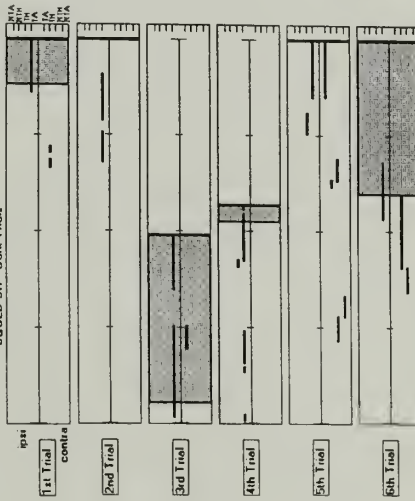
BGANGNE Sup./No Dbg. Trials



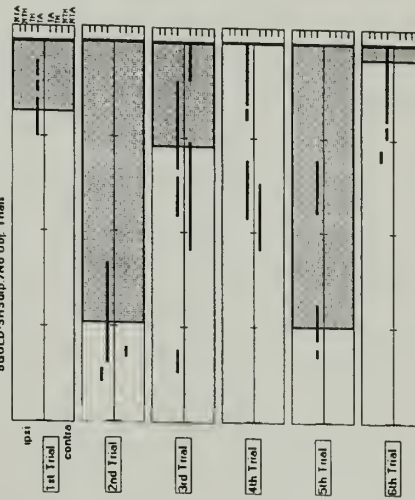
8GOLD-SH - Light Trials

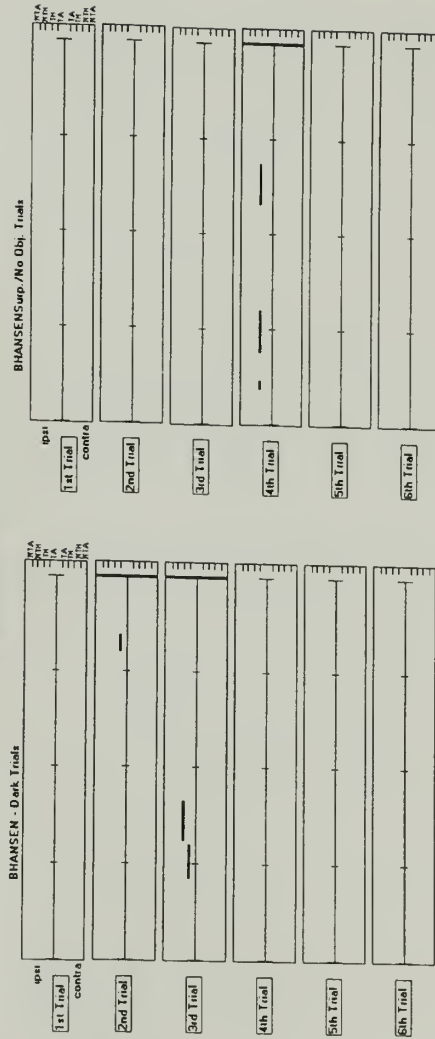
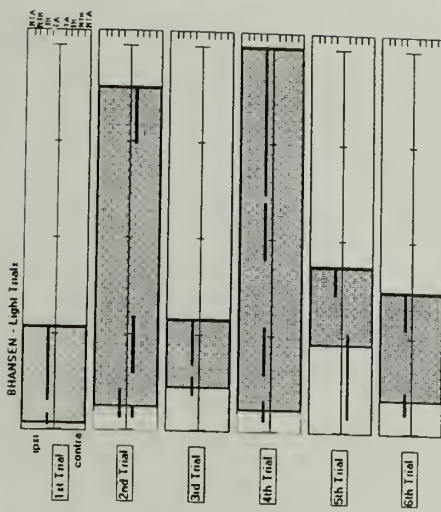


