Developmental Psychology
2004, Vol. 40, No. 4, 606–620

0012-1649/04/$12.00 DOI: 10.1037/0012-1649.40.4.606

Object Permanence After a 24-Hr Delay and Leaving the Locale of Disappearance: The Role of Memory, Space, and Identity

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Fourteen-month-old infants saw an object hidden inside a container and were removed from the disappearance locale for 24 hr. Upon their return, they searched correctly for the hidden object, demonstrating object permanence and long-term memory. Control infants who saw no disappearance did not search. In Experiment 2, infants returned to see the container either in the same or a different room. Performance by room-change infants dropped to baseline levels, suggesting that infant search for hidden objects is guided by numerical identity. Infants seek the individual object that disappeared, which exists in its original location, not in a different room. A new behavior, identity-verifying search, was discovered and quantified. Implications are drawn for memory, spatial understanding, object permanence, and object identity.

Adults conceive of inanimate objects, other persons, and themselves as temporally enduring entities contained within a continuous space. In the everyday adult understanding, this external reality exists independently of human attention or action. For example, if an adult sees an object hidden, the adult believes that that individual object continues to exist in its hidden location even when the observer has left the vicinity. Thus the adult's understanding of the external world is one that maintains both the existence and the identity of objects in space over time.

Do infants share this view of the world, and if so, from what age do they share it? Four positions have been articulated. First, some theorists hold that knowledge of object permanence either is an innate endowment or is attained in the first 2.5 months of life (Aguiar & Baillargeon, 2002; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Spelke & Hespos, 2001). The support for this view relies on studies in which young infants increase their looking time if occluded objects do not reappear where or when they are expected. It is argued that infants show prolonged looking to these events because their expectations, based on permanence, were not fulfilled.

Second, dynamic systems theorists argue that invoking object permanence to explain infant responses to hidden objects is unnecessary (Thelen, Schöner, Scheier, & Smith, 2001). They prefer to describe the dynamics of the behavior and the tasks that elicit it, rather than to ascribe underlying concepts to the infants. Infants' preferential looking in the first half year of life (Thelen & Smith, 1994) and their manual search when they are older (Smith, Thelen, Titzer, & McLin, 1999) are said to emerge from the interaction of more basic processes such as attending, reaching, and remembering, rather than from representing an object in its invisible place.

Third, identity-development theorists propose that infants' notion of object permanence develops during infancy and is not innate (Meltzoff & Moore, 1998). It develops out of a prior understanding of object identity (Moore & Meltzoff, 1999). Object identity is said to precede object permanence because infants must be able to re-identify an object as the same one seen previously in order to derive permanence from their experience with the world. Unless the disappearances and reappearances of an object are interpreted as involving a single individual, these experiences cannot be used to develop the notion that the object continues to exist *during the occlusion interval*. In this view, infants develop a notion of permanence to interpret what happens between visible encounters with objects that are re-identified as "the same one again."

Fourth, there are a number of developmental theorists who argue that permanence is a useful concept and not innate but that it emerges from something other than object identity. The "something other" is characterized in different ways by different theorists and includes: (a) coordination of action schemes with each other (Piaget, 1952, 1954); (b) graded strength of object representations (Mareschal, 2000; Mareschal, Plunkett, & Harris, 1999; Munakata, 2001; Munakata, McClelland, Johnson, & Siegler, 1997); (c) coordination of action and representation (Berthier, DeBlois, Poirier, Novak, & Clifton, 2000); and (d) growth in spatial understanding (Bremner, 1989; Campos et al, 2000; Newcombe & Huttenlocher, 2000).

Despite the interpretive differences, the empirical methods used by these four camps have much in common. Studies of permanence are typically conducted within one spatial setting, with occlusion periods ranging from fractions of a second to at most a few minutes. Object visibility is manipulated while the infant remains fixed in one locale, the test room. Thus, an object's

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This work was supported by Grant HD-22514 from the National Institute for Child Health and Human Development. We gratefully acknowledge the assistance of Calle Fisher, Craig Harris, and Dawn Kragness for help on this research project and thank the parents and children who participated in these studies.

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permanence may be put in doubt by a hiding, but permanence of the spatial setting is preserved through unbroken perceptual contact. Similarly, studies of spatial understanding typically require infants to move or observe movement after objects are hidden, but contact with the environmental frame is perceptually maintained throughout (Acredolo, 1985; Bremner, 1978a; Newcombe & Huttenlocher, 2000). Obviously, the mature adult conception of permanent objects in a stable world is far richer than that tapped by these approaches. For the adult, absent objects continue to exist in their hidden locations for days or longer, after all forms of perceptual contact with the original locale have been severed.

One could wonder, then, whether all previous infant studies on object occlusion have investigated a form of permanence that applies only if the setting remains constant between object disappearance and reappearance. Such "situational permanence" might enable infants to maintain the invisible existence of objects in the currently perceived spatial surround but be unavailable once infants are separated from that surround. In short, it is still an open question whether infants' notion of permanence is restricted to interpreting events occurring in the present visual field or reflects the deeper understanding that hidden objects continue to exist in the external world even after infants have left the locale and until they return there at a subsequent time. Such independence from constant perceptual contact is the essence of object permanence as understood and used by adults in everyday life.

The study reported here sought to distinguish these alternatives by asking the following question: Can infants watch an object being hidden, leave that locale, and return 24 hr later to find that same object? The current experiments differed from those traditionally conducted in two respects. First, infants were removed from the locale after witnessing the object disappearance. Second, the delay was far longer than the delay typically used. A delay of 24 hr was inserted between the object's disappearance and when search was first allowed. Infants simply observed the hiding on Day 1 but were not allowed to search. They were carried out of the room and only returned the next day. Given that infants had to sleep before returning, there would be no directly perceived continuity of object, space, or time to link the disappearance on Day 1 to the setting on Day 2. Situational permanence alone would not suffice to locate the hidden object. If infants were able to find it, this would suggest that they treated the hidden object as independent of perception and as enduring in space over time.

Infants' ability to remember the location of a hidden object and find it after a substantial break in contact raises theoretical issues regarding memory, identity, and spatial understanding.

Memory for hidden objects. Most current estimates of how long after disappearance infants can initiate search for a hidden object rely on studies of Piaget's (1954) A-not-B error, and the results suggest a short retention interval (Diamond, 1985; Fox, Kagan, & Weiskopf, 1979; Gratch & Landers, 1971; Harris, 1973). In this task, after infants find an object hidden at one place (A), they see it hidden at a new place (B). If a delay ensues before they are allowed to search at B, they often return to A—which is sometimes interpreted as indicating that they forgot the object's new location at B. Diamond (1985) found a strong correlation between age and the length of delay that could be tolerated before infants produced the A-not-B error. For example, the mean lengths of delay that could be tolerated before erring by 8-, 10-, and 12-month-olds were, respectively, 3.2, 8.0, and 10.6 s. Moreover, Diamond (1991) noted that if the delay is lengthened a few seconds beyond the level at which the A-not-B error occurs, infants err even on the initial trials at A. Thus, for hidings at A alone, the delays that can be tolerated are still thought to be relatively short, even though the hiding is in only one place and issues of habit memory and response inhibition do not arise.

The memory question has also been addressed using nonsearch analogues of the hiding-at-A test. For example, Baillargeon and colleagues used a looking-time procedure with 5- to 8-month-olds. Although the delays infants could tolerate were longer than Diamond (1985, 1991) reported, they were still of short duration, ranging from about 70 s up to 3–4 min (Baillargeon, DeVos, & Graber, 1989; Baillargeon & Graber, 1988; Luo, Baillargeon, Brueckner, & Munakata, 2003). McDonough (1999) examined memory for an occluded object using a nonsearch action measure (in this case, the general left–right direction of infants' reaching after the delay) and found that 7.5-month-olds succeeded after delays of 60 s. McDonough attributed these delays, which were also longer than Diamond's (1985, 1991), to the fact that the liberal criterion of "reach direction" avoids the need for means–ends recovery procedures.

The foregoing delay intervals are markedly shorter than those used with other assessments of infant recall memory at similar ages. For example, studies that investigated retention using deferred imitation (Hayne, Boniface, & Barr, 2000; Klein & Meltzoff, 1999; Meltzoff, 1988b) have documented recall memory after delays of 24 hr and longer at 6, 9, and 12 months of age. One difference between the deferred-imitation and the object-occlusion procedures is that the former involves recalling an *action* to perform on an object, whereas the latter involves recalling an object's hidden *location*. Another difference is that the deferred procedures involve cued-recall memory. The object serves as a cue for an action that is no longer present. This suggests that it may be helpful to use cued recall in the object hiding case. One way of accomplishing this would be to use the object's characteristic sound to provide an auditory reminder. In the present study we took advantage of this idea.

