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Object and event representation in 6-1/2-month-old infants.

Nathalie Goubet
University of Massachusetts Amherst

OBJECT AND EVENT REPRESENTATION IN 6½-MONTH-OLD INFANTS

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NATHALIE GOUBET

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by

NATHALIE GOUBET

Approved as to style and content by:

Rachel K. Clifton, Chair

Nancy A. Myers, Member

Melinda Novak, Member

Charles E. Clifton, Chair
Psychology Department

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ABSTRACT

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NATHALIE GOUBET, DIPLÔME D' ÉTAT D' INFIRMIÈRE,

ÉCOLE ST. JOSEPH FRANCE

B.A., UNIVERSITY OF MASSACHUSETTS AMHERST

M.S., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by Professor Rachel K. Clifton

Two experiments were designed to test the idea that 6.5-month-old infants can use a mental representation of a previously seen event to guide their later reaching behavior. In Study 1, infants were presented with two auditory events in the light and the same events in the dark. Events consisted of a ball bouncing down a tube and coming to rest in one of two locations. In one event the ball triggered a brief sound when it hit bottom and was available for pick-up at midline. In the other event, the ball triggered a different brief sound upon hitting bottom and was not available for pick-up. Reaching behavior was observed for 15 seconds after sound ceased. Results showed that infants searched for the object while in silence and in the dark. They began their reach with neither audition nor vision available to guide their reaching and they continued to search for the ball for nearly 6 seconds after termination of the auditory cue. Infants did not discriminate between the two endpoints of the ball's trajectory in the dark, however, because in the inaccessible event they tended to search for the ball at its location in the accessible event. In Study 2, two new events were presented. In one event, a ball was dropped through a tube but instead of landing at midline, it rolled down a left or right path and landed in a tray. Location of the last sound heard did not correspond to the resting location of the ball although it did indicate which side the ball

would be on. One group of infants was presented with this event both in the light and in the dark. A second group experienced a different event in the light and then received the same dark trials. In their light event the ball was dropped through the tube and landed in a tray at midline. The side paths were hidden. Results show that the group that saw the right-left events reached to the appropriate side significantly more often than the midline event group. This suggests that they built a mental representation of the events. Both groups continued to reach for up to 12 seconds while in silence and in the dark, searching for the object. These two studies show that infants know that objects exist even when no perceptual information is currently available about their presence or location.

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CHAPTER I

INTRODUCTION

A central issue in infant cognitive development is the development of the ability to represent mentally objects and events. As adults, we take this ability for granted. Our world is filled with perceptions to which we attribute meaning without even thinking about it. For example, upon hearing a loud noise coming from the neighbors' garden on Saturday morning, we infer that the noise is produced by the lawnmower and that the neighbor is mowing the lawn with it. Even though we do not see our neighbor, we know he or she is pushing the lawnmower. We do not need to see the scene to know what is going on. Our perceptual senses do not give us the details of the scene but our ability to mentally represent objects and people (and our knowledge of a lawnmower's sound) allows us to understand what is going on. This is our world. What about the infant's world?

A. Piaget's theory

Piaget (1952; 1954) has been a major influence in describing the origins of mental representation. His stage theory emphasized the construction of infants' cognitive processes. According to Piaget, the world of the young infant is made of "tableaux" or images that can appear or disappear, without any objectivity or spatial organization. Piaget identified six stages of the development of object concept during the sensorimotor period. In the first two stages, there is no special behavior when an object disappears. For example, a hungry infant will cry upon seeing her bottle but as soon as the bottle disappears, the infant stops crying (Piaget, 1954). Piaget argued that if the infant really knew that objects were permanent, she would not stop crying; she would

be actively searching for it, for example by changing her perspective. According to Piaget, during the first two stages infants are repeating earlier movements of accommodation. During the third stage, objects are not yet permanent for the infant. When an object disappears, the infant stretches the arm to retrieve it but does not search for it. Even though there is greater object permanence than in the previous stages, the infant's conception of the object is still totally dependent on his/her actions. Objects do not have an existence of their own. Infants at that stage of development, (between 3 and 6 months of age), fail the classical Piagetian task: When an object that they have been interacting with, is covered by a blanket in front of them, they do not attempt to retrieve it, but act as if the object had vanished. It is not until the fourth stage (between 8 and 10 months of age) that infants will remove the cover and retrieve the object. In the next two stages, infants will continue to construct objects so that by the end of stage VI (at about 18 months), they will be able to represent invisible displacements. At the end of the sensorimotor period, objects are not considered by infants as an extension of their actions. Infants understand that objects have an existence of their own.

According to Piaget, until stage IV, infants do not attribute a continuous existence to objects. They do not have mental representations of objects or events independently of perceptual cues or of motor interaction with the objects. Action was for Piaget the basis of reality construction. Infants first repeat the actions they just performed to get an object. The world of infants is thus very phenomenological, magical. It is a world of appearance and disappearance and one's reaching movement makes a situation reappear. Later in development, infants start searching for the missing object and this represented for Piaget a milestone in the construction of object concept. It was the sign that infants gave an existence to the object independent of their earlier movements, in other words that the object could be anywhere in the spatial field and

not necessarily where they last saw it. To Piaget, the onset of search was indicative of the infants' ability to withdraw themselves from the object and to develop spatial coding (Bremner, 1991).

B. Transitional search versus intentional search

Researchers have attempted to show that infants might fail Piaget's task because of a motor inability to pick up the type of cover traditionally used in this task. Rader, Spiro, & Firestone (1979) argued that retrieving the toy from under the traditionally large cloth might be difficult. They tested 5-month-old infants with a standard cover (large white washcloth) and a nonstandard cover (small blue cardboard cover). Infants had more success retrieving the object when it was under the card cover than when it was under the cloth. The authors argued that failure on the classical task reflected motor immaturity rather than absence of object permanence. Willatts (1984), however, has criticized this study on several grounds. First, one of Piaget's criteria to assess intentional search was that infants should remove the cover and immediately reach for the toy. They should not play with the cover. Nevertheless, Rader et al allowed the infants to manipulate the cover for up to 30 seconds. Moreover, Rader et al indicated that infants retrieved the object by pushing away the nonstandard cover. They did not specify whether infants could have picked it up or not. Infants might have pushed the cover because of lack of motor control instead of intention or just because they wanted to play with the cover. Finally, it was not reported where infants were looking during their search. When Willatts followed Piaget's criteria of intentional search, he found that 6 months-old infants displayed transitional search before showing intentional search. During this phase, infants removed covers but their behavior with the cover and their visual fixation demonstrated no intention to find the hidden object. He concluded that

infants' behavior in Rader et al's study was consistent with Piaget's Stage III of the sensorimotor period.

C. The Gibsonian approach

E. Gibson (1988) argues that babies explore the world from very early on. Even though the activities are "immature and unskilled...they do appear to be spontaneous and directed" (p. 13). This perspective differs from Piaget's in the sense that he believed that exploration would develop later with intentionality. The Piagetian infant does not really explore, he rather comes in contact by chance with the world and learns from it. He constructs knowledge by forming schemes based on his motor behavior with objects. To Piaget, perception does not provide knowledge by itself but can only be interpreted through operational knowledge. For Gibson, by contrast, any stimulation is rich of information. Information is in fact inherent in stimulation. The developmental issue for Gibson is how the child learns to extract more and more information from the stimulation. For Piaget the developmental issue is how the child builds different schemes and integrates them to produce a true account of reality.

Despite differences, common to both authors is the idea that any kind of exploration is a support on which cognitive activities are based. Action, whether it is sucking on a nipple, or fingering an object, or learning to walk, is necessary for cognitive development to be satisfactory. In support of this, Ruff, McCarton, Kurtzberg, & Vaughn (1984) have demonstrated that delayed children (born prematurely) showed less manipulation of objects, less fingering and later this low exploration correlated with cognitive functioning. Ruff et al suggested that the less infants explore the world around them, the less they can categorize objects which later leads to language delay. Action is a necessary condition for "normal" cognitive development. If action is a key

component of cognitive development, then experience is a key concept guiding development. This theoretical position is very different from a nativist perspective which grants much ability at birth.

D. Nativism vs. Construction

Is infants' knowledge innate or is it gradually constructed as a function of experience? Spelke is a major proponent in the nativist camp. She argues (1988) that from about 3 months of age, infants see the world as made of objects that are coherent, bounded and solid. Infants are able to reason and development only brings enrichment of a core knowledge. To Spelke, Breinlinger, Macomber, & Jacobson (1992): "Cognition develops from its own foundations, rather than from a foundation of perception and action" (p.605).

Piaget proposed that infants learn to construct the world by two processes, assimilation and accommodation. In assimilation, a new concept, motor response, or word, gets incorporated into the existing system. For example, an infant sees a new toy and reaches for it in the usual way. In this case, she uses her ability to reach to get a new toy. In the case of accommodation an infant might alter her grasp in reaching for a toy with a new shape.

E. The competent infant

In the last decade, a number of researchers have agreed with Spelke that some features of cognitive functioning might be present before infants perform much action. A growing body of data indeed suggests that infants are much more competent than Piaget thought (Spelke, 1988; Baillargeon, Spelke, & Wasserman, 1985; Baillargeon, 1986; Baillargeon, 1987; Spelke, 1988; Baillargeon, Graber, Devos, & Black, 1990;

Baillargeon, 1994; Kotovsky & Baillargeon, 1994). Such researchers have abandoned the use of reaching as a method of investigation and instead use a modified version of the visual habituation paradigm, called "violation-of-expectation" method (Baillargeon, 1994). In a typical experiment, infants are first habituated to an event. After habituation (usually between 6 and 9 trials) infants are alternatively presented with either an impossible event or a possible event. Because infants are known to be attracted by novelty, these experiments have usually been designed so that the impossible event is the more familiar event (it looks like the habituation event) while the possible event is the novel one. If infants look longer at the familiar event, then authors argue that they have noticed the impossibility of the event; it "violated their expectation". If on the other hand, infants look longer at the possible event (the novel one), then it is assumed that infants did not notice anything unusual, or that they are simply responding to perceptual novelty. Baillargeon, Spelke, & Wasserman (1985) used this method to investigate object permanence in 5-month-old infants. They habituated infants to a 180° rotation of a screen. After habituation, a box was placed behind the screen and infants were presented with two events. In one event, the possible event, the screen was rotated 112° until it touched the box. In the other event, the impossible event, the screen rotated 180° as if it was going through the box. Infants looked longer at the impossible event even though the possible event was the novel event. This suggested that they knew that: a) a box was behind the screen and b) the rotation of the screen violated the rule that objects are substantial entities. Baillargeon (1987) replicated this experiment with 3.5 and 4.5 month-old infants and showed that 4.5 month-old infants looked longer at the impossible event but only some 3.5-month-olds did. These experiments showed that infants seem to have object permanence much earlier than expected. Moreover, in this experiment, particularly with the younger children, it seems that action is not a crucial element in infants' learning. At 3 months of age, infants are far from being

proficient reachers (indeed they are still only "prereaching), and their exploratory skills are limited. Yet, they seem to understand many phenomena of the physical world. Contrary to Piaget's (and Gibson's) contention, these babies do not need to act on objects to develop their knowledge about them.

The body of literature described above departs drastically from established paradigms in two major ways: the first one refers to the contents of the infant's mind and the second to the path by which infants get to know what they know. In the new paradigm infants know a lot about objects and the physical world whereas they are extremely limited in the old paradigm. Moreover, in the old paradigm action was a main tool to gain knowledge whereas in the new paradigm, action is not necessary, and infants seem to come into the world with quite a sophisticated mental apparel.

F. Piaget's task versus visual-habituation task

Why would infants be successful in Baillargeon's task but fail Piaget's task? Several explanations have been proposed to explain these discrepancies pertaining to the complexity of the task, the problem of means-end sequences, the issue of boundaries, and detour reaching.

1. Complexity of the task

The first of these explanations refers to the idea that the two tasks are not comparable because they do not test the same processes. Fisher, & Bidell (1991) have argued that success in the Piagetian task requires true object permanence (i.e. the knowledge that objects exists even after they have been hidden) whereas Baillargeon's task is not an index of object permanence but a simpler, cruder representation of some sort. In Piaget's task, infants are required to act (by reaching) to

show their understanding. By contrast, in Baillargeon's task, they only need to look. Gaze duration is considered the index of mental representation in the type of studies described above. Looking, however, may only reflect the early steps of object permanence, (stage III of sensorimotor development) compared to Piaget's task (see also Bower & Wishart, 1972). Indeed, in some of Piaget's observations of behavior during the third stage, infants seem similar to Baillargeon's infants and yet Piaget gives a different interpretation. For example:

> "Obs. 5: At 0;4 (26) she [Lucienne] takes the breast but turns when I call her and smiles at me. Then she resumes nursing, but several times in succession, despite my silence, she turns directly to the position from which she can see me. She does it again after a pause of a few minutes. Then I withdraw; when she turns without finding me her expression is one of mingled disappointment and expectation (1954, p10-11)."

According to Piaget, this behavior, as sophisticated as it seems, is not the reflection of a knowledge similar to ours. The reason for this is the fact that the search is merely the repetition of earlier acts of accommodation, in other words, the infant looked where she looked before, repeating her movement without trying to change her perspective to try to find her father. It could be argued, however, that babies at that age might not know how to search in a more active way because of their lack of prehension and locomotion abilities. Piaget discarded this hypothesis on the basis that infants do not search for hidden objects at much older ages when they are proficient at reaching.

Diamond (1990, cited in 1991) addressed the issue of the complexity level of the two tasks. She tested the correlation between looking and reaching by presenting infants with a visual paired comparison and a delayed non-matching to sample task. In the first task, infants were shown an object until they habituated to it and then were

presented the same object plus a new one. Their visual preference was recorded after various delays. In the second task, another group of infants was habituated to reach for an object (direct reach). After a delay (10, 15 seconds, 1-10 minutes) the same object was presented along with a new one, and infants could reach for either of them. Diamond found that infants performed the same way at the same ages in both tasks suggesting that reaching and looking do correlate. She argued that when infants are required to demonstrate their knowledge on a task that does not require means-actions sequences, they are as precocious in reaching as in visual habituation tasks. In other words, to Diamond, using visual habituation is a valid way to investigate infant cognition since it avoids problems like mean-end actions.

2. Means-end sequences

A number of researchers (e.g., Bower, & Wishart, 1972; Baillargeon, Spelke, & Wasserman, 1985; Diamond, 1991), have suggested that infants fail Piaget's task because they are limited in their abilities to perform sequenced actions. In order to succeed, they must lift the cover and then get the object. The cover is not picked up for its own sake but only to get at the other object under it. The inability to perform means-ends actions prevents the infant from succeeding at this task, even though they know the object is hidden under the cover. Willatts (1989) has shown that when infants become able to pull a support toward them in order to get an object which is resting on it, they also become successful on the classical Piagetian task. Baillargeon et al (1990) have argued that infants are unable to perform means-end actions because they have difficulty engaging in activities that put them in conflict with their goal. In the example of the toy hidden under a blanket, reaching for the blanket put infants in conflict with their goal of reaching for the toy. Infants' lack of problem solving abilities prevents them from showing their mental representations.