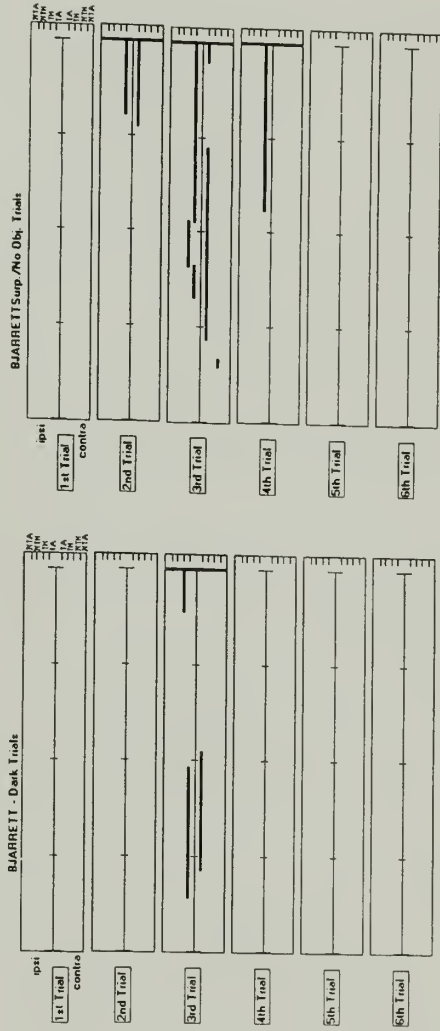
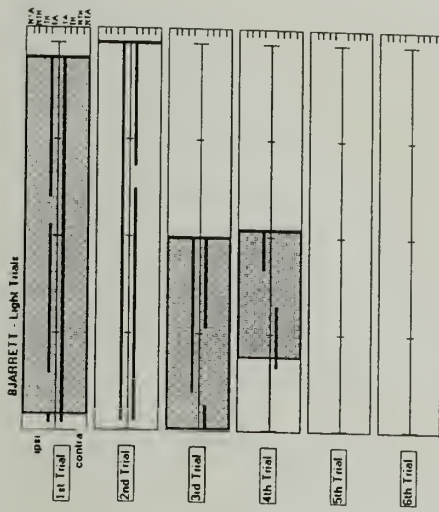
8GOLD-SH - Dark Trials