Object identity. For the adult, an object's numerical identity and its spatial history are inextricably intertwined (Campbell, 1994; Strawson, 1959).[1] When adults search for a hidden stationary object, they typically search in the same locale in which it

[1] Philosophers distinguish two meanings of the phrase *object identity* (Strawson, 1959). One is called *numerical identity* and refers to an object's being the self-same individual over time. The primary way of knowing that an object at one point in time is numerically identical to an object perceived at another point in time is by tracing the object's spatiotemporal history: If it is in the right place in space, it is the numerically same object (the same individual encountered again). The other type of identity is called *qualitative identity* or *featural identity*. The primary way of detecting this is by appearances. Many different Coke bottles share the same qualitative identity—they look the same. They form a category, in which the multiple exemplars are highly similar. Each exemplar of a category is a numerically different object but all the exemplars share a qualitative identity (for further discussion, see Meltzoff & Moore, 1998).

disappeared because they seek the specific individual they saw disappear. A featurally identical object in another place would only be accepted as the same one if it had been moved; otherwise it would not be the one they were looking for, and search would continue. In short, adult search is guided by the numerical identity of the object. The object that the adult seeks in an object-hiding situation is the one that was hidden, not any object that happens to look like it.

Is infant search similarly guided? If it is, then leaving the locale of the object's disappearance and returning after a significant delay immediately raises the issue of numerical identity. If the locale is the same, the stationary object hidden on Day 1 could be found there; but if the locale is different, then there should be no expectation that the object can be found there. To test this idea, we used a "room-change" condition and altered several factors specifying the original locale of hiding. Thus, if infants were seeking the individual object hidden in the original locale, they should not search in the room-change condition—if the room is a different room, there is no reason to search there for that particular object.

Spatial understanding. Leaving the locale of an object's disappearance poses a challenge to spatial understanding. How would one know if one had returned to the original locale? Research on spatial understanding has focused on discovering the factors that infants use to code locations in space "objectively," that is, independent of the viewer's perspective. Such coding allows infants to move or be moved within a locale while maintaining the location of a particular object. Research has illuminated at least three major aspects of infants' developing spatial understanding: landmark cues, the overall shape of the environment, and route or path information.

Infants' understanding of landmarks undergoes developmental change. The earliest form of externally referenced location coding is cue learning (e.g., the color or pattern of the screen that occluded the object); this is effective enough for 9-month-olds to search correctly when they have been moved after watching an object hidden under distinctive screens (Bremner, 1978b). With development, spatial coding begins to take into account landmarks in the environment (Acredolo & Evans, 1980; DeLoache & Brown, 1983), that is, perceptually distinctive, fixed elements of the locale. Because an object's location can now be coded relative to landmarks, this affords accurate search after movement even when the object is hidden by identical occluders or in an unmarked location (Newcombe, Huttenlocher, Drummey, & Wiley, 1998). It has been reported that landmarks are more effective when they are immovable characteristics of the environment, such as a built-in bookcase (Newcombe & Huttenlocher, 2000, p. 118). This implies that toddlers are beginning to differentiate and rely on certain aspects of the external environment as being more stable and reliable markers of location than others (e.g., bookcases, in contrast to movable objects such as toys, bottles, and curtains).

The overall shape of the space in which an object is hidden is also important. For example, 21-month-olds who were purposely disoriented after seeing an object hidden in the corner of a room searched systematically when the test room was rectangular but not when the room was square (Hermer & Spelke, 1996; Wang, Hermer & Spelke, 1999). This suggests that infants included the left–right relationship of the long and short walls in their spatial coding of the hiding place's location. Learmonth, Newcombe, and Huttenlocher (2001) also examined this sensitivity to asymmetric room shape with 20-month-olds and showed that it is used, in conjunction with landmarks, to code location in living-room-sized environments.

Research also indicates that path information is taken into account when locating objects in global space. In one study, infants were shown an object in a room and then were walked into an adjacent room and prompted to point straight to the object. Next, they were encouraged to find the object. Although all age groups searched correctly by retracing their path to the object's room, 12-month-olds did not point under any condition. Fifty percent of 18-month-olds and 100% of 24-month-olds pointed to the doorway, back along the path they had taken in leaving the object. Still older children (30- to 48-month-olds) pointed directly through the wall to the object (Rider & Rieser, 1988). These results suggest that infants 12 months and older remember route information; they could retrace their path between rooms to find the unseen object and by 18 months of age could even point back along the path to reach it.

The current study used a broad array of factors that might prompt infants to recognize a previously visited room and remember the hiding place within. Because previous research suggested that incidental observation of landmarks, room shape, and path can inform the spatial understanding of 2-year-olds, we thought that more explicit procedures might help younger infants. In the design used here, attention was repeatedly and explicitly focused on these three factors as a way to help toddlers recognize the test room and locate the hiding place after the memory delay.

In Experiment 1, we examined whether 14-month-olds treat an object as enduring in space after they leave the locale in which it disappeared. The results showed that infants searched for the absent object after a 24-hr delay. In Experiment 2, we investigated the boundary conditions for this long-term object location memory. In this experiment, three major spatial characteristics of the room were changed (landmarks, room shape, and path). The results showed that infants in the room-change condition did not search for the object in the hiding place (even though the actual hiding container was in full view), whereas infants in the same-room condition succeeded. Implications are drawn for theories of infant memory, spatial understanding, object permanence, and object identity.

EXPERIMENT 1: LEAVING THE DISAPPEARANCE LOCALE

In this experiment, we tested whether 14-month-old infants could remember an object's hidden location 24 hr after they left the locale in which it disappeared. Memory was assessed by accurate manual search on Day 2. To aid recognition of the locale, salient room characteristics were pointed out on Day 1 and again on Day 2. To help specify the location of hiding, the object was hidden in a large, immovable structure jutting prominently into the testing room. There was no familiarization play with the hiding places before the hiding to ensure that infants could not simply be repeating practiced responses.

Method

Participants

The participants were 48 typically developing 14-month-old infants (mean age = 13.99 months, *SD* = 0.13 months). Half of the participants were female. They were recruited by telephone from the University's computerized participant pool, which contained names of families who had returned a recruitment card soon after the birth of their child. Preestablished criteria for admission into the experiment were that infants have average birth weight (2.5 to 4.5 kg) and length of gestation (40 ± 3 weeks), have no known visual, motor, or mental handicaps, and have at least one parent who spoke English at home. Forty-six of the participants were White; 2 were Hispanic. All of the participants came to the laboratory without siblings so as to avoid distractions. Four additional infants were tested but dropped from the study because of experimenter error (3) or uncontrolled coughing for more than half of the response period (1).

Test Environment and Apparatus

Testing took place in a room furnished with a couch, chairs, and a large table (see Figure 1). The table was covered from the top to the floor with a solid blue cloth so that it appeared to be one large mass in the corner of the room; as described below, the hiding location was part of this structure (see shaded portion of Figure 1). Several special room features were shown to the infants: (a) a mobile with five dangling bears that was suspended over the table 75 cm below the ceiling, (b) a colorful poster of a frog, and (c) a Tiffany-style lamp. The room was also decorated with other colorful children's pictures.

Three cameras videotaped infant reactions. Two cameras provided wide-angle views of the entire room: one from the corner behind the hiding places directed toward the infant, the other from behind the infant directed toward the hiding places. The third was hidden under the table to give a close-up view of the infant when he or she was searching in the hiding place. A character generator electronically timed the experiment and inserted synchronized time on all three video records. It also provided electronic timing of the response periods.