Diamond (1991) has argued that the ability to perform means-ends actions is linked to the maturation of the frontal cortex. Before cortical maturation, infants lack relational abilities. During the first year of life, there is an immaturity of the interhemispheric connections. This immaturity makes it difficult for infants to relate information over temporal and spatial delays.

3. Boundaries

Bower (1977) proposed yet another explanation for the reason of the failure of infants to reach for an object hidden under a cloth. He argued that infants may have difficulty distinguishing boundaries. For example, infants might not know that when two objects touch each other, they are still two independent objects. Diamond (1991) rejected this hypothesis. She showed that, in the infant's mind, objects exist independently even when they share a boundary with another object. She presented infants with a Plexiglas box open at the top. A building block was then placed either at the center of the box (2 inches from the front wall of the box), directly behind the front wall or directly in front of the front wall (the block touched the wall in both instances). Infants had no problem retrieving the object when it stood at the center of the box. They did not retrieve it when it was directly behind the front wall which would support the boundary hypothesis, except that infants had no problem retrieving the object when it was directly in front of the front wall of the box. Diamond concluded that infants did perceive boundaries between objects. She argued for a different type of problem, mainly the difficulty for young infants to perform indirect reaches.

4. Detour reaching

Diamond (1991) proposed that infants could only perform direct reaches. As long as they could reach for an object on a straight line, they were successful; however, if

the reach required a two directional action (reach over the front wall then reach back for the object), infants would keep touching the edge of the box without reaching for the object. According to Diamond this example represents evidence that infants younger than 8 months of age are not able to inhibit some reflexes of the hand. Bruner (1970) did not allow infants to reach directly, by placing objects behind a transparent screen. He showed that up to 8 months, infants tend to first reach for the object through the screen, then to "scratch or bang" at the transparent screen and eventually to give up. In another study, Diamond (1991) covered a toy with a transparent box which had an opening on one side. Infants aged 6 ½ to 7 months reached only from the side of the box through which they could see the toy. They kept trying to get the toy from the same perspective even though they failed every time. It is not until 7½ or 8 months of age that infants will try other alternatives to get the toy. Even then, they will not be able to separate the line of sight from the line of reach. They will for example raise the box or bend down to look at the toy through the opening. By 8½ to 9 months of age, infants will reach through one side while looking through another one. According to Diamond, the maturation of the cortex (more specifically the supplementary motor area) will allow infants to inhibit the drive to reach directly for a visible object and also to perform actions in a sequenced manner.

5. Summary

When researchers use a visual habituation paradigm to test infants' abilities, they discover a much more competent infant than Piaget hypothesized. The evidence reviewed above tends to show that infants younger than 8 months may fail the standard Piagetian task, not because of lack of knowledge that objects continue to exist, but because of a lack of ability to demonstrate their knowledge. It has to be noted, however, that although the visual habituation paradigm unveils new abilities in

young infants, it does not necessarily help us specify the nature of representation they hold.

Indeed, Baillargeon, Spelke and colleagues use such words as inference, reasoning, prediction, estimation, etc. It seems that these words are sometimes used too generously as the actual data only consist of looking times and do not conclusively give information as to what infants represent. The whole method rests on the assumption that gaze duration reflect a particular cognitive activity, namely surprise. Siegler (1993) has noticed that one could be staring at some event or object for a number of different reasons, like interest and not necessarily surprise. Moreover, some of these experiments could be explained in perceptual terms as opposed to cognitive ones (Bogartz, 1995).

Another type of criticism pertains to the fact that we do not know what mechanisms are at work during visual habituation experiments. As Lecuyer put it: "Please infant, can you tell me exactly what you are doing in a habituation experiment?" (Lecuyer, 1988). Is visual fixation perfectly correlated with information processing? As adults we certainly stare blankly sometimes. Why not grant this to infants also? So far, we have not been able to devise a method to separate blank stares from what Holly Ruff would call "focused attention" (Ruff & Lawson, 1990).

G. Recall and representation

Piaget did not grant infants the ability to hold mental images until 2 years of age. To him, until this age, infants are imageless, with no symbolic ability. Mandler (1988) proposes that while it is difficult to assess mental imagery in infants (as it is in adults), one can study recall as an index of mental imagery. Recall, defined as the "evocation of absent objects" (Mandler, 1988), was not granted by Piaget until 2 years of age. A

number of researchers, however, have demonstrated recall much earlier than 2 years of age. Ashmead and Perlmutter (1980) for example, described recall for locations as early as 7 to 9 months of age. Meltzoff (1988) reported that 9 month-old infants could imitate actions they had seen but not performed themselves 24 hours earlier. Likewise, Myers, Clifton, & Clarkson, (1987) showed that infants who had been in an experiment when they were younger than 6 months of age, recalled aspects of the experience when tested at 2 ½ years.

H. Theoretical alternatives to Piaget

The ability to recall is, to Mandler, evidence that infants are not imageless organisms but do make some sense of their world. According to her, infants are born with the ability not only to perceive but also to engage in perceptual analysis. She describes this perceptual analysis as a process of comparison between perceptions. Infants engage in conceptual thought instead of simple perceptual recognition. She further argues that this perceptual analysis occurs as early as 6 months of age and that the results of this analysis are stored in an accessible representational system. This system is quite primitive at first as infants know little of the world. In support of this hypothesis, Mandler cites recall studies mentioned above and also the appearance of the stranger anxiety around 6 or 7 months of age. She proposes that the stranger's face is actively compared with an accessible representation of the image of the primary caretaker. In Mandler's view (1992), perceptual analysis is a sort of declarative knowledge which is not consciously accessible but is nevertheless usable.

Karmiloff-Smith (1992) proposes a similar model in which information is stored

according to a “cyclical process”. Mandler’s perceptual analysis is close to Karmiloff-Smith’s “representational redescription”. Information is first stored at the implicit level (L1). At this level, representations are in the form of procedures responding to environmental stimuli. At the second level, the Explicit level 1 (E1), the representations are the result of redescriptions into a new format. While it is not yet conscious, it is accessible. This is similar to Mandler’s perceptual analysis. There are explicitly defined representations that can be manipulated and related to others (e.g. the face of the caretaker vs. the face of a stranger). In the Explicit 2 level, the representations are available to conscious access but not to verbal report. These representations are available to consciousness but are stored in a similar code as E1. It is not clear how these two levels can be experimentally tested. At the last level, E3, knowledge is recoded in a verbal form.

I. Testing object permanence and mental representation in the dark

One way to explore the mental world of the young infant is to test her in the dark. Clifton, Perris, & Bullinger (1991) pointed out that the reaching-in-the-dark task avoids several problems that the classical Piagetian task has. For example, the object hidden by darkness can be obtained with a direct reach, and because there is no cover to remove, young infants' inability to perform means-end actions is not a problem. Moreover, there is no visual conflict posed by reaching for a cover when what they really want is the toy. Reaching-in-the-dark tasks are also closer to Piaget's task in that they require the same behavioral response (reaching).

Wishart, Bower, & Dunkeld (1978) presented a silent object, at midline, in the light while infants were prevented from reaching. The lights were then turned off and the infant was allowed to reach. Wishart, et al found that infants were successful in

reaching for the object. Nevertheless, this study was not found to be convincing evidence for the existence of mental representation in young infants because of methodological problems (see Baillargeon et al, 1985). More recently, Hood and Willatts (1986) presented an object in the light at one side while infants were prevented from reaching by their mother. Then, they turned off the lights and removed the object before the mother released the hands of the infant. They found that infants reached more often to the side where the object had been seen in the light than to the other side.

J. Auditory localization and mental representation

We know from a number of studies (Wishart, Bower, & Dunkeld, 1978; Perris, & Clifton, 1988; Stack, Muir, Sheriff, & Roman, 1989; Clifton, Perris, & Bullinger, 1991) that infants reach for sounding objects in the dark. In these studies though, it was not clear whether infants reached for the sound itself or for the unseen object producing the sound. Clifton, Rochat, Litovsky, & Perris (1991) designed an experiment which showed that 6 ½-month-old infants reached for a particular object and not just a sound. They used two objects, one small, one large, each with a distinctive sound (rattle or bell). Both objects were presented in the light and in the dark. Analysis of the type of reach performed showed that, both in the light and in the dark, infants tended to use one hand when reaching for the small object and two hands when reaching for the big object. Moreover, analysis of hand placement while reaching for the big object showed that infants did not systematically perform the same type of reach in the light and in the dark. Rather they often contacted different areas of the big object on successive reaches in the light and dark. This differential reaching for unseen objects showed that infants were not reaching for a sound but for a remembered object with a certain size, a

stored representation of the object. A limitation of this study was the fact that objects were continuously sounding. Infants could not see the object in the dark, but they could hear it throughout the whole trial. The continuous sound could have specified the continuous presence of the object, thus supporting object permanence through a perceptual cue. A more demanding task would be to have the same infant perform the reach with no perceptual support.

K. Present experiments

The studies proposed below were conducted in the dark as it appears to be a useful paradigm to test mental representation in young infants. Events were presented that required infants to make differential reaches in the dark after perceptual cues from the object were completed. Infants had to reach in silence with no sound to guide their reach to the object's location or remind them of its presence. As we know that it is difficult for infants to perform means-end actions, the tasks presented require simple, direct reaches in the light and in the dark. The general hypotheses of these studies were a) infants know that an object exists even when it is not visible or sounding, b) they can learn and remember the outcomes of two events, and c) they can respond appropriately to the outcome with no supporting perceptual information.

CHAPTER II

STUDY 1

The purpose of this study was to determine whether 6½-month-old infants could form a mental representation of an event based on auditory information. Two events were presented to the infants in both light and dark. In both events, a ball was dropped through a tube. In one event, the ball was accessible at the end for grasp and pickup. In the second event, the ball was never accessible but was visible from behind a Plexiglas cover. In both events the appropriate motor behavior could not be executed until the ball came to rest because the defining auditory information occurred at the very end. This restriction on reaching meant that search for the ball on dark trials was carried out in silence with no sensory information about the object's location or presence.

We hypothesized that if infants had a mental representation of these events, it would be demonstrated by their behavior in the dark. First, we predicted that they would reach for the object when they heard the sound corresponding to the Ball Accessible event. Upon hearing the sound corresponding to the Ball Inaccessible event, they would either not reach or they would reach where the ball was seen in the light, during this event. Secondly, if they did not find the object immediately, they would search for it, demonstrating their knowledge of the existence of the object. Finally, their reaching would take place while no perceptual cue was available to guide their reaching.

A. Method

1. Infants

Sixteen infants (7 females and 9 males) ranging in age from 28 to 32 weeks (*M* = 29; *SD* = .97) completed the session. They were recruited from birth announcements in the papers and contacted by a letter followed up by a phone call. All infants were born full term, and were healthy at the time of testing. Four criteria had to be respected in order for a baby to be included in the study: 1) Infants had to pick up the ball on at least 3 Light Accessible (LI) trials (if a baby was slow to warm up, more trials were added until the training trials were completed). 2) There was no fussing during the training trials. 3) If there was some fussing during the experimental trials, infants had to complete at least 2 Dark Accessible (DA) and 2 Dark Inaccessible (DI) events without fussing. 4) There was no interference of the mother during the session. Interference was defined as the mother breaking the infant's attention by talking, or directing the infant's behavior in one way or another. Each session lasted about 20 minutes. Fourteen additional infants were tested but not included in the final sample due to fussing in the dark (*n*=10), interference of the mother (*n*=1), technical failures (*n*=3).

2. Apparatus

The apparatus consisted of a bright blue wooden box (93 x 9.5 x7 cm) sitting vertically on the middle of a wooden board (61.5 x 41.2 cm). Rectangular pieces of wood (7 x 1 x 1 cm) were glued alternatively on the left and right side of the wall. The first one was glued at 6 cm from the top of the apparatus, on the right wall; the second one on the opposite wall at 9 cm from the top; the third one at 6 cm from the first one

on the same wall and so on. The purpose of these knobs was to allow the ball to bounce down when dropped from the top, making an interesting noise, and slowing it down to prolong the event. A Plexiglas cover (87 x 9.5) closed the front opening of the box except for 7.5 cm at the bottom. The top of the box was open to allow the experimenter to drop the ball. The bottom of the box rested on a small metallic tray (11 x 6.8 x 1.2 cm). Five cm of this tray stuck out from the apparatus so that the ball would roll out and be easily retrieved by the infant. Two horizontal openings (6 x 1.5 cm) on the left and right walls of the apparatus, at 6.8 cm from the bottom allowed the experimenter to slide in a wooden platform (5.6 x 15.1 x 1.5 cm), padded with foam, to close the bottom of the box. When the ball landed on the platform, it was not accessible to the infant because the Plexiglas cover enclosed the box.

In addition to the sound made by the ball as it was dropped down, an electronic device connected to a bell and a buzzer was used to create two different auditory events. For half the infants, a bell rang when the ball landed on the accessible tray and a buzzer went off when the ball landed on the inaccessible platform, for the other half of the infants the sound contingencies were reversed. A small infrared beam detector (IR.) was attached to the right side of the apparatus, at 5 cm from the opening for the platform. When the IR. was on, the beam from the IR. shone across the path to an infrared photo relay sensor (7.4 x 7.8 x 5 cm). The infrared beam detector could be turned on and off by a 2-position toggle switch. The experimenter turned on the IR. only when the platform was used. Each time the ball fell on the platform, either the buzzer or the bell went off.

A lever switch was attached at 0.5 cm above the tray so that when the ball hit it at landing, it triggered the sound (either the bell or buzzer). A small white cardboard cover (5.8 x 6.2 cm) was glued to the tip of the lever to hide the lever from the infant. Each time the ball hit the bottom of the apparatus it triggered the lever. As the lever switch

did not have a toggle switch like the IR., it could be triggered at all times. In order to turn it off, a manual power switch was attached to the device and could be easily manipulated by the experimenter in the light and in the dark. This power switch turned on and off the whole system. The system worked on a 12 volt DC adapter.

A call-bell was attached on the back of the apparatus, at 11.5 cm from the bottom. An electromagnetic relay located just above the bell hammered it when triggered. An electronic buzzer (2 x 1.5 x 1 cm) was mounted on the photo relay sensor. A second 2-position toggle switch allowed the buzzer and the bell to be triggered either by the IR. or the lever switch. Both toggle switches were attached to the back of the apparatus.

To summarize, when the ball landed on the platform, it broke the IR. beam and either the bell or the buzzer (depending on the positions of the toggle switches) went off. When the ball landed on the tray, it hit the lever switch which in turn either hammered the call-bell or triggered the buzzer (also depending on the positions of the toggle switches). Most of the device was attached to the back of the apparatus thus being invisible to the infant. The photo relay sensor was screwed to the left of the apparatus. In order to hide it, a wooden cover (13 x 25.2 x 9.7 cm) was added. Another cover (20.5 x 25.5 x 9.7 cm) was made on the right side to hide the IR. and to make it relatively symmetrical to the other side. All wooden works were painted in a bright blue color.

The apparatus was resting on a table (95 x 45.5 x 67 cm). On the left and right side of the table, two wooden poles (2 meters) supported a brass rod (1.37 m long) from which were hanging two white cotton curtains. The curtains were drawn in between each trial to hide the apparatus.