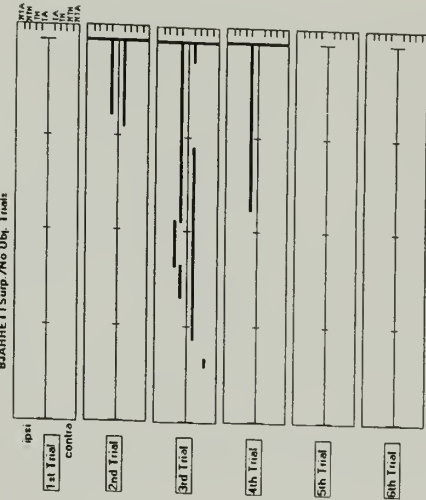
8GOLD-SHsup-/No Obj; Trials



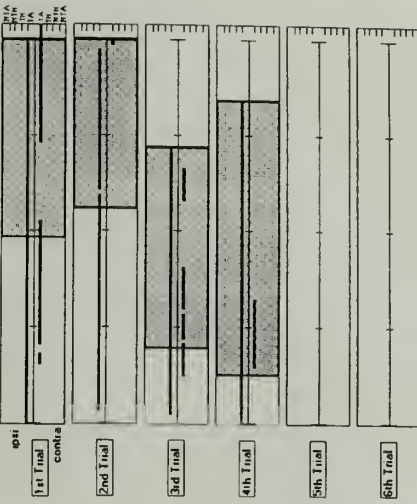




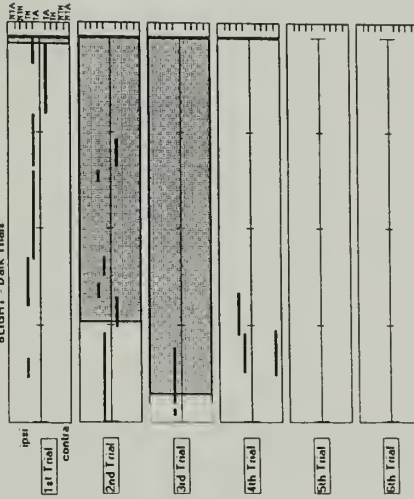
BJARRETT Sup / No Obj. Trials



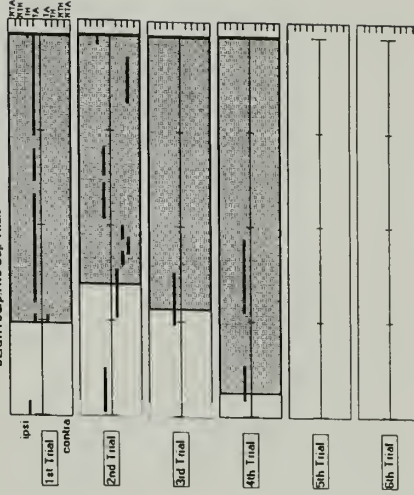
BUGHT - Light Trials



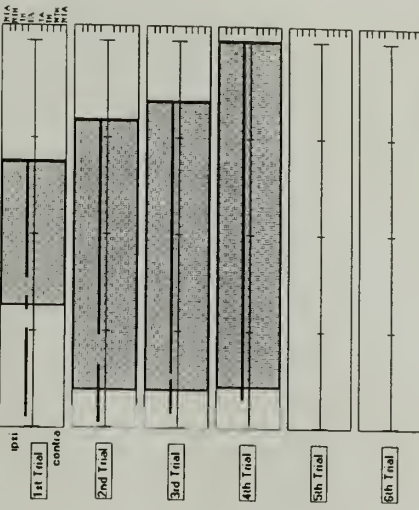