Test Materials

The object hidden during the memory test was a silver handbell (9.5 cm tall; bowl diameter = 6.5 cm). The hidings occurred in two places: (a) the *cupboard*—a small, brown Avanti refrigerator (46 × 46 × 46 cm) that was set flush against one end of the table with its rear edge obscured by the table's cloth covering (its hinged door opened in typical refrigerator style) and (b) the *box*—a 28 × 20 × 11.5 cm box secured to the top of the cupboard. The front side and the top of the box were attached to each other and could be rotated upward in one piece to completely reveal the inside of the box. The cupboard was fixed to the floor, and the box was secured to its top surface. The contiguous complex of the table, the cupboard, and the box protruded into the room (see Figure 1, shaded portion) to provide fixed hiding places that were part of the room's spatial structure.[2]

Design

The study used an independent groups design, with random assignment of participants to three groups. Infants in the *experimental (object hidden)* group (n = 24) played with the bell and saw it hidden in one of two locations on Day 1. Two hiding locations were used to assess search accuracy. This group returned after a 24-hr delay for the memory test. Infants in the *baseline control* group (n = 12) did not come to the laboratory on Day 1 and were treated identically to the experimental group on Day 2. Infants in the *occluder-manipulation control* group (n = 12)

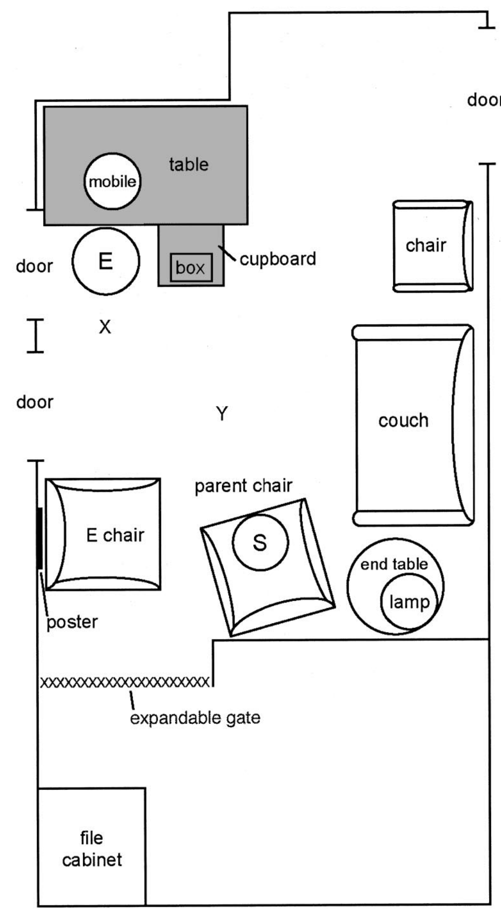

Figure 1. The test room used for the memory test. The test object was hidden in the cupboard or the box as the infant watched from across the room. The cupboard was fixed on the floor, and the box was permanently attached to its top surface. The shading on the table, the box, and the cupboard denotes their appearance as a massive and spatially contiguous whole. E = the experimenter's position when presenting the object hidings. S = the infants' position as they observed the hidings and at the start of the memory test on Day 2. X and Y are locations on the floor where certain events were presented in the course of the procedure (see text for details). Several salient features of the test room were altered for infants assigned to the room-change conditions (see text for details). The figure is drawn to scale; see text for physical dimensions.

[2] The design of the hiding places was based on empirical and theoretical considerations. Our pilot work showed that it was difficult to elicit 24-hr recall in 14-month-olds for objects hidden on the floor under freestanding containers. This is understandable within the framework developed by Moore and Meltzoff (1999), who argued that for young infants, a stationary object that is hidden resides in the *same* place in which it disappeared. Hidings under movable boxes on an unmarked floor could cause problems for infants in identifying what is the same place. In the current study, the hiding place was inside an immovable mass that was part of the room's spatial structure and thus a fixed location. This immovable mass could also aid in identification of the locale as the same place again (which is related to the issue of what makes an effective landmark; see Newcombe & Huttenlocher, 2000, p. 118, and Pick, Montello, & Somerville, 1988, p. 373).

played with the bell on Day 1 and saw the container door opened and closed, but the bell remained visible and was never hidden. They returned after the 24-hr delay and were treated identically to the experimental group on Day 2. Sex of infant was counterbalanced within each group. The use of the box or the cupboard as the hiding place was counterbalanced for the experimental (object hidden) and occluder-manipulation control groups.

Procedure

Day 1: Pretreatment Procedures

The procedure began by placing the infants on their parents' lap on the end of the couch closest to the end table (see Figure 1) and giving them a toy telephone to play with, while the experimenter sat in the chair facing them across the room. The experimenter talked to the parents about the general goals of the study while allowing the infant to acclimate. A structured series of five activities then ensued, with two goals: (a) familiarizing the infants with the room, the experimenter, and how he behaved and (b) having the infants encode a broad array of cues that might enable recognition of the room and the experimenter on Day 2. The activities included (a) focusing attention on salient features of the room, (b) playing a peek-a-boo game with the experimenter, (c) refocusing attention on the features of the room, (d) playing an interactive game with the experimenter, and (e) watching a warm-up disappearance event. This list was extensive in hopes of including any objects, events, or practices that might jog the infants' memory when they returned on Day 2. Further research will be needed to isolate the minimum set necessary to sustain successful search over a 24-hr delay.

(a) Focusing attention on features of the room. While parents filled out consent forms and asked questions about the upcoming study, the experimenter drew the infants' attention to the irregular shape of the testing room. He did so by talking to the infants while he went through the open doorways opposite the couch (see Figure 1). These doorways provided a view of two further rooms whose combined size was approximately equal to the test room itself. Next he drew attention to several special features of the test room by pointing and naming each and associating a distinctive vocal or physical gesture with it. The experimenter walked over to the corner of the room with the bear mobile (see Figure 1) and said, "Have you seen my bears? These are dancing bears," while he spun the mobile and made dancing movements. This was repeated three times. If infants later pointed or vocalized toward the bears, he said, "Yes, that's the bears," and put them in motion if they had stopped rotating. Next, he walked to the frog poster and pointed to it and said, "This is Froggie. Do you know what frogs say? They say rrrribbit. That's what Froggies say." This was repeated three times. If infants later pointed or vocalized to the frog, the experimenter said, "Yes, Froggie says rrribbit." He then walked to the lamp and said, "Let's turn on the lamp, click, click, click," while turning the three-way switch of the lamp, and then he said, "Let's turn off the lamp, click click click," while turning the switch again. This was also repeated three times and confirmed with "Yes, that's the lamp" if an infant later pointed or vocalized to the lamp. The repetitions were conducted with the goal of helping infants extract the three special room features while defining the experimenter's role as one who points them out. This entire procedure was then repeated in the same order.

(b) Peek-a-boo by the experimenter. The experimenter then returned to his chair and began playing a peek-a-boo game to provide a distinctive experimenter characteristic that was tied not to the room context but to his activities. He held a towel in front of his face and said, "Where's [infant's name]?" and then reappeared saying "peek-a-boo." This was done four times, with reappearances at each edge of the towel.

(c) Refocusing attention on the room. Parents picked up their infants and walked around the room with the experimenter as he pointed out the features again, and this time the infants were moved close enough to pet the bears, touch the frog, and touch the butterfly patterns on the lampshade.

(d) Interactive games. The experimenter then sat on the floor (see Figure 1), and the infant was seated opposite him on the floor. The experimenter and the infant played with rings from a stacking ring set. When the infant would willingly give the experimenter a ring, the infant was moved to his or her parent's lap on the chair (see Figure 1, S position). The experimenter then took out a small rubber baby doll (10 cm tall) and said, "Look who's here. It's a baby. The baby says squeak, squeak, squeak. The baby's favorite game is peek-a-boo." He then hid the baby on the floor in front of him (see place X in Figure 1) by covering it with a terry cloth washcloth in a series of three disappearances and two reappearances, saying "peek" at each disappearance and "a-boo" at each reappearance. Then the parent lowered the infant to the floor and the infant was allowed to crawl across the room to retrieve the baby. These games were designed to help the infants feel comfortable interacting with the experimenter and moving around the room.

(e) Towel-covering event. The infant was returned to the parent's chair, and a rattle was brought out (a blue plastic 6-cm cube with three multicolored rings attached to one face). The experimenter hid the rattle on the floor (see place X in Figure 1) using a half-folded hand towel, unfolding it toward the infant and over the rattle in a series of three disappearances and two reappearances. He said "Look" at each disappearance and each reappearance. Infants were not allowed to search for the rattle. This procedure allowed the towel to be folded back and the rattle revealed on Day 2 during the room acclimation phase. We thought that revealing the rattle might serve to reinstate memories from the previous day. Hildreth and Rovee-Collier (1999) reported that 12-month-olds used such priming cues even after an 8-week delay. Our hope was that uncovering the rattle might also remind infants that things were still where they were last left.

Day 1: Experimental (Object Hidden) Group

Infants in the experimental group remained on the chair, and the test object (the bell) was brought out while they were looking at the bears. The experimenter demonstrated three distinctive ways to ring the bell (banging on the floor at place X, rapid hand jiggles, and 90° arm rotations from the elbow) while saying "Listen!" and "Ding-a-ling, ding-a-ling." Then he gave it to them. After the infants were given a short time to play with the bell, the object was retrieved and the experimenter again rang it in the three ways. Then the experimenter placed the bell visibly on the floor 90 cm in front of the containers (see place Y in Figure 1) and showed the infants how to open and close the predesignated container once.

The critical test event was the object occlusion. The experimenter occluded the bell by opening the container, picking up the bell and placing it inside, and then hiding it by performing a series of three closings and two openings of the container, saying "Look" at each one. To ensure that infants attended, the experimenter tapped on the container's door before moving it. Before each closing, the experimenter rang the bell, tapped it on the surface inside the hiding place, and pointed to it as it sat there. In terms of Moore and Meltzoff's (1999) classification of object occlusions, this is a total occlusion of an object in place by movement of an occluder (a "hiding-by-screen"), which yields highly successful search in 14-month-olds (approximately 80% success according to their data).