Two infra-red cameras were used. Camera 1 (Panasonic Model WV-1850) was positioned at slightly to the right of the infant and focused on her face. Camera 2 (Panasonic Model WV-CD810) was located directly above the infant and oriented

vertically to focus on the apparatus and on the hands of the infant. In the light condition, two light bulbs positioned directly above the infant gave a soft light; in the dark condition, a pedal switch allowed the experimenter to turn off these lights. Each camera was fed through a For-A date-timer into a videocassette recorder (Panasonic Model AG-1950 and Sharp Model XA-200) and a video monitor (Sony Model CVM-1271 and Sanyo Model VM-4130).

The experiment was conducted in a double-walled sound-deadened chamber connected to an antechamber containing the video equipment. Two experimenters were required for each session. The first experimenter was in the chamber with the infant and her mother. Her role was to present infants with the different conditions, to control the sound and light switches and to assess the infant's state and willingness to participate during the session. She wore headphones to communicate with the second experimenter outside the chamber. The second experimenter controlled the recording of the session, gave instructions via a microphone and observed infants' behavior on the video monitor.

3. Procedure

The infant was seated on her mother's lap, facing the Plexiglas cover. Her head was located at the bottom 1/3 of the apparatus. Each session started with a 30 s period of familiarization with the apparatus. Then, the first experimenter closed the curtains and trials started. Each trial consisted of the experimenter shaking a small yellow plastic ball in front of the infant. Once the infant's attention was attracted, the experimenter moved the ball to the top of the apparatus and dropped it. During this move, the experimenter constantly checked where the infant was looking. If the infant's interest for the ball waned, (i.e., if her eyes focused on something other than the ball), the experimenter shook the ball gently to attract the infant. The ball was dropped only if

the infant was looking at it. After the ball had landed, the infant was allowed to pick up the ball (or explore the apparatus if the ball was not available) for 15 seconds. Intertrial intervals were about 15 seconds.

a. Types of events

Two events were presented in the light. In the first event (LA), the ball landed on the bottom of the apparatus and was available for reaching or grasping. In the second one (LI), the ball landed on the platform and was not available for pick-up. It was visible to the infants through the Plexiglas cover. The average duration from ball release to landing of the LA and for the LI events were 2.12 and 2.10 seconds respectively. Each event was associated with a particular sound (buzzer or bell) which remained the same throughout the session for a particular infant. Infants were randomly divided in two groups. For one group, Accessible events were always signaled by the buzzer and Inaccessible ones by the bell and for the other group it was the opposite.

b. Training trials

The first part of the session consisted of 6 light trials, 3 LA and 3 LI. The first LA and LI trials were warm up trials and were not included in the analyses. For each group, two protocols were presented. Each protocol had trials arranged in a random order with no more than 2 similar trials in a row.

c. Experimental trials

Once an infant had completed the 6 training trials, the experimental part of the session continued without a break. Eight dark trials (4 DA and 4 DI) were presented interspersed with 4 light trials (2 LA and 2 LI). Type of event was counterbalanced as

for the training trials. For each dark trial, the first experimenter turned off the lights, opened the curtains and tapped the top of the apparatus with the ball. The second experimenter monitoring the TV in the outer room signaled when the infant's attention was directed toward the sound, and the experimenter dropped the ball. The lights were turned back on fifteen seconds after the ball landed on the platform or on the tray. If the infant picked up the ball before 15 seconds had elapsed, the lights were turned back on immediately. If she had not picked up the ball within 15 seconds, the first experimenter gave her the ball for a few seconds once the lights were turned back on. For the DI event, the curtains were closed as soon as the lights were turned back on. Four light trials, 2 of each type (LA and LI) were interspersed among the eight dark trials to maintain interest and remind the infant of the two event outcomes.

In contrast to previous studies in the dark, in this experiment there was no continuous sound in the dark. Once the ball landed, there was absolute silence for 15 seconds. It was apparently difficult for some infants to keep up their interest and attention to the task for 15 seconds when there was nothing to see or hear. Moreover, in the LI event, there was no object to explore even though the ball was visible, and this could have become a frustrating experience! Interestingly though, the relative inaccessibility of the ball may have prevented the infant from becoming tired of it.

4. Data scoring

A number of measures have to be defined. First, when an infant made a forward movement of the hand toward the object, it was called a reach. Contact was defined as an infant touching a surface or grabbing the ball. The apparatus was divided in 4 surfaces or areas (Figure 2.1, p. 24): the tray (or ball), the Plexiglas cover and parts of the two side boards immediately adjacent to the Plexiglas board (called vertical surfaces) and to the tray (called horizontal surfaces). These areas were meaningful

destinations in the context of the task. For example, the tray was the destination of the ball in the "Ball Accessible" event. The bottom third part of the Plexiglas cover represented the destination of the ball in the "Ball Inaccessible" event. A search was defined as several successive contacts with different surfaces. For example, the infant first touched the Plexiglas cover then went on to touch the tray, then reached for the left side board and eventually rested her hands on the support board. The search ended when the infant's hand remained stationary for more than 3 frames, when an infant stopped orienting toward the apparatus, when an infant's hand left the areas of interest, or when an infant grabbed the ball.

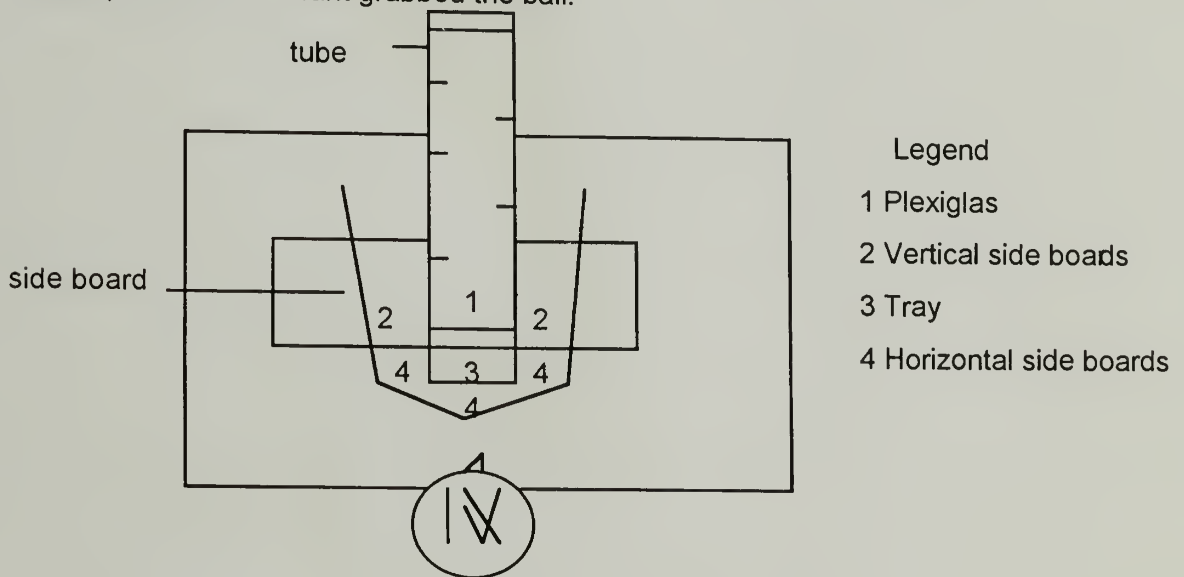

Figure 2.1 Areas of scoring are represented on this figure. Contacts outside these areas were not recorded.

A search might continue after a pause, as long as it was still within the 15 s period. A frame-by-frame analysis (sample of 33 frames/s) allowed us to determine precisely the onset of the trial (defined as the landing of the ball), the onset of first reach (defined as the first forward movement that ended with a contact), the time of first contact, and the time of each pause.

5. Reliabilities

Fifty percent of the infants were scored by two scorers and percent agreement was calculated. For onset of trial, time of first contact, onset of reach and end of search, there was agreement if the times of both scorers were within 3 frames of each other. There was 95.51% agreement on onset of trial; 89.87% agreement of time of first contact, 91.89% for onset of reach; 94.03% for location of first contact and 88.64% for end of search. The rest of the scoring was done by the author.

B. Results

1. Frequency of reaches

Each infant had 16 trials presented: 8 in the light (4 LA, 4 LI) and 8 in the dark (4 DA, 4 DI). Nine trials were eliminated, 5 for technical problem (3 DA, 2 DI) and 4 DI for fussiness. Infants reached (i.e. made contact with a surface) on 99% of the trials in the light and on 66% of the trials in the dark. A *t* test was performed on the proportion of contact trials in the light and in the dark and yielded a significant difference ($t(31) = -5.1$, $p<.001$). This result is consistent with other studies which have traditionally showed less reaching in the dark (e.g., Clifton et al, 1991a and b). Infants reached on 100% of the LA event and on 98% of the LI trials. Infants reached 72% of the time in the DA event and 59% of the time in the DI event. A *t* test was performed on the proportion of reaches in the DA vs. the DI event and yielded a significant difference ($t(15) = 2.29$, $p<.04$). Infants reached more often when the ball was accessible than when it was not. It may be that infants knew that the object was inaccessible in the DI event and thus reached less but it is also possible that the auditory cue was harder to

localize because the ball made a distinct sound when it fell into the metal tray on accessible trials, but not on inaccessible trials. This less distinct cue could have led to fewer reaches in DI trials. An inventory of the number of trials presented, eliminated and analyzed is presented in Table 2.1. Table 2.2 presents the distribution of contact and no contact trials among the trials analyzed. A contact trial was a trial during which there was contact with any of the surfaces represented in Figure 2.1. A no contact trial was a trial during which there was no contact with any surface during the 15-second period.

Table 2.1 Number of trials presented, eliminated and analyzed in the light and in the dark for both events.

	Trials presented	Trials eliminated	Trials analyzed
LA	64	0	64
LI	64	0	64
DA	64	3	61
DI	64	6	58

Table 2.2 Number of contact and no contact trials among trials analyzed in the light and in the dark, for both events.

	No contact trials	Contact trials
LA	0	64
LI	1	63
DA	17	44
DI	24	34

2. First contact with the tray on contact trials

If infants did remember the events and discriminated between them, they should then reach more often to the tray in the DA event where the ball could be handled, as opposed to the DI event where reaching for the tray did not result in contact with the ball. These two trial types were compared on whether infants reached first to the tray or not. Although infants could (and did) make several different contacts within one trial, we chose for this analysis to use only the first contact because we think it best reflects the "intention" of the infant. All contact trials were taken into account. For each infant, the number of trials in which the first contact went to the tray was divided by the total number of contact trials. Proportions were used as infants did not all reach on every trial in the dark. Figure 2.2 shows the percentage of first contacts with the tray in each lighting condition and each event type.

Data were analyzed in a 2 (light vs. dark) x 2 (Accessible vs. Inaccessible) x 2 (bell vs. buzzer) ANOVA[1]. Neither illumination nor type of sound affected infants' tendency to end their first reach by contacting the tray ($p > .60$). The accessibility of the ball, however, affected infants' reaching. Infants reached significantly more often for the tray in Accessible events ($F(1,12) = 6.21$, $p < .03$) suggesting that both in the light and in the dark, they discriminated between the two events. There was no interaction between accessibility of the ball and illumination.

[1] $N = 14$. Two infants could not be included in the statistical analyses because they did not reach in the dark. They were, however, included in the final sample because they completed the session without fussing which was our criterion to include infants.

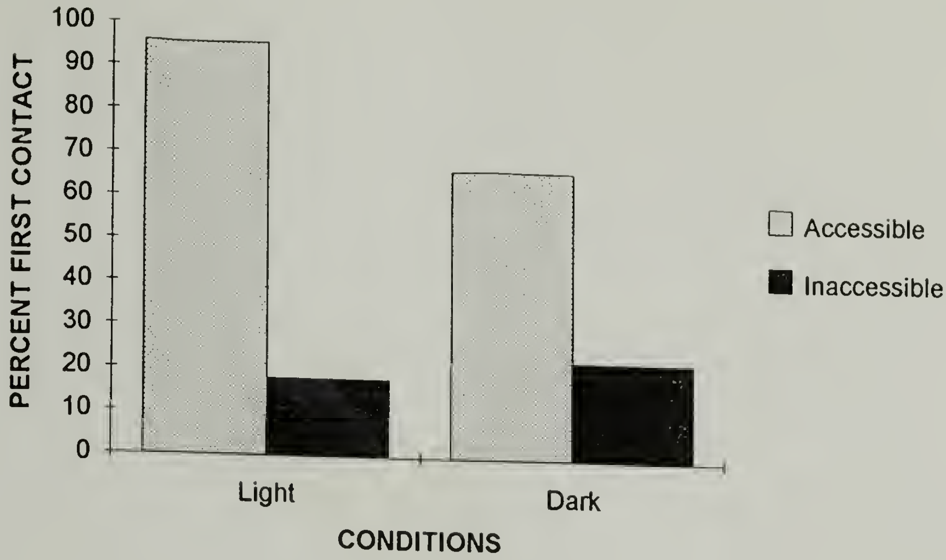

Figure 2.2 Percentage of first contacts with the tray in each condition and each event.

3. Location of first contacts

In the preceding section, we looked at the first contact to the tray or the ball. In the present analysis, all first contacts were included, whether they were directed to the tray, the Plexiglas cover, the area adjacent to the Plexiglas cover (vertical board) or the area adjacent to the tray (horizontal board). Table 2.3 presents group data of the actual number of first contacts for each area and in each condition. The first column of Table 2.3 presents different data from Figure 2.2, however. Figure 2.2 shows the percentage of trials in which the first contact went to the tray whereas Table 2.3 presents actual frequencies. In the light accessible trials as predicted, 94% of the contact trials went to the tray or the ball. In the dark accessible event, the tray was the first destination in 66% of the contact trials. In a substantial number of trials (23%), infants first contacted the area immediately adjacent to the tray, probably making a localization error. In the light inaccessible event, the Plexiglas cover was first contacted in the majority of

contact trials (62%). Infants could see the ball through the cover. Finally in dark inaccessible trials, the horizontal board (area adjacent to the tray) was first contacted in 47% of the contact trials. The tray was first contacted in only 29% of the contact trials. Infants made only a few reaches to the vertical board and even less to the Plexiglas board.

Table 2.3 Total number of contact trials in each condition, showing the location of first contact.

	Ball/Tray	Plexiglas	Vert. Board	Horiz. Board
LA	60	2	1	1
LI	11	39	12	1
DA	29	0	5	10
DI	10	2	6	16

4. Latency to reach and search duration

Latency to reach and search duration were two critical measures for two reasons. First, they are necessary to test our argument that 6½-month-old infants can represent events mentally. If infants are reaching and contacting target locations which they can neither see nor hear, then it suggests that infants can base their reaching on a mental representation of the situation as opposed to a representation based on perception alone. Secondly, the conditioning hypothesis argues that infants' reaching might be based on a conditioned motor response. If this were the case, as soon as infants heard the sound specifying the event, they should make the conditioned movement. Their performance should show similar latency durations both in the light and in the dark.

a. Latencies to first reach

We expected latencies to be longer in the dark than in the light. A difference in latencies would weaken the conditioning argument because it would show that reaching in the light and reaching in the dark corresponded to two different types of actions, one based on vision and the other based on a memory of the situation. Latencies might also reveal to what extent infants discriminated between the events. If for example, latencies were longer when the ball was inaccessible in the dark, it could suggest that infants discriminated between the two events and remembered which sound specified the accessibility of the ball.