BUGHT - Dark Trials



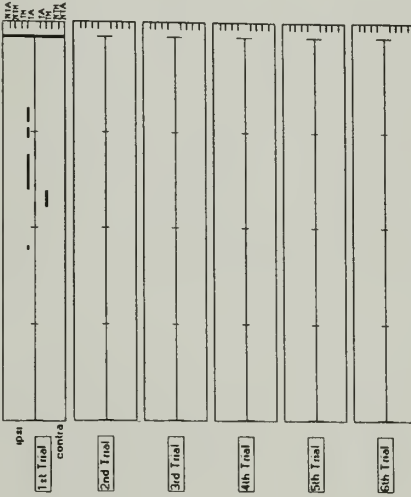
BUGHTSup / No Obj. Trials



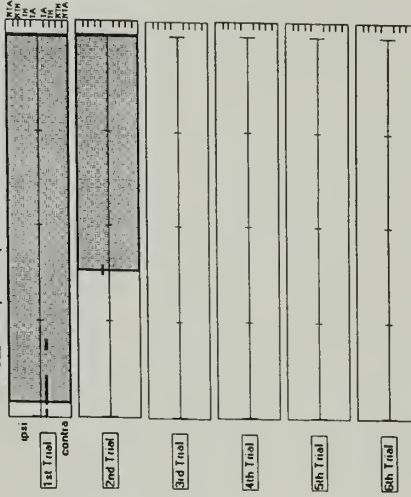
BLEVIN - Light Trials

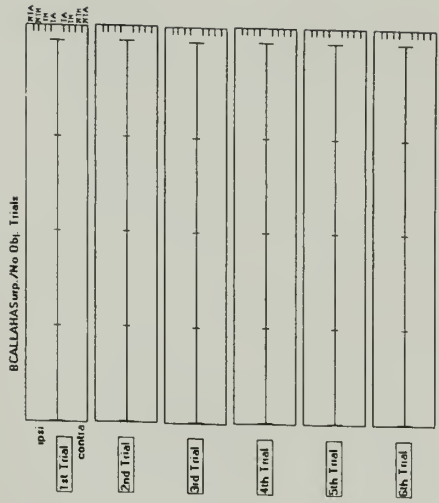
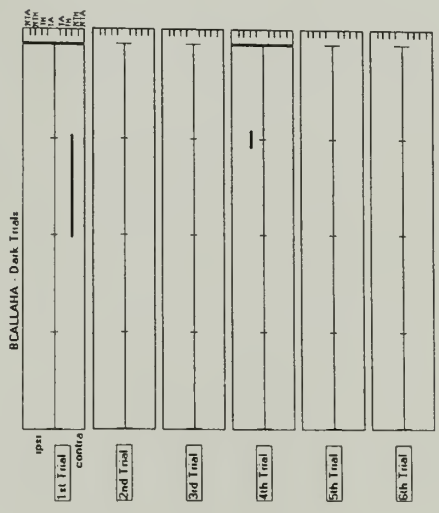
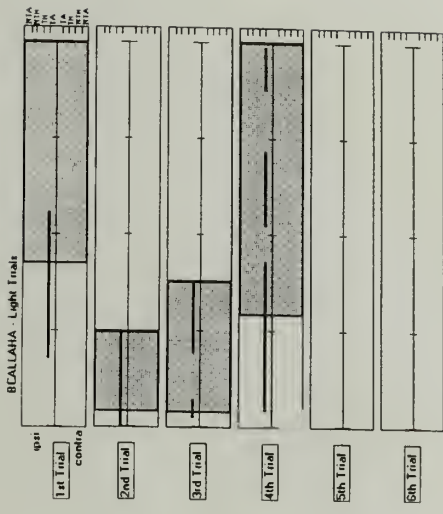