Infants were not allowed to search. After the hiding was complete, they were given a distracting toy (a television remote control) and were carried outside of the test room by their parents, where the toy was retrieved from them.

Day 1: Occluder-Manipulation Control Group

Infants in this group were treated identically to the experimental group in every way except that they did not see the object hidden. As with the experimental group, the experimenter demonstrated how to ring the bell in three distinctive ways. He then placed the bell on the floor 90 cm in front of the containers (see place Y in Figure 1) and showed infants how to open and close the container once. The only difference between this group and the experimental group was that for the occluder-manipulation control group the bell remained visible as the experimenter performed a sham hiding. This was done by opening the container, picking up the bell from the floor, and then performing a series of three closings and two openings of the container and saying "Look" at each one. To ensure that infants attended, the experimenter tapped on the container's door before moving it. Before each closing, he rang the bell, tapped it on the floor, and pointed to it as it sat on the floor.

Infants were not allowed to search. After the opening/closing event was complete, they were given the distracting toy and carried outside by their parents, where the toy was retrieved.

Day 2: Preassessment Room-Reminder Procedures

On Day 2, the room was arranged identically for all groups. The test object, the bell, was removed from the scene before the infants entered the test room so that it could not be seen or found inadvertently. Thus, for the experimental (object hidden) group, the bell was removed from its hidden location (inside the box or cupboard), and if infants correctly searched, they would not find the bell and their reactions could be monitored. Similarly, for the occluder-manipulation control group, the bell was removed from the floor.

The infants in all groups were treated identically. The infants were carried in and seated on their parents' laps on the couch, and, following the procedures of Day 1, they were given the toy telephone and faced the experimenter in his chair. The experimenter then instituted a structured series of three events from Day 1 to remind the infants about the room and the experimenter. This series of reminder events typically took 8–10 min. (To prevent infants from ranging around the room and perhaps playing with the hiding containers, the activities labeled earlier as "interactive games" were not used as reminders.)

(a) Reminder of the experimenter's peek-a-boo game. After a brief period of adjustment, the infants' attention was drawn to the experimenter, and the peek-a-boo game was played as on Day 1. This was done first to put the infants quickly at ease, because infants almost universally like the peek-a-boo game and it would serve to remind them that they had seen and played with the adult before.

(b) Reminders of room features. The experimenter next drew the infants' attention to the three special features of the room, which had been pointed out on Day 1. To emphasize the room and its features, rather than a simple repetition of experimenter behaviors, attention was drawn to the room's features in a different order than on Day 1. The experimenter began by pointing to the frog poster and saying, "Remember the froggie, he goes rrrribbit." This was repeated three times. He then walked to the bear mobile and said, "Remember the bears," as he put it in motion and made dancing movements. This was repeated three times. He then walked to the lamp and said, "Remember the lamp, it goes click, click, click," as he turned it on. This too was repeated three times. Finally, as had been done on Day 1, infants were picked up and carried around the room to touch the bears, frog, and lamp.

(c) Towel-uncovering event. Next the experimenter sat on the floor as he had on Day 1. The parents were instructed to hold their infants and turn 180° away from the experimenter so that the parents' and infants' backs were toward the experimenter. Thus obscured from view, the experimenter said, "Listen!" and shook the rattle repeatedly (for 20 s). The parents were then instructed to turn around and seat their infants on the edge of the chair, facing the experimenter (see S in Figure 1). The experimenter then asked, "What did you hear?" and slowly uncovered the rattle as the infants watched. He shook it and gave it to them. When they were satiated with the rattle, he placed it on the table behind him.

Day 2: Memory Test

The infants were then turned away from the experimenter, as before. The experimenter, while seated in his position on the floor, rang the bell in front of him for a 20-s stimulus-presentation period. The bell was rung in three different ways, as had been done on Day 1. This was the cue for the subsequent recall test. As the experimenter rang the bell he said, "Listen!" and "Ding-a-ling," as had been done on Day 1. The bell was then silenced and put out of view (behind his back), and the infants were turned around to sit facing the experimenter on the chair.[3] The experimenter asked, "Where is the bell?" Parents then lowered their infants to the floor in front of the chair, and a 180-s response period was timed, beginning when the infants' feet touched the floor and ending when 180 s had elapsed. Parents were instructed not to point or verbally indicate where to search; the experimenter used "Where is the bell?" and "Ding-a-ling" as verbal encouragements.

Day 2: Object-Visible Test

After the memory test ended, infants were given a second 180-s test. For this period, the bell was visible on the floor in order to monitor infants' reactions to seeing it again. Recall that the object had been removed from its hiding place, and thus no infants, even those who searched correctly, had yet recovered the object. To initiate this trial in a standard fashion, we seated infants on the parents' chair. Their attention was attracted to the bear mobile, and the bell was surreptitiously and silently brought out from behind the experimenter's back. The experimenter then attracted the infant's attention and rang the bell in its distinctive fashion for a 20-s stimulus-presentation period. He then put it on the floor in place X in full view of the infant (see Figure 1). Parents lowered their infants to the floor in front of the chair, and a fixed response period was timed, beginning when their feet touched the floor and ending when 180 s had elapsed.

Scoring Procedures

The video records of the 48 memory-test periods and the 48 object-visible periods were scored in two separate passes through the videotapes, each in a random order. The hiding event was not visible on the videotape, and there was no artifactual information on the videotape as to the infants' test condition or where the object had been hidden. Each video segment was 180 s in duration and began in an identical way, with an infant being placed on the floor facing the containers. The scorer was naive to the structure of the experiment and to the hypotheses, and she scored the tapes without listening to the sound track. The scorer recorded a dichotomous yes/no judgment as to whether the box or cupboard was opened and the direction of the infants' gaze as opening began. These scores were the main data analyzed.

Operational Definitions

Successful search during the memory test was defined as opening the container in which the object had been hidden and looking with visual

[3] It is common to use sound-making toys in object permanence tasks. Rattles and other noise-making toys are used to gain infants' interest before hiding them, and toys are often tapped on a surface before the occlusion event. For some studies, the sound continued after the occlusion and during the response period (Baillargeon, 1986, Footnote 2; Clifton, Rochat, Litovsky, & Perris, 1991; Meicler & Gratch, 1980). In the current study, sound was only used before the hiding; no sound was made during or after the occlusion event on Day 1. On Day 2, the object's sound was produced *before* the memory test began. Thus, the object's sound served only as an auditory reminder, as is standard in classic cued-recall paradigms.

expectation to the bottom surface where the object had been placed. To count as successful, the first opening had to be at the correct place. *Opening* was defined as a manual act that rotated the box lid or cupboard door 30° from its closed position, which was enough to see inside. *Visual expectation* was defined as gaze directed to the bottom surface inside the box or cupboard simultaneously with the opening (*simultaneously* was defined as occurring during the interval beginning when the occluder first moved and ending when rotation attained 30°).

Pilot work had revealed that when infants did not find the object in the hiding place and it was subsequently presented, they often searched in the hiding place again. To quantify this behavior in a rigorous way, we operationalized a new measure. *Verifying search* during the object-visible test was defined as opening the relevant container with simultaneous visual expectation (as defined above). Each instance of such search was tallied. (To count as a second instance, the occluder had to be fully closed and then reopened beyond the 30° criterion.)

Scoring Agreement

Scoring agreement was assessed by using a randomly selected 20% of the trials that had been scored by both the principal scorer and a second scorer (who was also naïve to the hypotheses and test conditions). For the memory test, there were no intrascorer or interscorer disagreements on the search measure. For the object-visible test, the intra- and interscorer kappas were .91 and .82, respectively, on the verifying search measure.

Results and Discussion

Memory Test

Table 1 displays the number of infants demonstrating successful search for the hidden object as a function of group. For the experimental group, 54.2% (13 of 24 infants) searched in the container where they had seen the bell hidden 24 hr earlier, and all 13 did so with visual expectation directed to the bottom surface, inside the container, where the object had disappeared. For the groups who did not see the bell hidden on Day 1, the corresponding data were 16.7% for the occluder-manipulation control group and 0% for the baseline control group. A 2 (experimental/controls) × 2 (yes/no) contingency table indicated that significantly more experimental infants than control infants performed successful search, $\chi^2(1, N = 48) = 9.70, p < .01$.

The spatial accuracy of infant memory can also be examined. Search failures could be due to search in the box when the object was actually hidden in the cupboard (or vice versa) or to no search at all. Table 2 displays the relevant data. No infants searched in the wrong container. Thus, search was quite specific—it was occurring neither in a general direction from the infant nor in a general area of the room inasmuch as such memories would have produced search in the wrong container as often as the right one.