Latency to first reach was computed by subtracting the time of trial onset from the time of first reach. Table 2.4 presents the means and standard deviations for each event in both conditions.

Table 2.4 Means and standard deviations for the latency to reach in both events in the light and in the dark.

	LIGHT		DARK	
	Accessible	Inaccessible	Accessible	Inaccessible
M	.13	.74	2.46	2.99
SD	.84	2.1	.87	2.83

Data were analyzed in a 2 conditions (light vs. dark) x 2 events (Accessible vs. Inaccessible) ANOVA. Our first two expectations were supported. The mean latency to reach in the light (M = .44 s, SD = .84) was significantly shorter than the mean latency in the dark (M = 2.72 s, SD = 2.46), $F(1, 13) = 22.95$; $p<.001$. Moreover, in the dark infants did initiate their reach while in silence and in the dark, and therefore did not

need sight or sound to act. The accessibility of the ball did not appear to affect the latencies, however. Infants waited the same amount of time whether the ball was accessible or inaccessible in the dark (p = .35).

b. Search duration

Search duration was for Piaget an index of the infant's knowledge that objects exist even when they are invisible. In the context of this study, if infants searched for the ball while in the dark and in silence, then one can argue that infants knew there was an object in the spatial field and were looking for it. Search was defined as the total amount of time infants were in contact with the "meaningful" areas of the apparatus (see Figure 2.1, p. 24). If infants reached directly for the ball, there was no search recorded, we scored the trial as "contact". As a result, there was never any search in the LA event because infants directly contacted the ball. If infants made several successive reaches and contacted several surfaces, the total amount of time they were in direct contact with the surface constituted the search duration. If an infant contacted, for example, the vertical board and continued to explore the board haptically for the remainder of the trial, we scored the search as lasting from the time the infants first touched the surface to the end of the trial. Table 2. 5 presents the means and standard deviations for search duration in LI, DA and DI.

Table 2. 5 Means and standard deviations for search duration in LI, DA, and DI.

	LIGHT		DARK	
	Accessible	Inaccessible	Accessible	Inaccessible
M	*	10.09	3.07	4.81
SD	*	2.27	2.23	4.02

Search was quite long in the LI event and lasted on average 10 s. Search durations in the DA event and in the DI were similar ($t(10) = -1.76$, $p = .11$). These means show that infants searched for the object while they were in silence and in the dark.

Figure 2.3 (p. 32) shows the time elapsed from the trial onset to the end of search with its two components, the latency to reach and the search duration. The figure shows that in DA, infants would reach or continue to reach for more than 5 seconds and for almost 8 seconds in the DI after the last auditory cue was heard. Infants were engaged in contacting or trying to contact the tray for more than 5 seconds while they were in silence and in the dark.

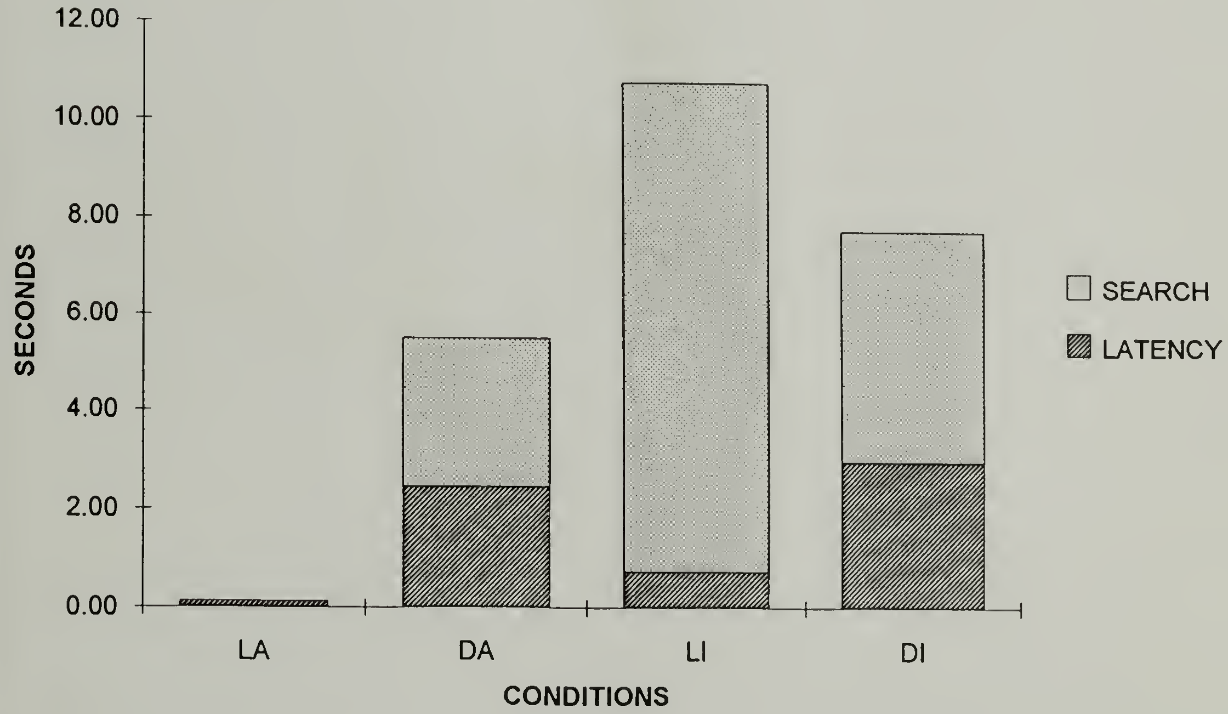

Figure 2.3 Latency to reach and search duration in accessible and inaccessible events.

5. Number of contacts per trial

This next analysis was another way to index the infant's representations during trials. While the previous analyses indicated that infants could search for an object for up to 8 seconds, this analysis is an attempt to describe differences in the quality of response and will show that infants were engaged in a dynamic search not consistent with a rigid motor pattern dictated by a conditioning explanation. The number of contacts infants made with the apparatus during the 15-second period was scored. In the light accessible event, infants went almost directly to the tray and grabbed the ball (M = 1.07, SD = .12). By contrast in the LI event, where no ball was accessible, infants made between 2 and 3.5 contacts (M = 2.88, SD = .45). In this condition, infants were quite interesting to watch as they were touching various areas around the Plexiglas cover in an attempt to get the object[2]. In the DA event, infants made almost 2 contacts per trial (M = 1.87, SD = .63), with a range going from 1 to 3 contacts. In the DI event, infants made an average of 2.01 contacts per trial (SD = .71), with a range between 1 and 3.

The accessibility of the ball significantly affected the number of contacts. Infants made significantly more contacts per trial in the inaccessible events than in the accessible ones ($F(1, 13) = 80.43$, $p<.0001$). While this result was expected because of the fact that the ball was accessible in one event (and therefore did not necessitate many contacts) and was not in the other, the important point is that infants in the DI event made several reaches while in the dark and in silence, seemingly searching for the object. Illumination did not affect the number of contacts (p =.80). There was an interaction between illumination and accessibility of the ball ($F(1, 13) = 29.07$, $p<.0001$). Contrasts showed that infants made significantly more contacts in the LI event

[2]Some infants appeared frustrated (manifested by banging on the cover, or loud noises) by the impossibility to contact the object.

compared to the DA event ($F(1, 13) = 29.05$, $p<.0001$). There was no significant difference between DA and DI ($p< .56$).

C. Discussion

Results show that infants searched for the object while in silence and in the dark. They initiated their first reach when neither vision nor audition was available to guide them and continued to search for the ball for up to 8 seconds after termination of the auditory cue. These actions suggest that infants were relying on a mental representation of the object and its approximate location.

According to Piaget, infants younger than 8 or 9 months of age rely only on perception to act. Infants in this study reached while neither sight, nor sound could provide any cues about the situation. It is not clear however, what the nature of their representation of the event was.

At first, it seemed that infants discriminated between the two events in the dark: they reached on fewer trials and were less accurate on dark inaccessible trials. This result was consistent with our hypothesis. If infants did build a representation of the events and of their outcomes, they should indeed, reach less for the DI event because there is no object available as outcome. Infants seemed to follow this rule. The basis of the discrimination is unclear, however. Although in both events the buzzer and bell sounds came from the same location (behind the apparatus), the landing of the ball was different for the two events. It is possible that in the DI event, the ball was more difficult to localize. In this event, the ball landed on a padded platform and the ball was enclosed in a box whereas in the Accessible event, the ball landed on a metallic tray and was not enclosed. The auditory cue for the dark inaccessible event might have been harder to localize and thus led to fewer reaches.

When infants did reach in the dark, they tended to reach for the tray in the Accessible event whereas in the dark Inaccessible event, only 29.4% of the contacts were with the tray. In 47% of the contacts in DI, though, infants reached for the horizontal board, area surrounding the tray. This suggests that infants were trying to contact the tray but made a localization error.

Infants might have accurately encoded the landing of the ball only in the accessible event for the reason discussed above. Moreover, the sounds associated with the two events (bell and buzzer) were very brief and very close spatially. They might have been overshadowed by the clattering sound of the ball bouncing down the apparatus. It is therefore possible that infants did not remember which sound corresponded to which event or that they never encoded the correspondence.

Another possibility is that infants were only reinforced to reach for the tray because it was the only location where the ball could be available. There was no such reinforcement in the inaccessible event. This might also have accounted for their reaching to the tray in DI event.

If infants did not discriminate clearly between the two events, what did they represent? Their representation could have been based on the sound of the ball clattering down the tube, and on the sound made by the landing of the ball. The sounds reminded them of the event in the light and of the location of the ball. The strongest perceptual cue was probably the sound the ball made when rolling down. This sound signaled infants that an object might be available at the end of the event. Combined with this perceptual cue, was a memory representation that this sound led to the availability of an object. Perception was not, however, the only basis for their representation. If ongoing auditory cues had been the only trigger of infant's reaches, reaches would have started much earlier (while the sound was on) and would have stopped as soon as silence occurred. The opposite happened. Infants started their

reach 2.5 seconds after termination of the auditory cue and continued for more than 4 seconds thereafter. Moreover, in the DI event, infants made between 1 and 3 different contacts with the apparatus, apparently trying to find the object. While this particular result seems to suggest that infants did not realize that the ball was inaccessible in such event, it also suggests that infants knew there was an object to contact in the dark. In other words, infants did not need ongoing perceptual cues to remind them of the existence of the object.

The fact that infants acted in the dark and in silence makes the conditioning hypothesis unlikely. The conditioning hypothesis argues that infants were conditioned to associate a sound with a motor response. If they were trained to associate each event outcome with a specific motor response, then one would have expected infants to reach for the Plexiglas upon hearing the sound specifying this event and for the tray upon hearing the other sound. This did not happen since they did not reach for the Plexiglas in the DI event. It is difficult to imagine that they were conditioned to the sound of the ball clattering down leading to the availability of a ball, since there were two events leading to two different outcomes. First contacts in the light clearly showed that infants did not confuse the two events in the light: They reached for the tray in LA and for the Plexiglas in LI.

There were however, several limitations in this study. First, in one event infants could not manipulate the ball. This might have influenced the infants to reach more toward the tray. Secondly, the bell and buzzer sounds might have been confusing instead of helping infants to identify the events. A second study was designed to overcome these problems.

CHAPTER III

STUDY 2

The purpose of this study was to present infants with two auditory events with equal reinforcement and to test first, whether infants could form mental representations of these events, and secondly, the nature of any representations formed. In both events a ball was dropped through a tube. In one event the ball rolled down a path on the left, and in the second event the ball rolled down a path on the right. In each event, the last part of the event was silent so that the last sound heard did not correspond to the final location of the ball. No buzzer or bell was used to differentiate the two events because the ball rolling to the left or to the right offered sufficient acoustic information to indicate the path's direction. Two groups of infants were tested. One group, the Side-Experienced group (SE) was presented with the events described above both in the light and in the dark. A second group, called the Midline-Experienced group (ME) was presented with these events only in the dark. In the light, they were presented with a midline event; namely the first part of the event was similar to the dark events (the ball bounced down the vertical tube), but instead of rolling down to the left or to the right, the ball rolled down the middle. The rationale for having such a group was that it should have no representation of the side events compared to the SE group. Their task should therefore be comparable to an auditory localization task and they should contact the target areas less often than the SE group.

1. Hypotheses for the light condition

In the light, we expected infants in both groups to reach for the ball and contact it. The ME group should reach equally with the left and right hand to the ball's midline

position while the SE group should display ipsilateral reaches to the left and right side where the ball rested.

2. Hypotheses for the dark condition

a. SE group

In the dark, we expected infants to contact the ball or at least to reach toward the resting location of the ball and not to reach where the ball was last heard, or where they last picked it up in the light.

b. ME group

We expected this group to either reach for the location of the sound (as in a typical auditory localization task) or to reach in the middle where they had last seen and handled the ball, or not to reach at all because the auditory event was unique.

A. Method

1. Infants

A total of 40 infants were tested. Eight infants were eliminated, 7 due to fussing (6 infants in SE group and 1 in ME group) and one (ME group) because he was too old for the study. Thirty-two infants (20 females and 12 males) ranging in age from 26 to 30 weeks (*M* = 27.7, *SD* = 1.01) completed the session. Sixteen infants (11 females, 5 males) were assigned to the SE group. Their age ranged from 26 to 29.5 weeks (*M* = 27.5, *SD* = 1.06). Sixteen infants (9 females, 7 males) were assigned to the ME group. Their age ranged from 26.5 to 30 weeks (*M* = 27.88, *SD* = .96). Table 3.1 (p. 39) gives summary information on number of infants tested and eliminated, age, and gender for each group.

Table 3.1 Descriptive information for each group

	SE	ME
Infants tested	22	18
Infants eliminated	6	2
Final sample	16	16
Average age	27.5 weeks	27.88 weeks
Age range	26-29.5 weeks	26.5-30 weeks
Sex	11 females, 5 males	9 females, 7 males

Infants were recruited as in Study 1. All infants were born full term, and were healthy at the time of testing. In order to be included in the study, infants in both groups had to reach for the object on at least 4 trials during the training period in the light. Infants in the SE group had to complete 2 trials on the left and 2 on the right. In the dark, both groups had to complete at least 4 trials (2 left, 2 right) without fussing. Infants did not have to reach in the dark in order to be included in the final sample. If we had accepted only infants who contacted the apparatus in the dark, it would have been a way to select the sample such that it would no longer be representative. Although an infant may not reach for many different reasons, it is possible that one important reason here would be that she did not know what to do.

2. Apparatus

A new apparatus was constructed with some similarities with the earlier apparatus (Figure 3.1, p. 41). A vertical tube (61 cm high, 11 cm large and 9 cm deep) was built. Its front part was closed by a Plexiglas cover. Rectangular pieces of wood were glued alternatively on the left and right side of the tube as in Study 1. The tube was attached

to a wooden support (22 cm high, 11 cm wide and 8 cm deep). The support was attached to a wooden surface (103 cm long 53 cm wide) itself resting on a table at 68 cm from the floor. Three wooden paths (49 cm long, 7.5 cm large and 5.5 cm high) were built. Four small wooden knobs similar to the knobs on the tube were glued alternatively on the left and right sides of each path to slow down the ball, covering 29 cm of each path. The remaining surface of the paths (20 cm) was padded with several layers of felt so that the ball could roll down silently. Two of these paths were screwed to the left and right bottom of the tube. The top part was located at 22 cm above the wooden surface and the endpoint rested directly on the wooden surface. The endpoint was connected to a wooden piece (15 cm long, 6 cm wide, .5 cm thick) positioned horizontally (glued to the surface) and perpendicular to the paths. This wooden board was called the tray. The tray was enclosed on its front side by a metallic piece (2 cm wide, 15 cm long) attached to the end point of the paths in order to prevent the ball from bouncing out. The tray's other sides were bordered by small wooden "walls" (2.5 cm high. 2 mm thick). The tray, the metallic pieces and the "walls" were also padded with felt.