BLEVIN - Dark Trials

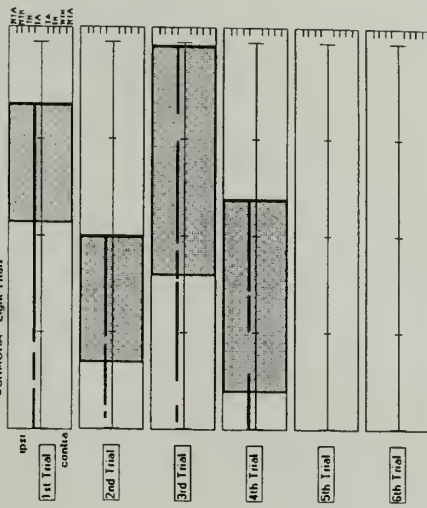


BLEVINsup./No Obj. Trials

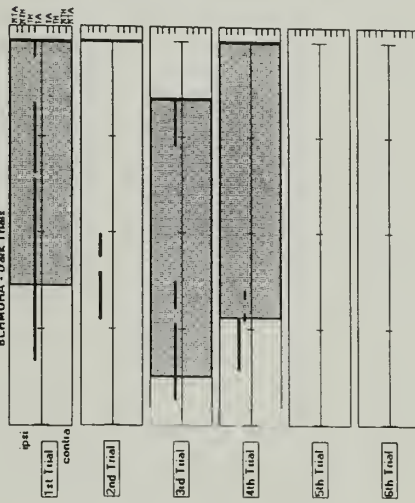




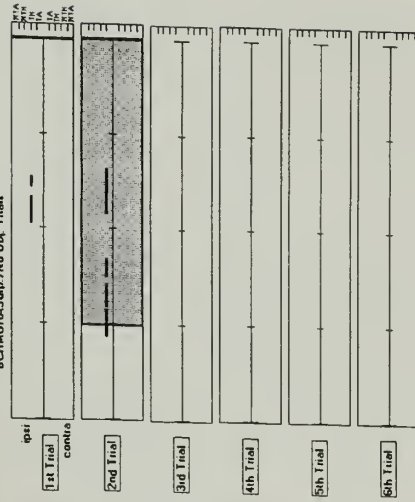
BCHMURA - Light Trials



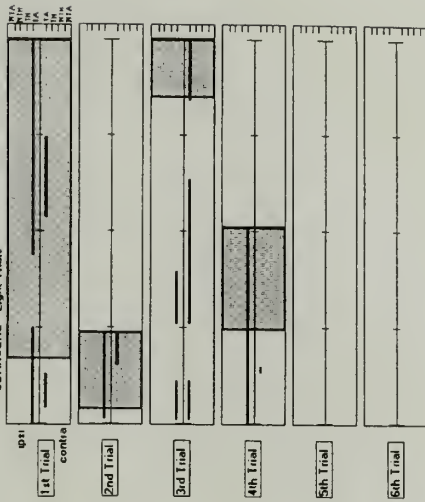
BCHMURA - Dark Trials



BCHMURASup/No Obx Trials



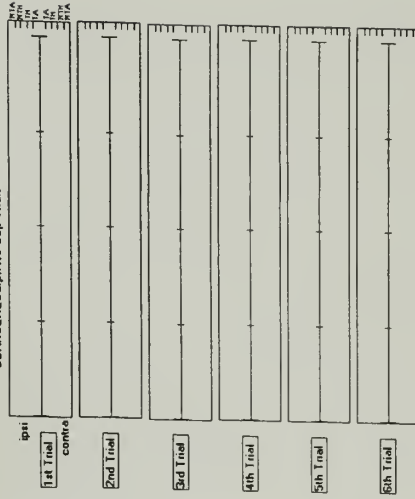
BDANSERE - Light Trials

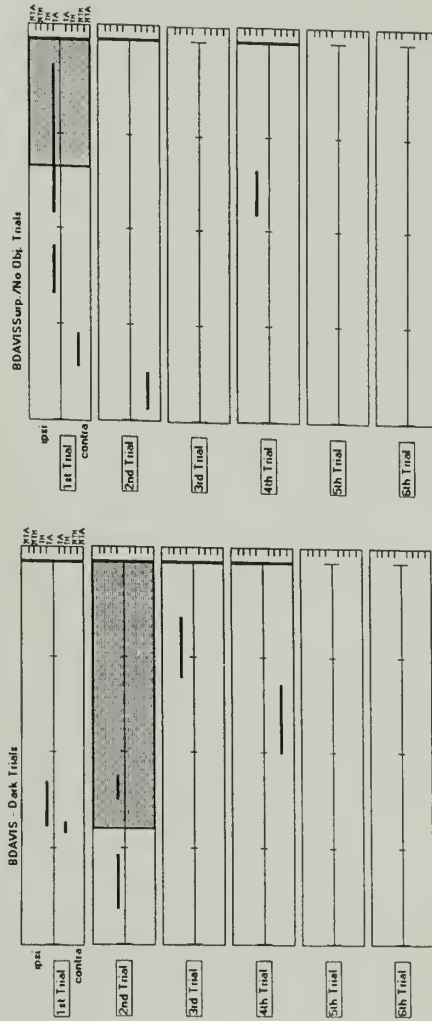
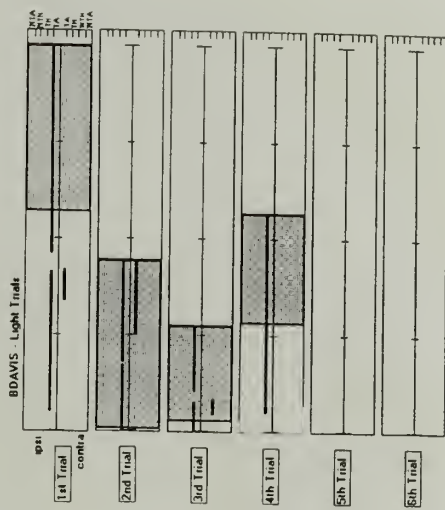