Table 2
Experiment 1: Number of Infants in the Experimental Group Searching a Hiding Place as a Function of the Place the Object Was Hidden

	Place searched		
Place hidden	Box	Cupboard	Neither
Box	5	0	7
Cupboard	0	8	4

Object-Visible Test

For this test, the object was visibly presented to the infants on the floor, and a 180-s response period was timed. Table 3 displays the number of infants who locomoted across the room while the object was in view and opened its previous hiding place with simultaneous visual expectation, which we call *verifying search*. In the experimental group, 66.7% of the infants performed verifying search, versus 16.7% in the occluder-manipulation control group and 0% in the baseline control group. A 2 (experimental/controls) × 2 (yes/no) contingency table indicated that significantly more experimental infants performed verifying search than control infants $\chi^2(1, N = 48) = 15.02, p < .01$.

Of the 16 infants in the experimental group who made a verifying search, 12 had searched in the memory test; the 4 additional infants had not searched but were apparently prompted to do so when presented with the visible object. Verifying search acts were frequently repeated. For these 16 infants in the experimental group, the mean number of verifying searches was 2.56 (range = 1–6). Most infants not only opened the container with visual expectation but also put the object on the inside floor of the container or touched it there (14 of the 16 infants did so).

This behavior of repeatedly searching in the hiding place when the originally hidden object is visible has not been reported before in the literature and is quite striking. The infants have the desired bell in sight or in hand, and yet they locomote to the place where it had previously been hidden 24 hr earlier, look inside, and often put it there.

In sum, 14-month-olds were able to successfully recall the object's hidden location 24 hr later. Although the experiment did not identify which aspects of the test environment and procedure were necessary for such long-term recall, a recent study of 14- to 25-month-olds provides an illuminating contrast (Russell & Thompson, 2003). In that study, objects were hidden on the floor in two or three movable boxes distinguished only by color; no landmarks or room features were explicitly pointed out. Only

Table 1
Experiment 1: Number of Infants Performing Successful Search as a Function of Group

Group	Yes	No	% Yes
Experimental (object hidden)	13	11	54.2
Occluder-manipulation control	2	10	16.7
Baseline control	0	12	0.0

Table 3
Experiment 1: Number of Infants Performing Verifying Search as a Function of Group

Group	Yes	No	% Yes
Experimental (object hidden)	16	8	66.7
Occluder-manipulation control	2	10	16.7
Baseline control	0	12	0.0

children in the oldest group (22 to 25 months of age) demonstrated significant recall after a 24-hr delay. This is consistent with our independent pilot work (see Footnote 2) and work by DeLoache and Brown (1983), who found that children between 24 and 29 months of age could use incidental observation of a landmark to recall the location of objects hidden in identical, movable containers over 5-min delays, whereas younger children could not. In light of these studies, we suggest that our findings of successful search by 14-month-olds after a 24-hr delay were fostered by (a) a fixed hiding place forming part of the spatial structure of the room and (b) explicit reminders about features of the room.

EXPERIMENT 2: RETURNING TO THE SAME OR A CHANGED LOCALE

In Experiment 1, we found that 14-month-old infants could remember a hidden object's location after a 24-hr delay. Their manual search was spatially accurate, and they also directed visual expectation to the place inside the container where the object should have reappeared.

In Experiment 2, we further explored the goal of infants' search. If search on Day 2 was guided by numerical identity—that is, if infants were looking for the particular individual that was hidden on Day 1—then theory provides principled ways to manipulate the situation. Infants should have to return to the same locale to find the same stationary object. If they thought they were in a different locale, there would be no reason to search for the original object. To test this, we instituted a "room change" treatment: Between Day 1 and Day 2, changes were made in the special features of the room, the shape of the room's interior space, and the path taken to it. All other factors remained constant between the treatment groups except for these room changes. For both experimental and room-change groups, the same object was hidden, by the same experimenter, in the same container, and it remained invisible for the same retention interval (24 hr). Thus, ancillary task demands such as object desirability, motor skills, means–ends understanding, and delay were identical for the two groups. A significant difference between the two groups would implicate spatial locale as an important factor in infants' search for hidden objects after a 1-day delay.

Method

Participants

The participants were 48 typically developing 14-month-old infants (mean age = 14.01 months, SD = 0.12 months). Half of the participants were female. The recruitment procedure and the preestablished criteria for admission into the study were the same as in Experiment 1. Of the 48 participants, 33 were White, 5 were Black, 7 were Asian/Pacific Islander, 2 were Hispanic, and 1 was a mix of four ethnic groups. Four additional infants were tested but dropped from the study because of parental assistance during search (1), not watching the complete disappearance/reappearance cycle (1), crying (1), or experimenter error (1).

Test Environment and Apparatus

Infants in the experimental and baseline control groups did not experience any change in the test room between Day 1 and Day 2. The rationale for the study was to introduce a room change between Day 1 and Day 2 for the room-change groups. This was achieved by having the room be different on Day 1 for the room-change groups as compared with the other groups. For all groups, the room was the same on Day 2 as has been described for Experiment 1 except that there were no colorful children's pictures on the walls. (These pictures were not used because they might interfere with the room-change manipulation.)

For the room-change groups, the room's shape was altered between days by closing the doors opposite the couch on Day 1 (making the perceived space nearly rectangular) and leaving them open on Day 2 (approximately doubling the volume of visual space and making it irregular). This manipulation and the experimenter's walking through the open doorways while talking to the infants were designed to direct attention to the changed shape of the testing room's interior space (see Figure 1). The special features pointed out to room-change infants on Day 1 were (a) a duck poster hung on the wall above and at one end of the table, (b) a picture of a baby yawning hung above the other end of the table, and (c) a Playskool Raggedy Andy doll (38 cm tall) that sat on top of the file cabinet at the far end of the room. These features were replaced on Day 2 by the bear mobile, the frog poster, and the lamp. Finally, the toy given to the infants to play with upon first visiting the room was different on Day 1 and Day 2. For room-change infants, an orange rubber cat (20 cm tall), which emitted a two-tone meow when squeezed, was used on Day 1, and the toy telephone was used on Day 2. Aside from these changes, the apparatus, furniture, cameras, timing devices, and the physical room were the same as those in Experiment 1 for all groups.

Test Materials

The test object used for the hiding was a merry-go-round music box activated by pushing a plunger on its top. Once activated, it continued to play a tune for 20 s. We used this new object to gain generalizability and also because, unlike the bell in Experiment 1, it did not have to be shaken and could produce its sound while resting in place. More specifically, the object was a Push n Play Puppies toy (14 cm tall and 11.5 cm in diameter, made by TOMY).

Design

The design was similar to that of Experiment 1 except that infants were randomly assigned to four groups (n = 12 each), and only one container (the cupboard) was used. The experimental (object hidden) group was treated the same as in Experiment 1. The baseline control group came to the laboratory both days and was treated the same as the experimental group except that the test object was never introduced on Day 1. For the two room-change (object hidden) groups, the room shape, the special features of the room, and the path taken to it were experimentally manipulated between Days 1 and 2.

Procedure

Day 1: Experimental Group (Object Hidden)

The preassessment and test procedures were identical to those in Experiment 1.

Day 1: Baseline Control Group

All aspects of the procedure were identical to those for the experimental group except that the test object was not introduced and hidden.

Day 1: Room-Change (Object Hidden) Groups

Previous research suggested that infants are able to use information about the route taken after leaving a desirable object in order to retrace their path (Rider & Rieser, 1988). Thus, to minimize the likelihood that infants would identify the room on Day 2 as the same one visited on Day 1, we systematically changed the path the infant and parent took to and from the room according to the following procedure.

When the parents were on the telephone scheduling their first visit, they were given instructions on the spatial route to follow when bringing their infants from the parking lot to the third-floor laboratory. The route was purposely changed between visits. On Day 1, the room-change-1 group was instructed to go from the parking lot around the outside of the building to reach the entrance lobby. Parents were also instructed to take the stairs to the laboratory. The stairway doors on each landing leading to the third floor were marked with yellow smiley-face dots. Parents were instructed to follow the smiley faces and to take this path upstairs. When the parents were leaving on Day 1, the experimenter pointed out the smiley faces on the third-floor stairway door and encouraged the infants to touch them; then the parents retraced their path back to the parking lot.

The room-change-2 group was handled similarly, but the parents were instructed to take a different path cutting across the parking lot to the building's entrance and also to take the elevator to the third floor. When the parents were leaving, the experimenter pointed out the elevator button and encouraged the infants to push it; then the parents retraced their steps to the parking lot.