From the infant's perspective, the vertical tube was located in front of her, out of reach. Two paths were attached to the tube and oriented forward so that their end parts could easily be touched by the infant on her left or right. Between each trial, the experimenter could block one of the paths by placing a small dividing piece of wood (10 cm. high, 10 cm wide) at the exit of the tube.

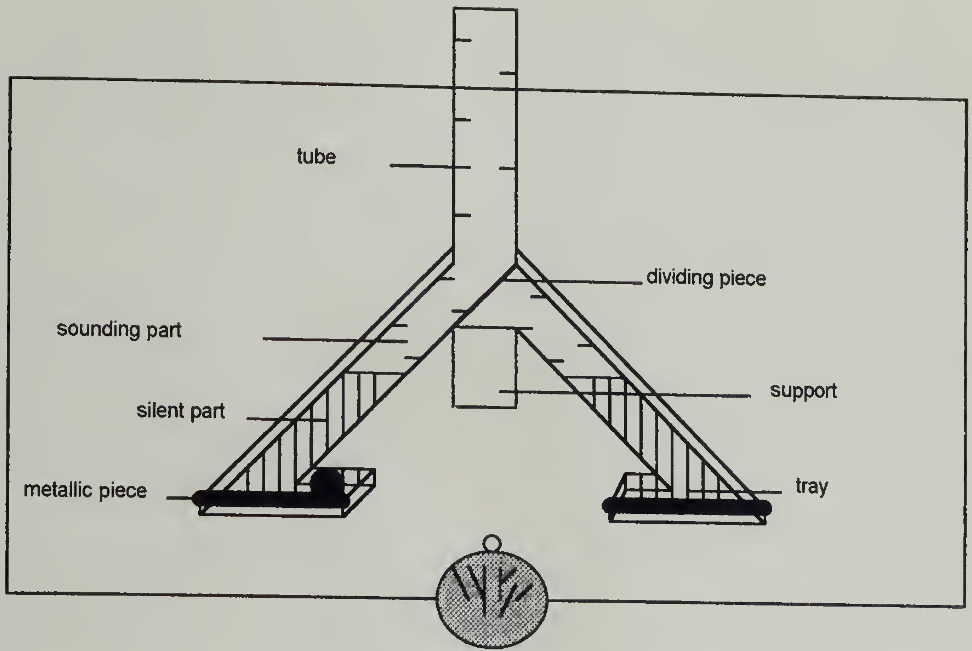

Figure 3.1 Apparatus used in the light condition for the SE group and in the dark condition for both groups. The shaded areas represent the padded part of the paths.

The third path was identical to the other paths except for its endpoint. The ball landed in a small tray (8.5 cm wide, 6.5 cm long, 4.5 cm high) also padded with felt. This path was used for the ME group in the light and was positioned at midline. It could easily be removed for the dark trials.

The entire apparatus was painted in forest green. The felt used was of the same color. During light trials for the ME group, the side paths were covered by 2 large pieces of black fabric (Figure 3.2, p. 42).

An infrared camera was positioned above and slightly behind the infant. A TV monitor was placed under the table supporting the apparatus and was turned on during

sessions to provide white noise and eliminate any sound the ball could have made when rolling down the padded paths. A white curtain decorated with small bunnies hid the apparatus during the intertrial interval.

Infants were tested in the same room as in Study 1 and the same recording equipment was used. In the light condition, two light bulbs positioned directly above the infant gave a soft light; in the dark condition, a pedal switch allowed the experimenter to turn off these lights.

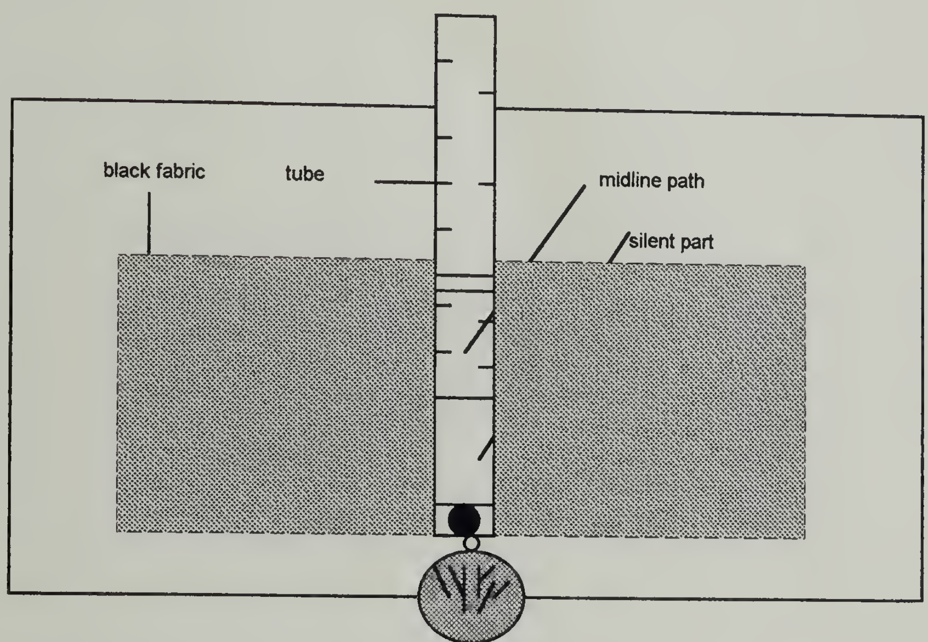

Figure 3.2 Apparatus as it appeared in the light to the ME group. The two side paths are covered with black felt and the ball lands in a tray at midline.

Parents were asked to wear opaque glasses and headphones during the experiment to prevent their hearing or seeing the test event. A masking sound using the sound of balls rolling down the apparatus at midline and of a rattle being shaken

was recorded on a reel to reel tape recorder and was played over the headphones for the duration of each event (about 4 seconds).

3. Procedure

Two experimenters were needed to conduct each session. The first experimenter was in the room with the infant and was wearing headphones to communicate with the second experimenter. The second experimenter's role was to tell the first experimenter what trial type to present, to indicate (during dark trials) whether the baby was orienting toward the tube before the start of a trial, to trigger the masking sound for the parent, and to signal the end of a trial to the first experimenter.

Equal number of infants were randomly assigned to either the SE or ME group. All infants were seated on their parent's lap facing the apparatus. Each session started with a 30 s familiarization period with the object and the setting. Then, the experimenter closed the curtain and trials started. Sessions for both groups lasted about 20-25 minutes.

a. SE group

Each trial consisted of the experimenter opening the curtain, then tapping a small yellow ball on the top of the apparatus to attract the infant's attention. Once the infant was paying attention, the ball was dropped. After clattering down the tube, it rolled down to the left or right path depending on the protocol and landed in the tray on the corresponding side. The total length of the event was about 3.5 seconds. The sounding part of the event (i.e. from the time the ball was dropped to the time it hit the felt on the paths) lasted 2.5 seconds. The silent part (i.e. from the time the ball hit the felt to the time it landed in the trays) lasted 1 second. The training part of the session consisted of

6 light trials, half of them left (Light Left) and half right (Light Right), randomly presented with no more than two similar trials in a row. Infants had 15 seconds after the landing of the ball in the tray to pick it up. After 15 s the curtain was closed and another trial was presented a few seconds later. If an infant did not reach for the ball during the 15 s of the training trial, the experimenter would give her the ball to play with for a few seconds. Once infants completed the light trials, eight dark trials (4 Dark Left and 4 Dark Right) were presented in a random order with no more than two similar in a row, interspersed with 4 light trials (2 Light Left and 2 Light Right). The procedure was similar to the light condition except for the fact that the ball was not given to the infant if she didn't contact it .

b. ME group

In the light, this group was presented with a midline event. The first experimenter covered the side paths with the black fabric, positioned the midline path and opened the curtain. Infants' attention was attracted the same way and the ball was dropped. As for the SE group, trials lasted 15 seconds after the landing of the ball in the tray. The ME group received 6 trials in the light, as did the SE group. For the dark trials, the experimenter removed the fabric, removed the midline path, blocked off one of the side paths, turned off the lights, opened the curtain, attracted the attention of the infants by tapping the ball on the top of the apparatus, then dropped the ball. At the end of the trial, she would close the curtain, turn on the lights, and prepare for the next trial. The ME group received 8 dark trials (as the SE group) interspersed with 4 light trials (middle trials). Infants in this group never saw the side paths.

4. Scoring

Videotapes of the trials were analyzed frame-by-frame (33 frames/s). Trials were analyzed if infants made at least one contact with a surface during the 15-second period. For each trial we determined the onset of silence, the landing time of the ball, the orientation of the head at landing time, the time of onset of first reach, the time of first contact, the orientation of the head at first contact, the location of all contacts to surfaces during 15 seconds, the hand used for each of these contacts, and the time at which infants stopped contacting surfaces.

i. The onset of silence was defined as the moment the ball first rolled down the path covered with felt. It was the first frame where the ball visibly touched the padded part of the felt.

ii. The time of landing was the moment the ball landed in the tray and touched one of the walls bordering the tray.

iii. The orientation of the head was noted at the time of landing. The possible orientations were left, right or middle. If the infant looked up in the air, no orientation was recorded.

iv. The onset of first reach was defined as in Study 1 as the time of the first forward movement that ended with a contact.

v. The time of first contact was the time at which a surface was first contacted.

vi. The location of all contacts to surfaces during trials were recorded. The apparatus was divided into 2 hemifields (left and right) each of them further divided into 3 areas (Figure 3.3, p. 46). The sound areas included the unpadded part of the paths and the surfaces right below them. The sound of the ball clattering down could be localized within these areas. The target areas included the trays and the surfaces right in front of them. The areas located between the sound areas and the target areas were called silent areas. The padded part of the paths and the regions right below them were included in the silent areas and within this area no sound could be heard.

vii. The number of contacts made during the 15-second period for each contact trial.

viii The hand used for each of these contacts was recorded,

ix. Finally, search duration was scored. This measure was similar to search duration in Study 1. Search was defined as the total amount of time infants were in contact with the apparatus. If the infant removed her hand from the apparatus for more than a second, then the time she removed her hand was recorded. This was the end of her search. If, however, she made a second contact before the end of the trial, then the time of second contact was recorded and added to the previous contact. End of search was either the end of the trial (if infants were still in contact with the apparatus) or the time the infant removed her hand from the apparatus and did not make any further contact until the end of the trial, or contact with the ball.

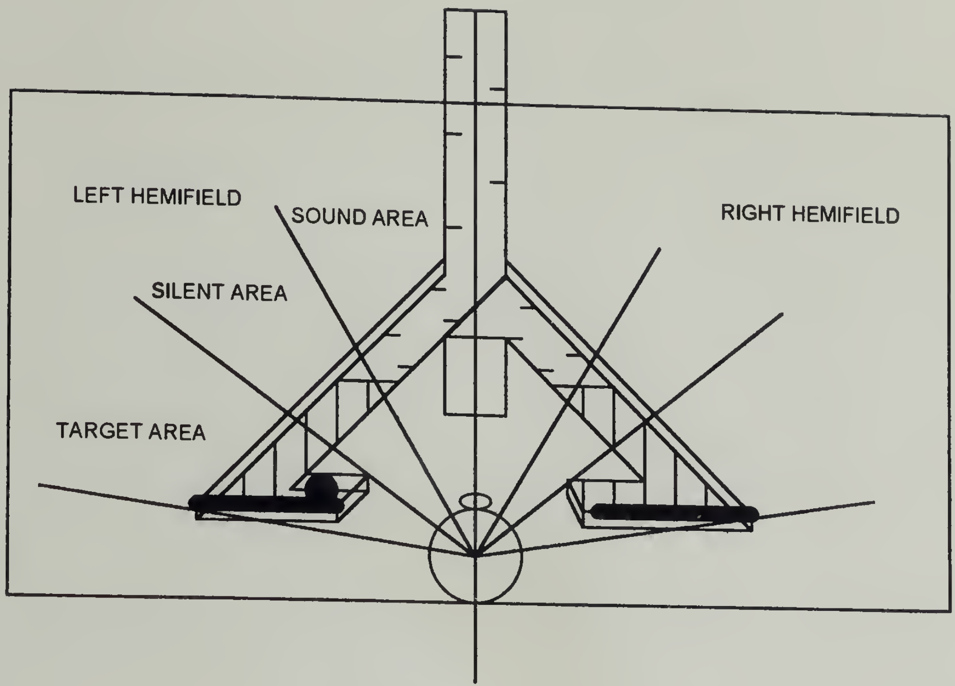

Figure 3.3 The apparatus was divided in two hemifields each further divided into 3 areas. The shaded areas represented the padded part of the paths.

5. Reliabilities

Agreement between two scorers was computed on 56% of the infants as percent agreement on the measures described above. Reliability for onset of silence was 99.48%; 92.3% on landing time; 98.67% on head orientation at landing time; 86.71% on time of first contact; 90.26% on location of first contact; 95.9% on head orientation at first contact; 87.1% at onset of reach and 89.86% on time of end search.

B. Results

1. Inventory

Table 3.2 presents a detailed inventory of trials. The total number of trials in the light for the SE group which could have been presented was 160 (80 on each side).

However, 4 trials were not presented because subjects got fussy before the end of the session. In the dark for the same group, the total should have been 128 (64 on each side). For the same reason mentioned above, 10 trials were not presented. For the ME group the total number of trials presented in the light should also have been 160, but 7 trials were never presented for fussiness. In the dark, out of a possible of 128, eight trials were not presented because of fussiness.

2. Activity level in the light and dark

Table 3.3 presents a descriptive account of the activity level during trials. In these tables, every trial infants received is accounted for and divided between no contact trials and contact trials. A no contact trial was a trial during which the infant either made no contact at all, or made a contact outside the apparatus. A contact trial was a trial during which infants made at least one contact with the apparatus.

Table 3.2 Inventory of trials in the light and dark for both groups.

	LIGHT					
	Number of trials presented		Number of trials eliminated		Number of trials analyzed	
	Light Left	Light Right	Light Left	Light Right	Light Left	Light Right
SE	78	78	3	2	75	75
ME	153		23		130	
	DARK					
	Number of trials presented		Number of trials eliminated		Number of trials analyzed	
	Dark Left	Dark Right	Dark Left	Dark Right	Dark Left	Dark Right
SE	59	59	13	7	46	52
ME	59	61	2	3	57	58

Table 3.3 Distribution of contact trials and no contact trials among trials analyzed in the light and dark for both groups.