BDANSERE - Dark Trials

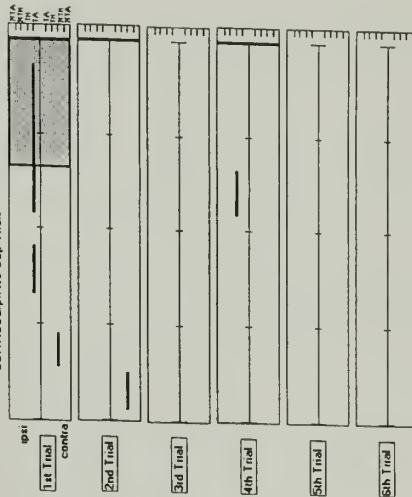


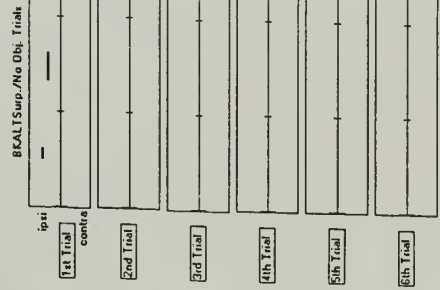
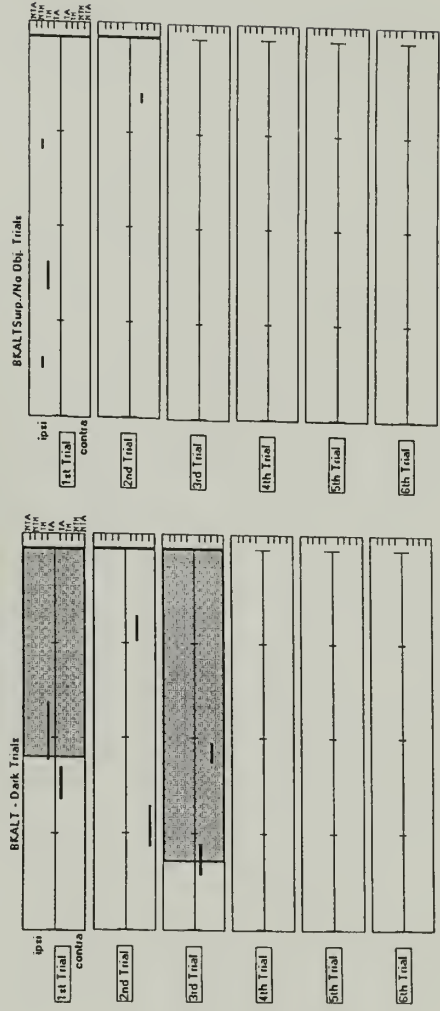
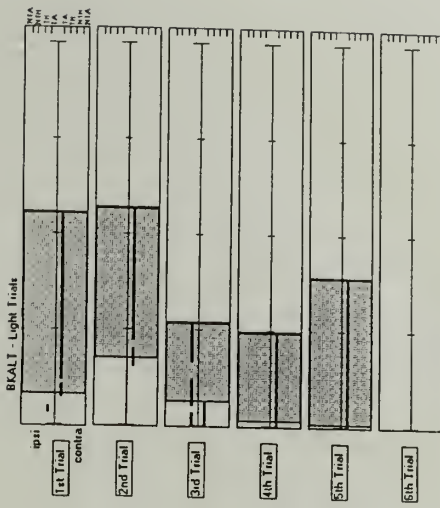
BDANSERE sup./No Obj. Trials