Parents in both groups were instructed to return by the other path on Day 2 (thus the stair group took the elevator and vice versa). All infants in the experimental and baseline control groups cut across the parking lot and took the elevator on both days.[4]

Procedures were instituted to ensure that infants noticed the room features that were manipulated between visits. The experimenter drew the infants' attention to the three special features (duck, yawning baby, and Raggedy Andy) in the same manner as in Experiment 1, by pointing to a feature, naming it, and associating a distinctive vocal or physical gesture with it.

Day 2: Preassessment Room-Reminder Procedures

Infants in all groups were treated identically starting from the infants' entrance to the testing room. They all followed the procedures described in Experiment 1.

Day 2: Memory Test

All groups were treated in an identical fashion and followed the procedures described in Experiment 1.

Day 2: Object-Visible Test

All groups were treated in an identical fashion and followed the procedures described in Experiment 1.

Operational Definitions and Scoring

The scoring procedures and operational definitions were identical to those in Experiment 1 but with one additional coding category. To assess whether infants might be put off by meeting a familiar experimenter in a changed environment, we measured their reaction to him. During the preassessment peek-a-boo game, infants' reactions to the experimenter were assessed on a 3-point scale designed to capture recognition/comfort with the experimenter on Day 2. The three scoring categories were as follows: 1 = infants smiled, waved, pointed, and/or vocalized to the experimenter; 2 = infants only looked at the experimenter, showing no other reaction; 3 = infants did not look at the experimenter or showed a negative reaction such as fussing, whimpering, or turning away.

Table 4
Experiment 2: Number of Infants Performing Successful Search as a Function of Group

Group	Yes	No	% Yes
Experimental (object hidden)	7	5	58.3
Room-change-1 (object hidden)	2	10	16.7
Room-change-2 (object hidden)	2	10	16.7
Baseline control	0	12	0.0

As in Experiment 1, both the primary and secondary scorers were kept uninformed about the study and the infants' test conditions. A randomly selected 20% of the trials were rescored to assess intra- and interscorer agreement. For the 3-point reaction-to-the-experimenter scale, there were no intrascorer or interscorer disagreements. For the memory test, there were also no intra- or interscorer disagreements on the search measure. For the object-visible test, there were no intrascorer disagreements, and the interscorer kappa was .89 for the verifying search measure.

Results and Discussion

Memory Test

Table 4 displays the number of infants searching successfully as a function of group. Fully 58.3% (7 of 12 infants) in the experimental (object hidden) group searched correctly, and all did so with simultaneous visual expectation directed inside the container. For the other groups, 16.7% of the room-change (object hidden) groups and 0% of the baseline control group searched successfully. Because more than 20% of the cells in Table 4 have an expected count of less than 5, these data are appropriately analyzed by collapsing the control and room-change groups to yield a 2 × 2 table ($p < .01$, Fisher's exact test).

A global assessment of infants' comfort with the situation on Day 2 was captured by the reaction-to-the-experimenter measure (on a scale from 1 to 3). The results showed that infants in the room-change groups responded no more negatively on Day 2 (22 positive vs. 2 neutral) than did the nonchange infants (21 positive vs. 3 neutral). No infant in any group showed a negative reaction.

Object-Visible Test

As in Experiment 1, the test object was placed on the floor after the memory test was completed, and the 180-s object-visible test was conducted. The measure of verifying search was locomoting to the hiding place and manually opening it with visual anticipation of the object's reappearance place. Table 5 displays the results as a function of group. In the experimental group, 41.7% of the infants made a verifying search in the place they had seen the object hidden 24 hr earlier, versus 8.3% of the room-change groups, and 0% of the control group. These data are appropriately analyzed by collapsing the room-change and control groups to yield a 2 × 2 table ($p < .01$, Fisher's exact test). These results replicate and extend the findings on verifying search from Exper-

[4] When parents arrived on Day 1, before the test began, they were queried as to whether they followed the correct path. All but three parents reported that they did, and those three were not included in the study.

Table 5
Experiment 2: Number of Infants Performing Verifying Search as a Function of Group

Group	Yes	No	% Yes
Experimental (object hidden)	5	7	41.7
Room-change-1 (object hidden)	1	11	8.3
Room-change-2 (object hidden)	1	11	8.3
Baseline control	0	12	0.0

iment 1. The extension derives from the fact that the experimental infants checked in the hiding place not only more than baseline infants but also more than room-change infants, who had seen the object hidden there.

In sum, the results of Experiment 2 are concordant with those of Experiment 1. The memory effect found in Experiment 1 was replicated: 14-month-old infants can remember a hidden object's location after a 24-hr delay. The verifying search effect was also replicated: Significantly more infants in the experimental group than in the other groups searched in the hiding place in the object-visible test. The results of Experiment 2 specify a boundary condition for the memory effect. The effect is driven to baseline levels when the room is changed. Infants in the room-change groups did not search any more than did baseline infants, even though they had, in fact, seen the object hidden on Day 1. There were no differences between the experimental and room-change groups in terms of the hiding. Moreover, the test room was identical for all groups during the memory test on Day 2. The only differences were the changes between Days 1 and 2 in (a) the features of the room, (b) the shape of the room's interior space, and (c) the path taken to the room. The results show that these changes were sufficient to prevent search 24 hr after the hiding occurred.

GENERAL DISCUSSION

In two experiments, we investigated object permanence and recall memory in 14-month-old infants. In Experiment 1, infants watched an object being hidden, left the test environment, and returned 24 hr later to successfully find the object. In searching for it, they not only opened the correct hiding place but also demonstrated visual anticipation of the object's expected reappearance place. The object was not there (because it had been previously removed by the experimenter). Control infants, who saw no object disappearance on Day 1, did not search in the hiding place either in the 24-hr memory test or the subsequent object-visible test.

Two types of control groups were used. The baseline control group showed that infants do not spontaneously search in the closed containers upon entering the room, hearing the sound of a bell (the cue), and being asked "Where is the bell?" No baseline control group infant did so. The second control group, the occluder-manipulation control group, was treated identically to the experimental group in all ways save for seeing the object being hidden. Infants in this control group met the experimenter and played with the bell on Day 1, were shown the special features of the room, and were shown the same number of openings and closings of the containers with bell ringing interposed between each opening and closing. They simply did not see the object hidden in a container. Few of these control infants (2 of 12) searched on Day 2. Thus, these control groups provide a good assessment of whether infants were simply playing with the occluders spontaneously or were remembering occluder actions and performing them whenever the opportunity presented itself. The results from the control groups show that such behavior cannot account for the search exhibited by the experimental group. Taken together, the results for the control groups and the experimental group support the inference that the disappearance of the object was necessary to generate accurate search 24 hr later.

In Experiment 2, we replicated and extended these findings. The extension derived from the fact that two further groups were added that experienced a room change. These room-change infants saw the same hidings as the experimental group but returned to the laboratory on Day 2 via a different spatial path and were brought into a room that had been changed in several salient ways. The actual container where the object had been hidden was still present and unchanged. The room-change infants behaved much like control infants who had never witnessed the hiding: They did not search.

In both experiments, infants were given an object-visible test after the completion of the memory test. For this test period, the previously hidden object was presented visibly on the floor, and a second response period was timed. Infants in the experimental group were significantly more likely than control group infants to engage in what we termed *verifying search*. They locomoted across the room to the hiding place, opened it, and peered inside, even though the object was in full view. They often placed the now-visible object back in the hiding place. These reactions provide further evidence for location memory after a 24-hr delay.

There are four phenomena for which to account: (a) 24-hr memory, (b) successful search for the hidden object after leaving and returning to the same room, (c) no search after a room change, and (d) a new behavior, verifying search, exhibited by infants in the experimental group who, when presented with the test object, searched again in the original hiding place.

Memory

Successful action after a 24-hr delay requires memory, but memory of what? Consideration of the experimental procedures and the nature of the infant's recovery acts suggests that the accurate search consists of more than remembering past motor habits in recovering the object or simply recognizing the hiding place. In both experiments, the hiding events occurred with infants seated well out of reach of the hiding places. Infants were not given any opportunity to manipulate the containers before the hidings occurred. Immediately after the occlusion events, the infants were carried out of the room by their parents. Thus, infants could not be remembering their own recovery acts.

The successful infants did more than simply recognize the container holding the hidden object. They also opened the container and directed their gaze to the place where the object should reappear on the floor inside the hiding place—before they could see inside. In the experimental group, all 20 of the 20 infants who searched in the container did so. Their attention was not attracted to the inside of the container after the opening, but rather they *anticipated* the reappearance location before it was visible, peering inside as opening occurred (see operational definitions). This spatially directed visual expectation suggests that they recalled the *object in its hidden location* before it could have been seen there.[5]

These results show that a representation formed on the basis of an occlusion event can be accessed after a 24-hr delay. This suggests that the short retention intervals previously reported for manual search at one location ("search at A") may not reflect simple retention deficits per se. The myriad accounts for why hidings at A interfere with subsequent search at B in the A-not-B paradigm (Munakata, 1998) do not apply to hidings in a single location; so the short retention spans previously reported for hidings at A present a puzzle for current theories.