LIGHT									
	No contact trials			Contact trials			Contact trials/Trials analyzed		
	L. Left	L. Right	Total	L. Left	L. Right	Total	L. Left	L. Right	Total
SE	0	1	1	75	75	150	75/75	75/76	150/151
ME	*	*	7	*	*	123	*	*	123/130

DARK						
	No contact trials		Contact trials		Contact trials/trials analyzed		
	Dark Left	Dark Right	Dark Left	Dark Right	Dark Left	Dark Right	DL + DR
SE	8	8	38	44	38/46	44/52	82/98
ME	7	9	50	49	50/57	49/58	99/115

a. Light trials

Infants in the SE group reached on 99% of the trials analyzed in the light. Infants reached equally often on the left and on the right. The ME group reached on 95% of the trials in the light.

b. Dark trials

In the dark, the SE group reached on 84% of the trials analyzed, the remaining 16% were trials during which infants did not make any contact. Their performance was similar on the left and on the right, 83% on the left and 85% on the right.

The ME group reached on 86% of the trials analyzed and made no contact on 14% of the trials analyzed. They reached on 88% of the trials analyzed on the left and on 84% on the right.

Both groups were quite active in the dark. Although this result was expected of the SE group, it was surprising in the case of the ME group. We did not expect this group to be as active in the dark.

3. Analysis of first contact in first two trials analyzed in the dark

As mentioned in the previous analysis, the ME group was very active in the dark and reached as much as the SE group. In a subsequent analysis, we looked at the location of their contacts. This was particularly important for our purposes because we expected the ME group not to be able to reach in the correct location as often as the SE group, as they had not been able to form a representation of the events in the dark. The location of the first contact infants made in the first two dark trials[3] (one on the left

[3]For the ME group, in 4 trials out of 32, there was no contact in the first trial and one trial could not be scored. In 4 of these 5 instances, the second trial was analyzed instead and in one case the third trial was analyzed. For the SE group, in 6 trials, the infant's hand was already in the tray before the ball was dropped and in 3 cases, there was no contact. For 6 of these trials, the second trial was scored instead and for the other 3, the third trial was analyzed.

and one on the right) was analyzed. These trials were the first two instances when the ME group heard the side event, compared to the SE group who had the experience in the light. The first contact was analyzed in 3 different ways (see Figure 3.4, panels a, b, c, p. 52; also see table 3. 4, p. 53 for means and standard deviations).

First, an analysis was performed on the percentage of infants whose first contact was directed to the correct hemifield (panel a). This area included the sound area, the silent area and the target area. In this analysis, if infants reached, they had a 50% chance of contacting the correct hemifield. A 2 x 2 analysis of variance (ANOVA) was conducted on group[4] (SE vs. ME) and side of trial (left vs. right). Infants in the SE group contacted the correct hemifield significantly more often than infants in the ME group ($F(1, 28) = 7.84$; $p<.01$).

The SE group was able to use the auditory information specifying on which side the ball was going and to reach accordingly. By contrast, the ME group with the same type of perceptual information was not able to use the perceptual cues to reach into the correct hemifield. For their first encounter with the events in the dark, they exhibited a strong side bias (group x side interaction $F(1,28) = 6.53$, $p<.02$). Contrasts showed that there was no difference between the two groups in the dark left event ($F(1, 28) = .046$, $p< .833$) but that the ME group contacted the right hemifield significantly less ($F(1, 28) = 15.60$, $p< .001$) in the dark right condition. It appeared that the ME group had a strong bias to reach left, regardless of the ball's location.

[4]For all analyses in the dark except for head orientation analyses, $N = 14$ for the SE group. In this group, one infant never reached in the dark and one never reached in dark left trials. For analyses in the light, $N = 16$. For all analyses both in the light and in the dark for the ME group, $N = 16$.

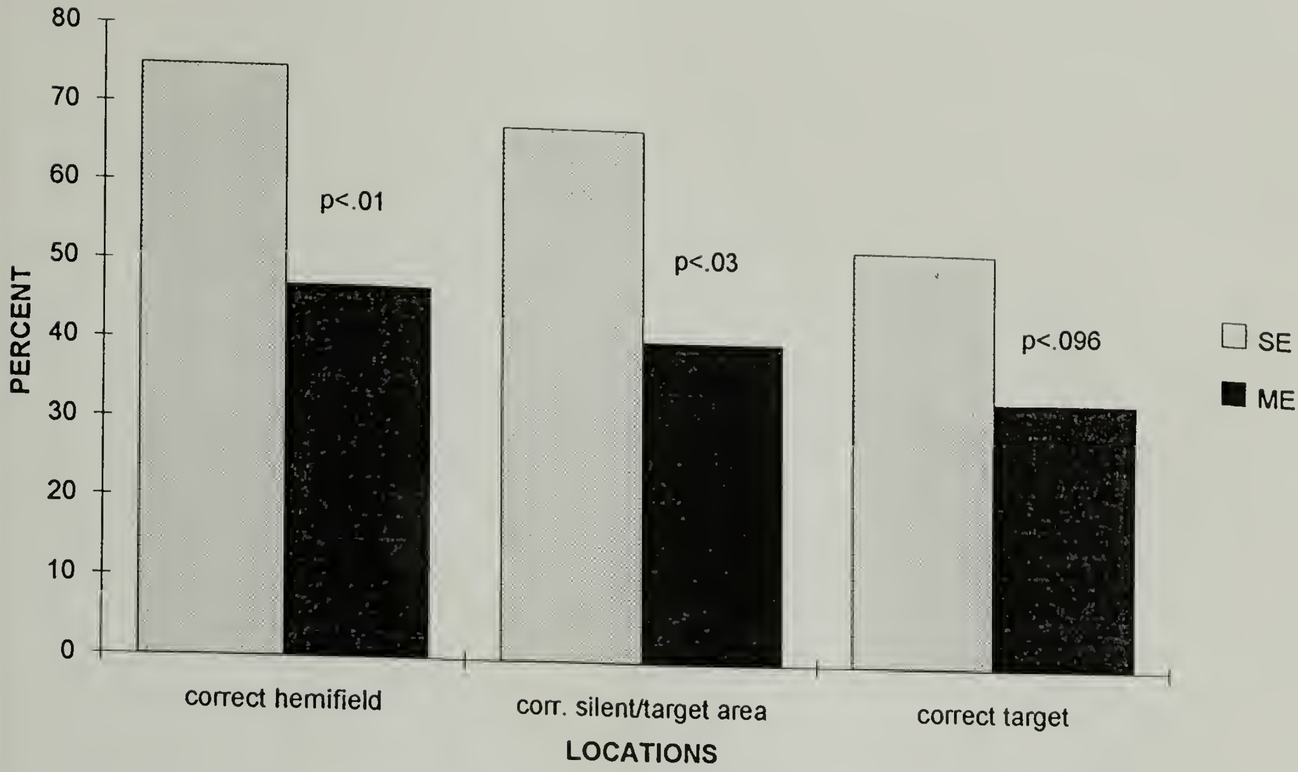

Figure 3.4 Percentage of first contact in first dark trial directed toward the correct hemifield (panel a), the correct silent/target area (panel b) and/or the correct target area (panel c).

The percentage of infants whose first contact went to the correct silent area plus the target area was next analyzed (panel b). In this analysis, if infants made their first contact in the correct hemifield but in the sound area, they received a 0, the same score they received when reaching to the wrong hemifield. If they made their first contact in the correct hemifield and in the silent area, they received a 1. The same ANOVA as above was performed. As in the preceding analysis, the SE group contacted the correct silent/target area significantly more often ($F(1, 28) = 5.32$; $p<.03$) than the ME group. Again, a side x group interaction was found ($F(1,28) = 4.64$; $p<.04$). As before, contrasts showed that in the dark left event infants in the ME group tended to contact the correct silent area as often as the SE group ($F(1, 28) = .005$, $p< .88$). In the dark right condition, however, the performance of the ME group was significantly lower than infants In the SE group ($F(1, 28) = 11.3$, $p< .002$).

Finally, the percentage of infants whose first contact went to the correct target area was analyzed (panel c). In this analysis, a score of 1 was given if the infant contacted the target area whether they contacted the ball or not. If contact was made anywhere else, the score was 0. This was the most restrictive way of analyzing the data. The same ANOVA as in preceding analyses was performed. A marginal difference between groups was found ($F(1,28) = 2.97$; $p<.096$). This result could be due to the fact that reaching into the correct target area was a difficult task because there was no ongoing sound to guide the reach and because the ball came to rest at a distance away from the last sound heard. Reaching had to be guided solely by memory and under these conditions it was difficult to place the hand in the small target area. Moreover, the ME group tended to systematically contact the correct target on the left while they were rarely correct on the right side. A side x group interaction was found ($F(1,28) = 6.53$; $p<.01$). Contrasts showed the same pattern as in the preceding analyses; in the dark left event, the ME group did not differ from the SE group ($F(1, 28) = .45$, $p< .51$) but on the right side, the SE group contacted the target area significantly more often than the ME group ($F(1, 28) = 12.40$, $p< .001$).

Table 3. 4 Means and standard deviations for proportions of first contact in first two dark trials in correct hemifields, silent and target areas.

	SE group						ME group					
	Hemifield		Silent		Target		Hemifield		Silent		Target	
	DL	DR	DL	DR	DL	DR	DL	DR	DL	DR	DL	DR
M	.71	.79	.68	.71	.50	.57	.75	.19	.68	.12	.62	.06
SD	.47	.43	.48	.47	.52	.51	.45	.40	.48	.34	.50	.25
M	.75		.68		.54		.47		.41		.34	
SD	.44		.48		.51		.51		.5		.48	

4. Hand used for contact and hemifield contacted

The previous section showed that infants in the ME group tended to contact the correct hemifield on the dark left condition significantly more than on the dark right condition. This tendency was not expected. The hand used during contacts, in the light as well as in the dark, was analyzed. Table 3.5 shows which hand the ME group used in each condition (light and dark) and each side (left and right). We can see that this group used the left hand more often both in the light and in the dark. In the light infants had no particular reason to use one hand more than the other because the ball was resting at midline. Yet the ME group reached with the left hand on 60% of the trials and with the right hand on only 40% of the trials.

Table 3.5 Number of first contacts performed with the left or right hand in the light and dark for the ME group.

ME group	Left hand used	Right hand used	Total contacts
Ball on middle	67	45	112
Ball on left	37	13	50
Ball on right	31	18	49

The data in the dark seem to indicate that the resting place of the ball did not greatly influence which hand was used. Indeed, with an equivalent number of trials on the left and on the right, infants reached in 69% of the trials with the left hand and only 31% with the right hand. They reached more with their left hand no matter where the ball landed.

There were, however, 7 instances of cross-over for the ME group: in 3 cases the wrong hemifield was contacted[5] and in 4 cases the correct hemifield was contacted. In

[5] There were two cases in DL where the right hemifield was contacted with the left hand and 1 case in DR where the left hemifield was contacted with the right hand.

1 of these 4 cases, the left hemifield was contacted with the right hand and in the other 3 cases the right hemifield was contacted with the left hand. In the rest of the contacts, hand and hemifield contacted correlated. Table 3.6 presents the number of first contacts directed to the correct and wrong hemifields in the dark condition.

Table 3.6 Number of first contacts directed toward the left and right hemifields in the dark condition for the ME group.

ME group	Cont. in left hemif.	Cont. in right hemif.	Total
Ball on left	36	14	50
Ball on right	29	20	49

We used detection theory in order to analyze hand use. Detection theory was indicated in this study as it establishes whether a response is based on "merit" or on some kind of bias (MacMillan & Creelman, 1991; p. 31, 273), in this case a tendency for the ME group to use the left hand no matter where the stimulus (the ball) was. Analyses were performed on the number of first contacts presented in Table 3.6. The bias measure, *c* was .408. In order to find the significance level, we computed a *z* score[6]; $z = 2.89$, $p < .01$. Infants in the ME group had a significant bias to reach with their left hand and to contact the left part of the apparatus.

By contrast the SE group did not show such bias. The hand used during first contact was analyzed both in the light and in the dark. Table 3.7 shows which hand was used in each condition (light and dark) and each side (left and right). In the light, infants in the SE group overwhelmingly chose the ipsilateral hand. Such a result was expected in the light because infants at that age rarely cross midline.

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[6] $z = \frac{c - 0}{SD(c)}$

Table 3.7 Number of first contacts performed with the left or right hand in light and dark contact trials for the SE group.

LIGHT			
	Left hand used	Right hand used	Total contacts
Ball on left	73	3	76
Ball on right	2	73	75
DARK			
	Left hand used	Right hand used	Total contacts
Ball on left	25	13	38
Ball on right	11	33	44

In the dark, infants reached on 66% of the left trials with the left hand and on 75% of the right trials with the right hand.

There were 5 cases of cross-over: In one case, the wrong hemifield was contacted (right hemifield contacted with the left hand in DL). In the 4 remaining cases, the correct hemifield was contacted: The left hemifield was contacted with the right hand in DL on one occasion, and the right hemifield was contacted with the left hand in DR on 3 occasions. Table 3.8 presents the number of first contacts directed to the correct and wrong hemifields.

Table 3.8 Number of first contacts directed toward the left and right hemifields in the dark for the SE group.

SE group	Cont. in left hemifield	Cont. in right hemi	Total
Ball on left	25	13	38
Ball on right	8	36	44

Bias was measured using the number of first contacts presented in Table 3.8. *c* was -.251. Contrary to the ME group, the SE group did not show any side bias, $z = 1.65$, $p > .05$.

5. Analysis of first contact in all dark trials

Our main hypothesis in this study was that infants in the SE group could form a representation of the side events and use this representation when reaching in the dark. Results from section 3 showed that the SE group contacted the correct area in their first dark trial significantly more often than the ME group. Our next prediction was that when all trials were considered the same result would be found. Contact trials in the dark for each group were averaged and we looked at contact to correct hemifields, correct silent areas and correct target areas (Figure 3.5, panels a, b, c, see also Table 3. 9 for means and standard deviations). When first contacts to the correct hemifield were analyzed (panel a), the SE group reached significantly more often to the correct hemifield than the ME group ($F(1.28) = 7.52$; $p<.01$). More reaches were directed to the left side ($F(1, 28) = 4.13$, $p<.05$) but this was due again to the strong left bias of the ME group ($F(1, 28) = 6.84$; $p<.01$). Contrasts showed that the SE group contacted the correct hemifield significantly more often on the right side than the ME group ($F(1, 28) = 13.06$, $p< .001$). There was, however, no significant difference on the left side ($F(1, 28) = .16$, $p>.69$) due to the ME group's tendency to reach toward this side in general.

Secondly, first contacts to the correct silent plus target areas were analyzed (panel b). Here the difference between the two groups was only marginally significant ($F(1, 28) = 3.8$; $p<.06$). More reaches were directed to the left side ($F(1, 28) = 5.63$, $p<.02$) but again this was due to the left bias of the ME group ($F(1, 28) = 8.20$, $p<.008$). Contrasts showed as in prior analyses that infants in the SE group contacted the correct silent plus target areas significantly more often on the right side ($F(1, 28) = 10.17$, $p<.003$) but not on the left side ($F(1, 28) = .955$, $p<.34$).