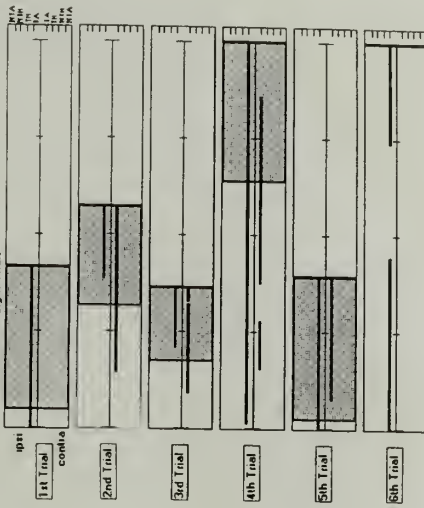


BDAVIS Sup./No Obs. Trials

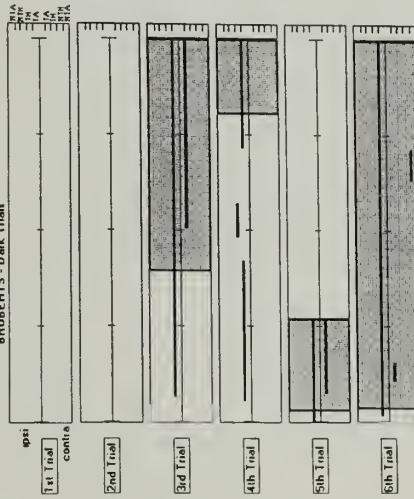




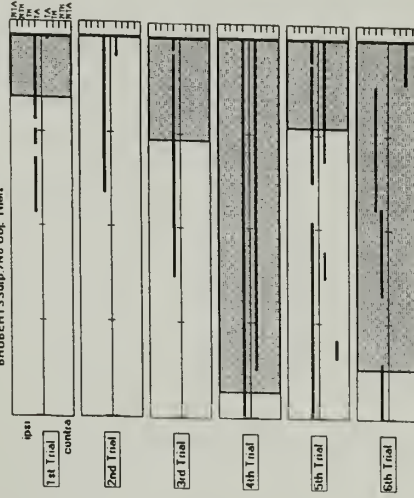
BRUBERTIS - Light Trials

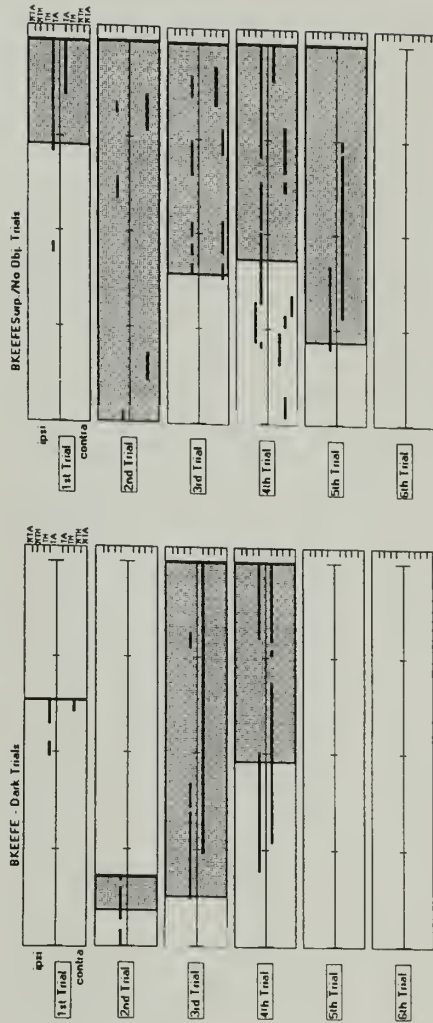
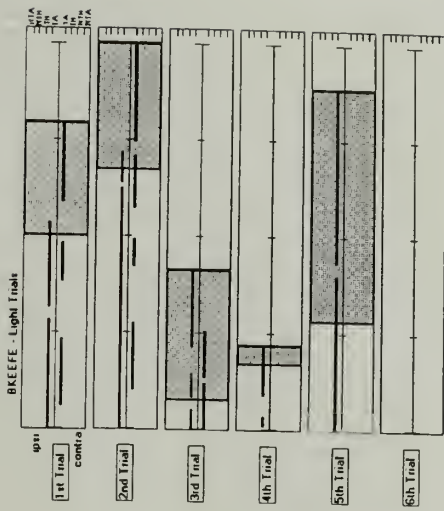