The current research suggests an intriguing possibility. It may be critical *when* in the memory cycle the delay is imposed. In the Diamond (1985) study, infants saw the hiding and were then forced to wait (by holding down their hands) before they acted on their representation. Thereafter search was allowed but without any further cuing about the hidden object. In the current experiments, there was a 24-hr delay imposed after the hiding by removing infants from the room. When infants returned on Day 2, they were cued to search by the object's sound. At that point, they were allowed to search immediately. Thus, there was a long delay between the hiding and the recovery act but a short delay between the time when the object's location was (presumably) brought to the infants' attention and when they were permitted to act on that information. We suggest that a representation of a hidden object can be held in memory over long delays at this age but that when it is brought to mind, it must be acted on while it is still the focus of attention. If infants are blocked from acting on this representation, they move on to other things. This could confuse or mask assessments of their retention capacities. (Campos et al., 2000 [see pp. 193–194] made a similar argument about developmental changes in infants' ability to tolerate a delay while keeping a goal actively in mind.)

It is interesting, in this regard, that deferred imitation also uses a cued-recall methodology with a long delay between the demonstration of the to-be-remembered event and the response period but no further delay once the absent event is cued. In deferred imitation, the adult demonstrates an action on an object on Day 1, imposes a lengthy delay, and then re-presents the test object on Day 2 (e.g., Meltzoff, 1988a). The test object acts as a cue for the infant to bring the absent action to mind. There is no delay imposed between showing the object on Day 2 and infants' being able to act on it. Under these circumstances, infants in the same age range tested by Diamond (1985) and in the current study exhibit representation and memory after delays compatible with those reported here, that is, 24 hr or longer (Klein & Meltzoff, 1999; Meltzoff, 1988a, 1988b).

Object Permanence

Dynamic systems theorists have questioned the explanatory value of a concept of permanence and demanded that more general processes be eliminated before concluding that infant search indicates such knowledge (Smith et al., 1999). For example, infants might remove an occluder because they are playing with it, remembering their own prior acts, performing previously rewarded behaviors, or merely acting where their attention had been directed. None of these require a notion of permanence.

To prevent such artifacts in the present study, we used an "observation-only" method to assess object permanence (Meltzoff & Moore, 1998). Infants were brought to a novel, laboratory environment where they observed an object occlusion well out of reach. They received no warm-up trials on the apparatus and were not allowed to search on Day 1. Thus, there was no opportunity to perform acts on Day 1 that would be relevant to search on Day 2. Upon return, no attention was drawn to the hiding place. Therefore, infants had to initiate search based on a representation of the object in its invisible location. Some notion of permanence seems to be required.

The current studies test whether search behavior is limited to "situational permanence" in which infants can act only after short delays and only if they remain continuously in the disappearance locale. The mature adult notion involves being able to break perceptual contact with the disappearance locale and then to return after appreciable delays. The current test used a lengthy delay, and the break in sensory contact after disappearance encompassed not only the object but also the locale of hiding itself. Yet, 14-month-olds searched accurately with appropriate expectation.[6]

The current procedures demand more than the tests of early object permanence that use preferential-looking measures. In those tasks, the events are highly constrained: (a) The duration of the object hiding (e.g., an object disappearing and reemerging from behind a screen) is usually on the order of a few seconds, (b) infants are typically stationary, (c) events occur within a small region in space, and (d) the behavioral responses are differences in eye movements. Of course, such severe constraints are adopted to

[5] Experiment 2 provides further evidence that infants were not just recognizing the container. If correct search reflected only cued recognition of the container, rather than a representation of the object in its hidden location, room-change infants might have performed better. (Note the findings of robust visual recognition memory across context change in infants 9 months and older reported by Hayne et al., 2000; Klein & Meltzoff, 1999; and Rovee-Collier, 1997.) However, the room-change infants did not successfully recover the hidden object. Recognition memory is necessary but not sufficient for the dual data obtained: (a) successful manual search coupled with (b) anticipatory looking inside the container to see the hidden object.

[6] Although the text stresses the maturity of the 14-month-olds' understanding of permanence, we believe there is also further development before they achieve the adult concept. The disappearance transformation used in the current studies was a hiding-in-place by the movement of an occluder, a task that is understood at this age (Moore & Meltzoff, 1999). Disappearances that are understood only later in development (e.g., serial invisible displacements) would not yield successful search after a long delay. Similarly, even though the *existence* and *location* of an invisible object can guide 14-month-olds' search after a significant delay, we do not think this dictates that all attributes of the object are available to the infant while the object is still occluded. For example, it has been reported that it is not until 2.5 to 3 years of age that children use the *solidity* of a hidden object blocking the path of a rolling ball to guide search (Berthier et al., 2000; Hood, Carey, & Prasada, 2000; Hood, Cole-Davies, & Dias, 2003). For further analysis of related developmental changes see Meltzoff and Moore (1998).

enable assessment of visual behavior in very young infants. Nonetheless, it would greatly inform theory building to test whether the looking-time paradigm could be adapted to allow infants to leave the disappearance locale and to assess whether they demonstrated an expectation of the object's continued existence upon return. Infants in the typical looking-time studies may be exhibiting a form of situational permanence that is crucially different from the permanence found here and from that of adults.

Is Room Change Interpreted as a Change of Spatial Locale?

In Experiment 2, we found that infants in the room-change condition did not search successfully on Day 2. The factors experimentally manipulated were the features of the room, the shape of its interior space, and the path by which infants returned to the room. Two accounts are considered here.

One hypothesis derives from the effects of context change on memory. Extensive research with mobile-conjugate reinforcement in young infants shows the importance of context (Rovee-Collier, 1996, 1997). In this procedure, infants are trained to use foot kicks to move a crib mobile, and memory is indexed by the production of significantly more foot kicks than baseline levels of foot kicking. In this work, a change of context as simple as altering the pattern on the crib liner between the training and memory sessions is sufficient to reduce performance to baseline levels. This effect has been widely replicated in 2- to 6-month-old infants over variations in length of delay and conditioning procedures.

In the study reported here, object disappearance in the hiding place was observed in one visual surround, and recall was tested in the same or a different surround. Altering the room's shape and its salient features could remove important contextual cues supporting memory.

The argument must be tempered, however, in its application to the age group tested here. Rovee-Collier and colleagues (Hartshorn et al., 1998) also tested older infants and found an interesting developmental change. Unlike 2- to 6-month-old infants, 9- to 12-month-olds showed robust retention of conditioned responses across changes in context after delays of 24 hr. This comports with findings from studies that used deferred imitation, which showed that context change had no significant dampening effect on recall memory over a 24-hr delay in 12- to 14-month-olds (Barnat, Klein, & Meltzoff, 1996; Klein & Meltzoff, 1999), though it did with 6-month-olds (Hayne et al., 2000). Thus, at 14 months, the age tested here, it is not clear that context change has the same effect on memory that Rovee-Collier (1996, 1997) found with infants 6 months of age and younger; at least, it has not been shown to have this effect in either conditioning or deferred imitation studies.

A second hypothesis, and the one favored here, is that the infants interpreted the context change as indicating that they were not back in the same room. In this view it is not so much that the memory of the absent object is inaccessible but that the sought-for object should not be found in this locale. This is a subtle but important difference. To use an adult example, if I leave a textbook on my bookshelf at work, walk to my car, and discover that I do not have the book, I do not search the trunk. The fact that I do not search in my car is not an indication that the change in context has disrupted my memory for the book or its present location. Rather, the change of context indicates that I am not in a location where the book is. The book is perfectly well remembered and known to be permanent. It is just not present in *this* context. It exists in a different locale.

There are two points congruent with the hypothesis that infants are noticing the change of context and interpreting it as a change of locale. First, research on spatial understanding shows that older infants use the types of spatial factors that were changed between Days 1 and 2 to locate objects within a locale (Newcombe & Huttenlocher, 2000). For 2-year-olds, even incidental observation of landmarks and room shape influences spatial coding (Learmonth et al., 2001). In the present experiments, attention was explicitly and repeatedly drawn to these spatial factors. One can imagine that the spatial relationship among a number of landmarks in an asymmetric environment provides a particular locale's unique "spatial signature," allowing infants to recognize when they are or are not back in the same place again (for relevant neuroscience and adult data see Nadel, Willner, & Kurz, 1985, p. 391; Pick et al., 1988, p. 373).