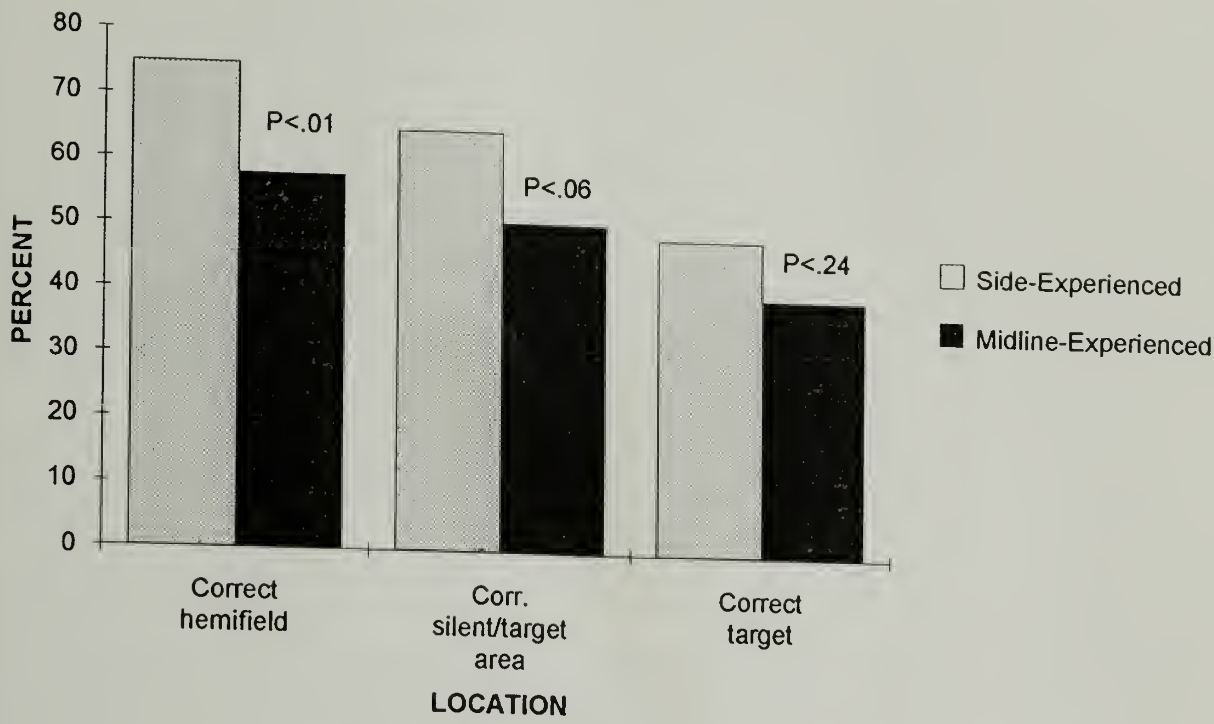

Figure 3.5 Percentage of first contacts in all dark trials directed toward the correct hemifield (panel a), silent/target area (panel b) and target area (panel c).

Third, analyses were performed on the proportion of first contacts to the correct target area (panel c). The SE group did not contact the target area significantly more often than the ME group ($F(1, 28) = 1.44$, $p<.24$). As before, however, there were more reaches directed to the left side ($F(1, 28) = 4.32$, $p<.05$) and this was due to the left bias of the ME group ($F(1, 28) = 5.3$; $p<.03$). Contrasts showed again that the SE group contacted the correct target area significantly more often on the right ($F(1, 28) = 7.28$, $p<.012$) but not on the left ($F(1, 28) = .86$, $p<.36$).

It was of interest to see whether infants' performance was influenced by the preceding trial. We looked at the number of times infants reached to the location they

had contacted in the previous trial. Among these occurrences, we identified the cases where reaching to the previous locations was justified and the cases where it was a mistake (perseverative error). Infants in the SE group reached back to the previous location on 17% of the trials. In 7% of these instances, it was a perseverative error. Infants in the ME group repeated their reach in 23% of the trials. They made a perseverative error in 19% of the trials. The SE group rarely made perseverative errors, by contrast the ME group made almost 3 times as many errors.

Table 3. 9 Means and standard deviations for proportions of first contact in all dark contact trials in correct hemifields, correct silent/target areas and correct target areas.

	SE group						ME group					
	Hemifield		Silent		Target		Hemifield		Silent		Target	
	DL	DR	DL	DR	DL	DR	DL	DR	DL	DR	DL	DR
M	.70	.80	.57	.73	.40	.59	.73	.43	.67	.57	.52	.29
SD	.22	.26	.47	.31	.31	.36	.29	.30	.33	.17	.38	.27
M	.75		.65		.49		.58		.51		.40	
SD	.24		.26		.34		.32		.35		.34	

<u>6. Analysis of second contacts when the first contact was an error in location</u>

In these analyses, second contacts were taken into account if the first contact was a mistake (Figure 3.6, panels a, b, c, see also Table 3. 10 for means and standard deviations). The rationale for looking at second contacts was to investigate the extent to which infants could correct their previous mistake. If an infant contacts the wrong surface in the first contact, but then makes a second reach and contacts the correct area, this correction suggests that the infant is not simply reaching randomly or making

a conditioned response but has an understanding of the event and is searching for the object.

The first analysis was on the proportion of second contacts directed to the correct hemifield given the fact that the first contact was directed toward the wrong hemifield (panel a). The two sides were pooled together because there were not enough data in each side for statistical analysis. Infants in the SE group were significantly more likely to correct their mistake than infants in the ME group ($F(1, 28) = 6.25$, $p<.02$).

Second contacts were then analyzed given that the first contact was directed to the wrong silent area and/or the wrong hemifield (panel b). Here again infants in the SE group were more likely to correct their mistake compared to the ME group ($F(1, 28) = 3.94$, $p<.057$).

In the third panel, the proportion of second contacts ending with a contact with the target area was analyzed given the fact that the first contact was a mistake (panel c). There was no significant difference between the two groups ($F(1, 28) = 2.5$, $p<.12$).

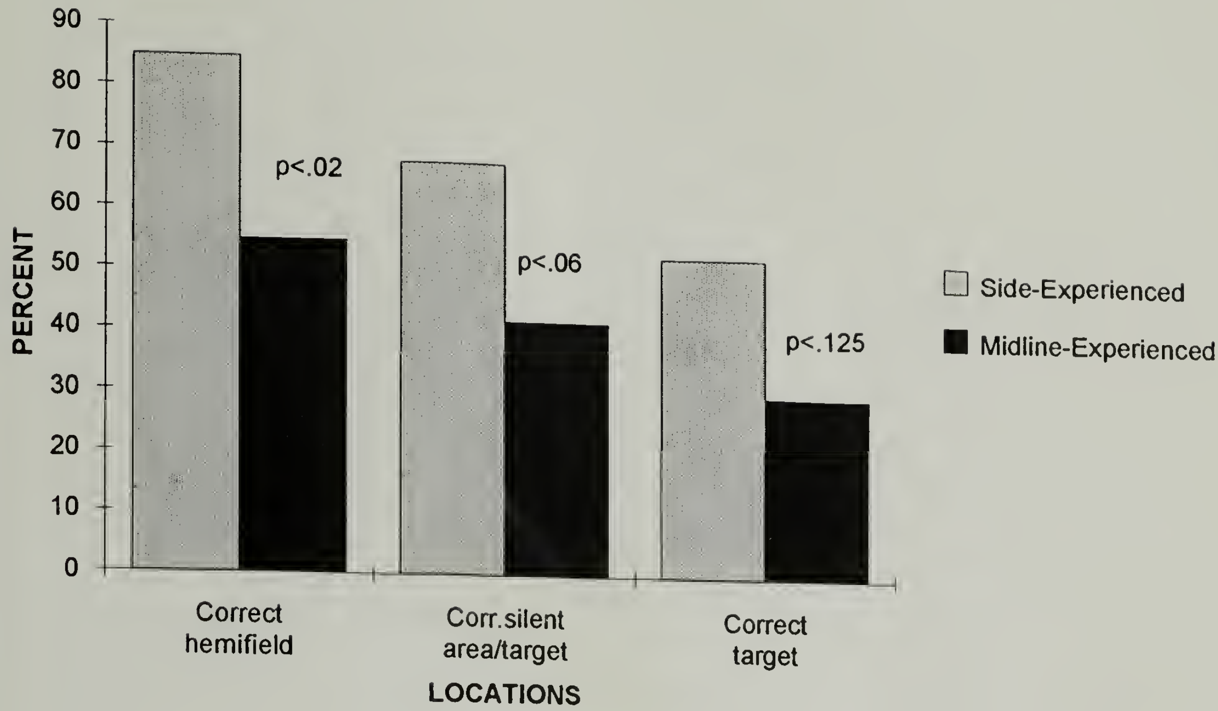

Figure 3.6 Percentage of second contacts in the dark directed toward the correct hemifield (panel a), silent/target area (panel b), target area (panel c) given that the first contact was an error in location.

These data repeat the pattern observed in the preceding set of results. The more restrictive the analysis, the less difference between the two groups. Here again, we believe that the SE data for the target area reflect the difficulty in placing the hand in a small area when no perceptual cues to guide the reach.

Table 3.10 Means and standard deviations of second contacts to the correct hemifield, silent/target areas, or target areas given that the first contact was an error in location in dark condition.

	SE			ME		
	Hemif.	Silent	Target	Hemif.	Silent	Target
M	.84	.68	.52	.55	.43	.30
SD	.28	.36	.42	.35	.32	.32

7. Comparison of the first dark trial and last dark trial

Results so far have shown the advantage of the SE group over the ME group in contacting the correct areas of the apparatus. It was of interest, however, to see whether performance between beginning and end of session improved. This was particularly interesting for the ME group as performance could have improved as infants repeatedly heard the event in the dark and got reinforced sometimes when they got the ball. We compared accuracy of first contact on the first contact trial with first contact on the last contact trial. For each group we performed ANOVAs on the proportion of contacts to the correct hemifield in the first trial compared to the last trial.

a. SE group

We compared the proportion of first contact to the correct hemifield on the first dark trial with the proportion of first contacts to the correct hemifield on the last dark trial. Mean for the first dark trial was .75 (M = .75 both on the left and on the right). Mean for the last trial was .62 (M = 58 on the left, M =.67 on the right). Four babies were not included in these means, 2 because they reached in only one trial in the dark and therefore no comparison could be made between first and last trial and 2 because they made contact only once in dark trials. A 2 trials (first vs. last) x 2 sides (left vs. right) ANOVA[7] yielded no significant effect of trial, side, nor any interaction (all $p>.39$). It seems as though performance across the session did not improve in the SE group. Performance in the first dark trial and in the last one remained similar .

b. ME group

The same analysis was performed on the ME group. Three infants were not included in this analysis because they reached in only one dark left and one dark right

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[7] N = 12

trial[8]. Mean was .41 for the first dark trial (*M* = .75 on the left, *M* = .08 on the right). Mean for the last trial was .65 for the rest of the trials (.85 on the left and .46 on the right). The first trial and the last trial were not significantly different ($p < .14$). As before performance was significantly better on the left ($F(1, 12) = 26$, $p < .0001$). There was no trial x side interaction ($p < .17$).

8. Latency to reach and search duration

As in Study 1, latency to reach and search duration were critical measures to support our argument of mental representation in young infants. In this case, we expected infants in the SE group to have shorter latencies than the ME group and to search longer as a result of their familiarity with the situation. Latency to reach was computed as the time between the onset of silence and the onset of first reach. Latencies in the light condition were computed for the SE group. The mean latency was .77 s (*SD* = 1.32)[9]. By contrast, the mean latency in the dark was 3.92 s (*SD* = 3.27), see Table 3.11, p. 64 for means and standard deviations. The mean latency for the ME group in the dark was 3.85 s (*SD* = 3.45) [10], see table 3.11. A 2 groups (SE vs. ME) x 2 sides (left vs. right) ANOVA was performed on latency in the dark. There was no significant difference between the groups. Experience of the events in the light did not affect latencies to reach.

Search duration was computed as the time between the first contact made and the end of search. It was the total amount of time infants spent in contact with the apparatus. The mean for the SE group was 8.85 s (*SD* = 4.38), see Table 3.11 for means and standard deviations. The mean for the ME group was 8 s (*SD* = 4.60. A

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[8] $N = 13$
[9] Mean latency on the left was .87 (*SD* = 1.05). Mean latency on the right was .67 (*SD* = 1.54)
[10] The latencies in the light could not be computed in most trials because of infants' posture. The midline path ended right in front of the infants and they tended to lean forward above the path therefore hiding the exact moment at which they contacted the ball.

group x side ANOVA was performed on these means and no significant difference between the two groups was found.

Table 3.11 Means and standard deviations in latency to reach and search duration in dark trials for both groups.

SE				
	Latency to reach		Search duration	
	Dark left	Dark right	Dark left	Dark right
M	4.75	3.50	8.25	8
SD	2.66	2.51	3.11	2.96
ME				
	Latency to reach		Search duration	
	Dark left	Dark right	Dark left	Dark right
M	4.14	4.53	7.24	8.12
SD	2.51	2.61	2.97	3.11

As in Study 1, we combined the latency to reach and the search duration in a graph to give an indication of the time elapsed between the onset of silence to the end of search (Figure 3.7). Infants in both groups were on average in contact for up to 8 seconds with the apparatus while in silence and in darkness.

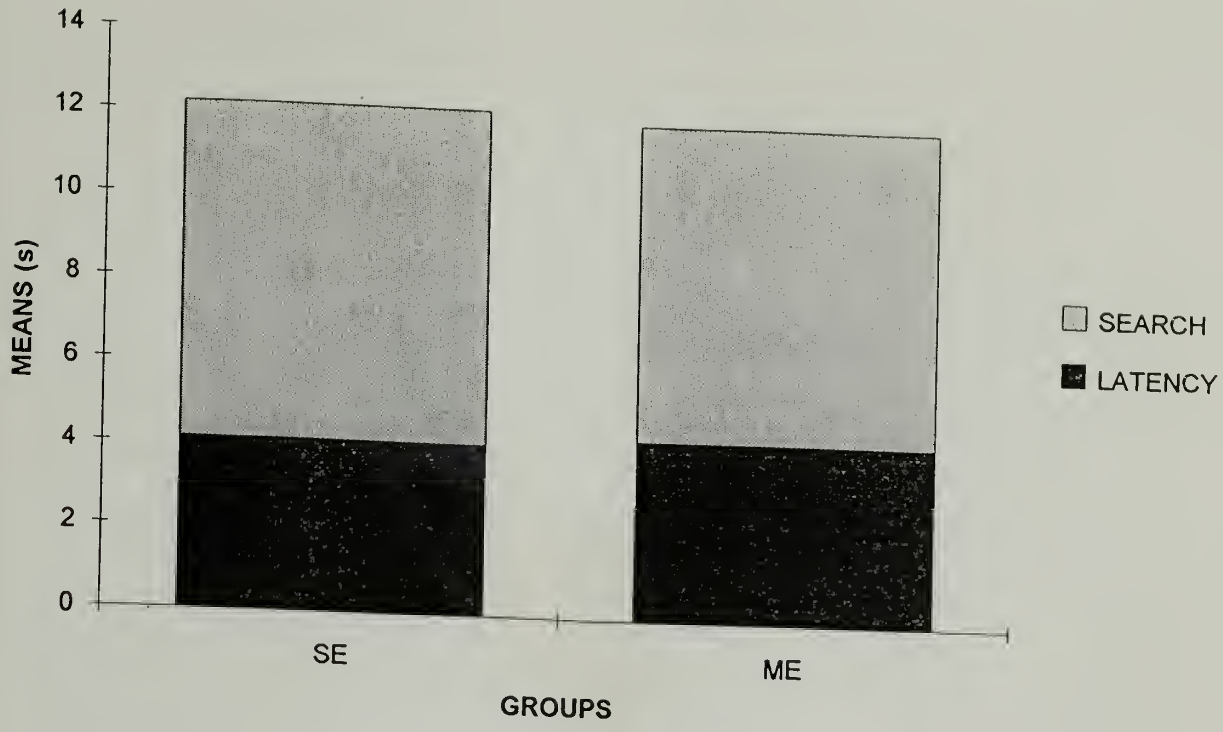

Figure 3.7 Time elapsed from the onset of silence to initiation of reach and the end of search in dark trials.