BRUBERTIS - Dark Trials

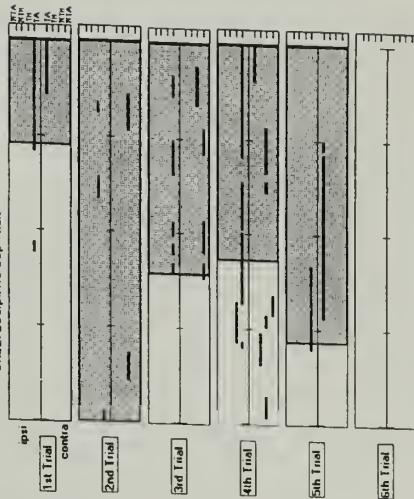


BRUBERTIS - Sup/No Ob, Trials

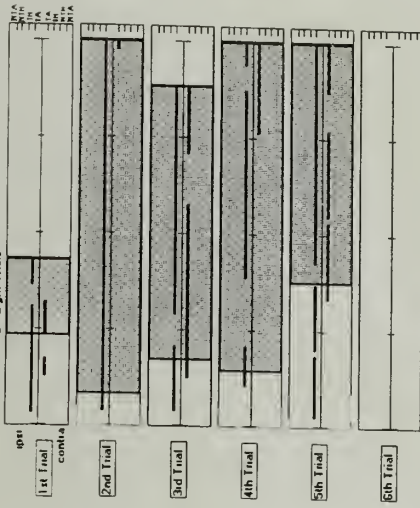




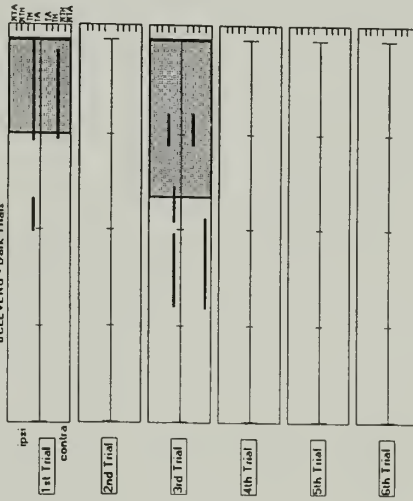
BKEEFESup No Obj. Trials



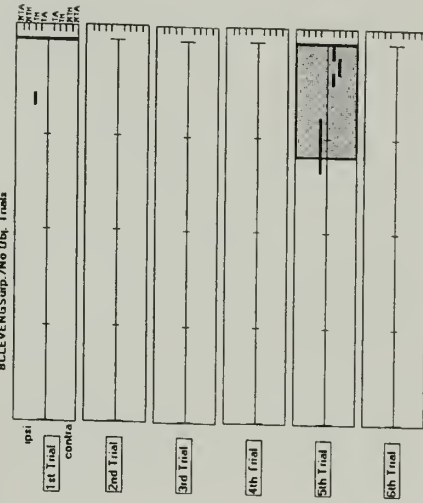
BCLEVENG - Light Trials



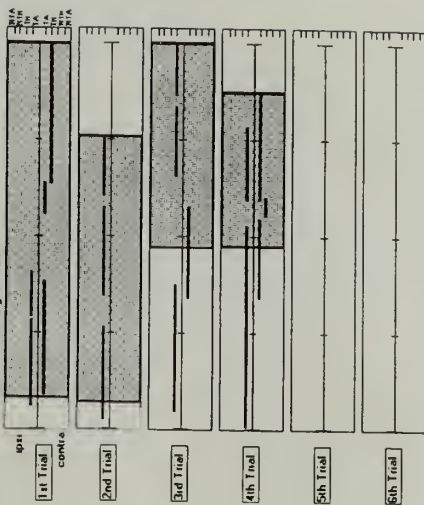
BCLEVENG - Dark Trials



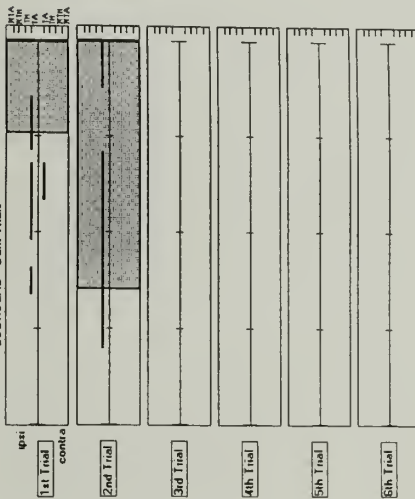
BCLEVENG Sup. / No Obj. Trials



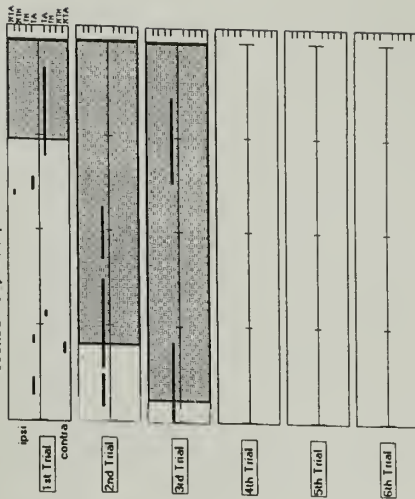
BBURDEAU - Light Trials



BBURDEAU - Oak Trials



BBURDEAUSup Mo Oh Trials



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