Second, the most certain way of reidentifying the same place in space is to retrace the steps taken in leaving it. It has been found that 12-month-olds do this when searching for objects in another room after a short delay (Rider & Rieser, 1988). In our study, infant attention was explicitly drawn to route markers on the paths to and from the laboratory (the elevator button and the smiley-face dots on the stairway door) to foster application of such spatial understanding.

The room-change infants were deprived of all three kinds of information about locale (room features, room shape, and path information), and these factors were the only differences between the room-change and experimental infants. The fact that previous work has established that these factors play a role in spatial coding across a variety of tasks and ages suggests that they may be relevant to young infants as well, especially when they are made the focus of their attention, as was done in this study. In short, there is a plausible logic for infants interpreting the changes as indicating a different locale. Moreover, such an interpretation would make sense of the infants' behavior if their goal was to recover the self-same, stationary object that was hidden 24 hr earlier. To do this, they would need to search in the same place the object was hidden. If infants interpreted the locale as a different one, there would be no reason to search (recall the adult example given earlier).

Object Identity

In the course of these experiments, a new behavior was documented that we called verifying search. Recall that in the Day 2 memory test, infants were allowed to search for the bell, but no infant actually recovered it because it had been removed from the hiding place by the experimenter before the test began. This allowed an investigation of infants' responses to the bell when they observed it rung and placed before them in the subsequent object-visible test. The results from this period showed that 67% of the experimental infants (16 of 24) opened the hiding place and peered inside with visual expectation even though the bell was now in full view. Moreover, about half of them did this before they picked it up or played with it (7 of the 16), indicating that the sight and sound of the test object prompted them to recheck the hiding place.

What is striking about this pattern of behavior is that the response was triggered by seeing an object whose features and functions matched those of the sought-for original. But this matching object did not satisfy the infants. They searched again in the hiding place of the original object. Apparently, the object's features or functions do not completely capture what the infants are seeking. Instead, they treat the location of the object's expected reappearance (the place in which it was seen being hidden, i.e., inside the container) as a relevant factor, even putting the object back in that place.[7] One might say that spatial location has priority over object features, inasmuch as infants toddle off to check a spatial location when they have a featurally identical object (in reality, the one that was hidden) in front of them.

This priority of spatial parameters over object features is characteristic of criteria for numerical identity (see Footnote 1), as discussed in both the philosophical (Strawson, 1959) and the developmental literatures. Several investigators have reported that featurally identical objects appearing in different places (or on different trajectories of motion) are often treated as different objects by young infants (Bower, Broughton, & Moore, 1971; Moore, Borton & Darby, 1978; Van de Walle, Carey & Prevor, 2000; Xu & Carey, 1996), which suggests that, at least at some ages, an object's spatial history is a more reliable indicator of its numerical identity than what it looks like. Similarly, young infants do not treat a pre- to post-disappearance change of object features as specifying a different object as long as the altered object reappears where infants expect (Bower, et al., 1971; Gratch, 1982; Newcombe, Huttenlocher, & Learmonth, 1999; Ramsay & Campos, 1978; Van de Walle et al., 2000; Wilcox & Baillargeon, 1998; Xu & Carey, 1996).

Could considerations of numerical identity help account for the verifying search behavior? Our identity interpretation of this behavior is that these infants were searching the disappearance place to check whether the original object was there. This would help them determine if the visible object was the original individual or merely one that looked and acted like it. The numerical identity of the object in sight depends in part on whether there is an object where the original was expected; if looking in that place reveals one, it would suggest that the object in sight is not the original individual. The verifying search behavior suggests that infants were remembering and seeking the particular object that was hidden, in a location determined by their notion of permanence.

The current findings highlight a subtle and interesting relationship between object identity and object permanence. Where to search depends on which individual is sought (Moore & Meltzoff, 1999). If infants were searching for the self-same object they saw disappearing, that would explain why the room-change infants did not search. Because infants' rules for determining a stationary object's numerical identity are primarily spatial at this age, search for an individual would include where that *one* disappeared and, given object permanence, should still be hidden. To find that same object after leaving the disappearance locale, infants must somehow know they are back in the same global space in which it was hidden. If the locale is a different one, there is no reason to search.[8]

This theoretical account of the relationship between search and numerical identity suggests a possible explanation for the differential effects of context change on different measures of long-term recall memory when age is controlled. The current findings show that object search after a 24-hr delay is dependent on returning to the same spatial surround. However, previous research with 12- to 14-month-old infants has shown that 24-hr recall memory is typically independent of the spatial surround when it is assessed by deferred imitation procedures. For example, 12- to 14-month-olds observed an adult demonstrate actions on objects on Day 1 in one room. On Day 2, the objects were offered to the infants for the first time in a different room or even a different building. The infants performed deferred imitation in the new spatial surround (Barnat et al., 1996; Klein & Meltzoff, 1999). Why is recall memory so spatially bound in one case and not the other? There are, of course, many differences between object permanence and deferred imitation (e.g., the former involves memory for an object's location; the latter, memory for actions; see Meltzoff & Moore, 1998, for further analysis). We acknowledge these differences, but the puzzle remains: What is the principled reason for context affecting performance in one case and not the other?

In the viewpoint favored here, object permanence requires the maintenance of numerical identity, and this is not the case for deferred imitation. In the case of a hidden object, the target of recall is an individual object—a token, not a type. Spatial location is a primary factor in finding and reidentifying stationary objects. Thus object search depends on locale; the missing object was left in a place, and to find that same one again, the infant must return

[7] We have considered whether infants' putting the object back in the hiding place could be described as deferred imitation of what they saw the adult do on Day 1. Clearly, components of this behavior are picked up from observation and retained over the delay (e.g., the object goes in the container). However, is the infant's goal action imitation or using the information they have seen in the service of another goal? The current data do not permit a decisive answer, but we speculate that it goes beyond action imitation per se. We think that when infants heard the cue (the bell ringing) and were asked, "Where is it?" their goal was to recover the object (which they failed to do, by experimental design). When the object was subsequently presented on the floor, it was in the wrong place (i.e., not inside the container), and infants took action to restore cognitive consonance by putting the object in its expected reappearance place. Thus, it comes down to the infants' goals—action imitation or restoring the object to its expected place. We favor the latter, which is also concordant with the finding that the room-change infants did not put the object back in the container (because there was no reason for them to expect the object in that locale; see the text), although they might have imitated the action if that was the overriding goal.

[8] The differential performance of the experimental and room-change infants suggests an emerging notion of what might be called *location identity* (analogous to numerical object identity). It suggests the onset of thinking about space as encompassing more than what is currently perceived—"Is this the same locale again?" This notion entails that the currently perceived space is related to a represented space that was previously encountered but is no longer visually present.

to that same place.[9] In deferred imitation, the numerical identity of the object does not matter as long as it belongs to the same category of objects as the one on which the actions were demonstrated. It is reasonable for infants to try out the target actions on any similar-looking objects, even if they are not numerically identical to the one used by the experimenter. Because multiple exemplars of a category can be encountered anywhere, deferred imitation is context independent. In short, our account of this difference in the effects of context stems from the underlying nature of the task. Object permanence taps numerical identity, because search is for the particular individual that was hidden (not any object that is featurally similar), and imitation of object-directed actions taps qualitative or category identity (this exemplar is similar to the object on which the target actions were performed).[10]

In conclusion, the current experiments demonstrate that 14-month-old infants can accurately remember a hidden object's location 24 hr after leaving the disappearance locale. Performance drops to baseline levels if infants are brought to a different room. The hypothesis advanced here is that infants are searching for a particular object, the individual that was hidden, and therefore have to return to the same room to be sure that they have found that one. Successful search after substantial perceptual breaks in time and space involves the interaction of memory, spatial understanding, object identity, and object permanence.

[9] A similar argument can be made regarding the recall of moving objects and moving people by using their trajectories of motion as the spatiotemporal criteria for identity. In this case, path of motion or trajectory is the primary identifier in young infants (for people, see Meltzoff & Moore, 1992, and 1998, pp. 218–219; for moving inanimate objects, see Hofsten, Vishton, Spelke, Feng, & Rosander, 1998; Moore et al., 1978).

[10] One might explain the context independence of deferred imitation by the idea that a person is involved in demonstrating the act to be performed. The relevant context, therefore, might be the person, the agent of the action, rather than the spatial surround. Because this agent is mobile, imitation could occur in different locations. However, deferred imitation does not depend on one person serving as demonstrator and tester. It is found even when one person demonstrates an action in Context 1 and recall is tested by a second person in Context 2 (Klein & Meltzoff, 1999, Experiment 2). Thus by 12 to 14 months of age, an unchanged context or locale is not required for deferred imitation.

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Received April 7, 2003
Revision received February 6, 2004
Accepted March 4, 2004 ■