9. Number of contacts per trial

As in Study 1, we analyzed the number of contacts infants made on average per trial. Figure 3.7 showed that both groups were reaching for up to 8 seconds while in the dark and in silence. The next analysis attempted to show that in addition to acting in the dark and in silence, infants did not simply make one long reach but made several reaches per trial in an attempt to get the ball. Within each trial infants had 15 seconds to make several successive reaches and contact different areas. The SE group made an average of 2.79 (*SD* = .71) contacts per dark contact trial (2.72 in left trials, *SD* =.74; 2.85 in right trials, *SD* = .97) with a range between 1 and 4.33 contacts. The ME group was very similar and had an average of 2.49 (*SD* = .75) contacts per trial (2.52 in left trials, *SD* = .72; 2.46 in right trials, *SD* = .89) also with a range between 1 and 4.33. A 2

(SE vs. ME) x 2 (left vs. right) ANOVA[11] was performed. Neither groups nor sides differed significantly ($p<.27$).

10. Success in contacting the ball in the dark

Table 3.12 shows the number of trials in which infants in the SE group contacted the ball in their first reach (2nd column) and in subsequent reaches (3rd column). Infants in the SE group contacted the ball in 61% of the trials (50% on left trials and 70.% on right trials). In 34% of these success trials, infants contacted the ball with their first reach (12% in the left condition, 22% in the right condition). In the remaining 66% they contacted the ball in subsequent reaches.

Table 3.12 Success in contacting the ball in the first reach and in subsequent reaches for both groups.

	SE		
	First reach	Subs. reaches	Contact trials
DL	6	13	38
DR	11	20	44
TOTAL	17	33	82
	ME		
	First reach	Subs. reaches	Contact trials
DL	9	18	50
DR	7	13	49
TOTAL	16	31	99

[11] N = 14 in the SE group; N = 16 in ME group

Table 3.12 also shows the number of trials in which infants in the ME group contacted the ball in their first reach and in subsequent reaches. This group contacted the ball on 48% of the trials (54% on left trials and 41% on right trials). In 34% of the success trials, they contacted the ball with their first reach (18% in the left, 14% in the right). In the remaining 66%, they contacted the ball in subsequent contacts.

The SE group tended to be better at contacting the ball although it did not reach significance ($F(1, 28) = 2.92$, $p < .10$). There were more successes on the right side ($F(1, 28) = 9.87$, $p < .01$) and this was due to the fact that the SE group was more successful on the right than on the left ($F(1, 28) = 8.97$, $p < .01$). Contrasts showed that groups' performance was similar on the left ($F(1, 28) = .01$, $p < .93$) but that the SE group was better on the right ($F(1, 28) = 7.92$, $p < .01$).

11. Head orientation

So far results showed that the ME group was significantly less good at reaching in the correct areas in the dark. In this last analysis we looked at the orientation of the head at the time the ball landed in the tray. By the time the ball had landed in the tray, it was clear from the sound on which hemifield the ball had gone, although the last sound heard did not correspond to the resting position of the ball. The rationale for this analysis was that if the SE group did have some representation of the apparatus, they would show it by orienting their head to the correct hemifield when hearing the perceptual cue. By contrast, the ME group should not be able to orient as well because they had no spatial representation of the apparatus. As in the analysis of the first contact to the correct hemifield, in which the ME group did not take into account the perceptual cue to guide their reaching, we expected the ME group not to orient the head as well for the same reason. The idea was that perception by itself was not sufficient to guide action. A representation of the spatial layout of the apparatus was necessary. A 2 group (SE vs. ME) x 2 sides (left vs. right) ANOVA was performed on

the proportions of correct head orientation at landing time in the dark (see Table 3.13 for means and standard deviations). Infants could orient their head to the left, to the right or to the middle. The middle was a wrong orientation in every case. As expected, infants in the SE group[12] were quite good at orienting their head to the correct hemifield and were significantly better than the ME group ($F(1, 30) = 6.08$; $p<.02$).

Table 3.13 Means and standard deviations for correct head orientation at landing time in the dark.

	SE		ME	
	Dark left	Dark right	Dark left	Dark right
M	.77	.70	.63	.49
SD	.29	.29	.23	.33

There was no side effect nor side x group interaction. Infants in the ME group had their head oriented to the middle at landing on 29% of the trials whereas the SE group oriented to the middle only 18% of the trials. The sound by itself was not enough to make infants in the ME group orient correctly their head.

C. Discussion

Results in this study showed that infants who had experience of an event in the light, were subsequently able to use this experience to reach toward the correct areas while in the dark and in silence. In comparison to the naive group, infants in the Side-Experienced group reached significantly more to the correct hemifield and to the correct

[12]In head orientation analyses, every infant in the SE group gave data ($N = 16$); the two infants who did not give complete data in the dark were nevertheless included in the analyses as they completed at least two dark trials without fussing.

silent area. Infants were not always accurate because the task was difficult to perform in the absence of perceptual cues. Nevertheless, infants demonstrated that they understood the task and knew where to search for the object.

What was the nature of this representation? One possibility is that their representation of the events included both a perceptual aspect (the auditory information specifying on which side the ball is going) and a cognitive one (a memory of where the ball came to rest after the auditory cue). Their representation of the events could have included both perceptual and cognitive elements. The perceptual element could have been the auditory information given by the ball bouncing down the vertical tube and then specifying on which side the ball was going. The cognitive element could have been a memory that such sound led to the availability of an object and also a memory of where the ball came to rest after the last auditory cue. This is quite a complex representation integrating perception and cognition and allowing action.

Let us now examine the issue that infants' reaching was due to conditioning as opposed to the existence of a mental representation of the events. A problem emerges as we try to identify what infants might have been conditioned to. Was it conditioning to a sound? For example, did infants learn to associate the sound made by the ball rolling down with a reach in the tray? This explanation is not likely because the last sound heard did not correspond spatially to the motor response required. Moreover, the occurrence of a sound did not signal the immediate availability of the object. In conditioning studies in the animal literature, delaying the reinforcement leads to less efficient learning (Davey, 1981).

Could it be, then, that infants were conditioned to reach when silence happened? If this were the case, then one would expect that in the light as well as in the dark, infants waited for silence before reaching. Latencies to reach showed that infants in the light often started their reach right when the ball reached the padded part of the paths. By contrast, in the dark, they waited on average 4 seconds before initiating a reach.

Finally, if infants had been conditioned (whatever the conditioned stimulus was), one would probably observe a single motor response or reach within a trial as infants repeated the same action they had performed in the light. Results showed that infants' reaching was far more complex than a simple reach. Indeed, infants in the SE group made an average of 2.8 contacts (between 1 and 4.33 contacts) per trial in the dark and continued haptic exploration for about 8 seconds. In other words their motor activity indicated that they were searching and not simply performing a practiced motor action. Moreover, if infants in the ME group had been conditioned, they should have been reaching toward the middle where they had gotten the ball in the light. Instead they rarely went to the middle but explored the area.

In order for infants to act correctly, they had to associate auditory information (specifying on which side the ball was going) with a spatially and temporally remote target location, then act on this association with a highly complex and variable motor response. I would argue that this type of behavior is probably best be understood in terms of cognitive activity. In order to show this experimentally, we would need to have a new group of subjects who would not be given the opportunity to associate vision and sound of the ball. This group would be exposed to a simple contingency in the light and then have the same dark trials as the SE and ME group. In the light, infants would hear the events from behind a curtain. The only thing visible would be two cups located to the left and right of the infant just as the trays of the apparatus were positioned to the left and right of the SE and ME group. In light trials, the ball would be dropped by the experimenter from behind the curtain. The ball would roll down one of the paths, for example the right path. At the time the ball would land in the tray (behind the curtain), a second ball would appear in the right cup. The infant would have 15 seconds to pick up the ball. We would thus create an artificial contingency between a moment of silence (corresponding to the ball rolling on the padded path) and the appearance of a ball in a cup. This group should not be able to form a spatial representation of the event,

because they will have no visual experience with the ball's action in the apparatus. Contrary to the SE group who had the opportunity to integrate sound and vision, this new group could not do such integration. We would expect the new group not to perform well at all in the dark. We would expect them either not to reach for the tray at the end of the event, or to reach in wrong locations, or if they do reach in the correct location, not to respect the timing of the event (e.g., reach when there is sound). The low performance of this new group would give weight to the argument that infants had to integrate vision and sound in order to reach in dark events and that their performance could not be explained by a simple contingency of acoustic event followed by reinforcement in the tray.

In Piaget's theory, infants do not know that an unseen object still exists until about 9 months of age. Infants in the Side-Experienced group showed that they knew that the outcome of the events was the availability of a ball. By searching for up to 8 seconds while in the dark and in silence, they demonstrated that they were looking for something, that they had an understanding that there was an object to reach for. Likewise, the Midline-Experienced group who had only a limited knowledge of the situation was also actively searching in the dark. This behavior is consistent with the idea that these infants knew that an object existed even though there was no sight or sound to remind them of its presence. Moreover, infants only rarely made perseverative errors (7%). Their behavior cannot be explained in terms of circular reactions, where action is thought to be creating the situation. Action in this case was tightly linked to a representation of the event and varied from trial to trial.

The performance of the Midline-Experienced sheds some light as to what infants do when they have limited knowledge of a situation. Infants in this group had a partial familiarity with the dark events. In the light, they saw and heard the ball clatter down the vertical tube. In the dark, as each trial started the same way, infants had at least some experience of the situation. They had, however, never experienced the complete event

in the light and as a result could not have a complete representation of the event. Results showed that these infants did search while in the dark and in silence. Their performance seems to indicate that they knew that there was something to get somewhere in the area, without knowing the exact location. They might have understood the general purpose of the task (which was similar to their light experience) without having the knowledge to understand its specific. Their representation of the event might have been based on the auditory cues available while the ball bounced down the vertical tube and on the memory that in the light such sound led ultimately to the availability of a ball. This is strengthen by the fact that on 19% of the trials, infants made perseverative errors. Furthermore, the fact that they were sometimes reinforced in the dark (when they found the ball) helped strengthen some representation of the event. We are not arguing that infants actually "understood" what the shape and the spatial layout of the apparatus was[13], but that they remembered enough of their light experience to make them reach and search in the dark. There was no significant improvement in the accuracy of their reaching across the session.

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[13]In fact, pilot data from a group of adults who never saw the apparatus but only heard the events, showed that they had no idea of what the apparatus looked like, and the type of object producing the sound.

CHAPTER IV

CONCLUSIONS

The two studies reported show that infants can represent events and object in the absence of perceptual cues. In Study 1, infants searched for an object while in silence and in the dark. In Study 2, infants used their knowledge of the events gained in the light to act in the dark, while in silence. These findings demonstrate that infants are able to hold mental representations earlier than Piaget claimed. A question of importance, however, is the extent and the nature of this contradiction.

According to Piaget, in Stage 3 of the sensorimotor period, if an object disappears from sight, infants would repeat the action performed earlier. In other words their activity was a mere "continuation of action" as opposed to an anticipation. We cited in Chapter I the observation Piaget made of his daughter turning back and forth to her father even though he was silent. For Piaget, infants do not understand objects as being independent entities. Instead, if an object disappears from sight, an infant will reproduce her previous action because she believes it will produce the object. It is not until infants start searching for the disappeared object by using different motor actions that they demonstrate that they know that objects have an existence independent of one's actions. Search is therefore the landmark signaling a change in the understanding of object concept. In Study 2, not only did infants search during trials but if our results could be explained by the fact that infants were simply repeating earlier actions, the ME group should have been reaching toward the middle where they had gotten the ball in the light. Instead they rarely went to the middle but explored the area. This shows that infants did not simply repeat earlier actions but were flexible in their actions and integrated perception and mental representation of a previous experience to guide action.

A number of researchers who have used the visual habituation paradigm have demonstrated that Piaget underestimated infants' capabilities. Baillargeon's work for example has uncovered amazing capabilities in young infants (1994). For example, as mentioned earlier she argued that 4½-month-old infants (and fast habituators 3½-months-old) possess object permanence (1987). In one study related to ours, she argued that infants younger than 9 months of age can represent the properties of occluded objects (Baillargeon, 1986). She habituated infants to a toy car rolling down a ramp, passing behind a screen, and exiting the apparatus on the other side. After habituation, infants were presented with two events: In both events a box was placed behind the screen. In the possible event the box was placed in back of the car's tracks making it possible for the car to pass behind the screen and to exit on the other side. In the impossible event, the box was positioned on the car's track making it impossible for the car to exit. The screen was raised in both events to show where the box was and then the car was shown exiting in both cases. Infants looked reliably longer at the impossible event suggesting that infants "a) represented the location of the box behind the screen; b) assumed that the car pursued its trajectory behind the screen; c) understood that the car could not roll through the space occupied by the box; and hence d) were surprised in the impossible event to see the car roll past the screen" (Baillargeon, 1993, p. 274). The situation was comparable to an invisible displacement. The car continued to move although it was invisible.

In Study 2, infants were also in a situation where the object moved while invisible and <u>silent</u>. While it is difficult to show that infants had a representation of the trajectory of the ball, we can at a minimum say that infants in the SE group had to possess a memory of the final resting position of the ball and that they used this memory to guide their reaching in the dark. Likewise, we cannot argue that the ME group figured out the configuration of the apparatus, but we can at a minimum say that this group used a memory of the light situation to influence their reaching in the dark. This assumes that

infants were able to hold the memory of the outcome of the event. They had to remember that the sound heard during the first part of the event referred to an object and they then had to remember that silence led to the availability of a ball. This ability to hold a memory without any perceptual remainder of the situation is not consistent with Piaget's description of infants prior to 9 months of age. In our studies, particularly in study 2 infants could not have reached to the proper locations without the ability to recall some of the event (whether its trajectory or more simply its outcome).

The two studies presented in this thesis show a case of declarative knowledge similar to Mandler's perceptual analysis or to Karmiloff- Smith's representational redescription. Infants had to compare their experience in the light with the events in the dark. They had to hold a representation of the events. While this representation was obviously not in a verbal code, it was accessible. These studies do not address the question of the origins of such knowledge, but it agrees with current work on infant cognition while using a different methodology.

Further research should be done to investigate more fully the epistemological question. One way to do so would be to assess infant's abilities to extrapolate information from a situation to apply it to another one. Investigating infants' ability to learn, and their rate and quality of learning is one way to know more about what can be learned and what has to be given from the beginning.

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