New findings on object permanence: A developmental difference between two types of occlusion

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Manual search for totally occluded objects was investigated in 10-, 12- and 14-month-old infants. Infants responded to two types of total hiding in different ways, supporting the inference that object permanence is not a once-and-for-all attainment. Occlusion of an object by movement of a screen over it was solved at an earlier age than occlusion in which an object was carried under the screen. This dissociation was not explained by motivation, motor skill or means–ends coordination, because for both tasks the same object was hidden in the same place under the same screen and required the same uncovering response. This dissociation generalized across an experimentally manipulated change in recovery means—infants removed cloths while seated at a table in Expt 1 and were required to crawl through 3-D space to displace semi-rigid pillows in Expt 2. Further analysis revealed that emotional response varied as a function of hiding, suggesting an affective correlate of infant cognition. There are four empirical findings to account for: developmental change, task dissociation, generalization of the effects across recovery means, and emotional reactions. An identity-development theory is proposed explaining these findings in terms of infants' understanding of object identity and the developmental relationship between object identity and object permanence. Object identity is seen as a necessary precursor to the development of object permanence.

Infant object permanence is still an enigma after four decades of research. Is it an innate endowment, a developmental attainment, or an abstract idea not attributable to non-verbal infants? In classical theory, permanence was thought to be a developmental achievement because infants progressed from initial failures to successful search for hidden objects (Piaget, 1954). Although Piaget's progression in search has been replicated, his deeper inference can be questioned. Drawing inferences about object permanence *per se* may be unwarranted because search errors may be due to other factors such as motor skill, memory demand, and/or means–ends coordination. Permanence could be present at every age but masked by performance variables.

Researchers have attempted to circumvent the problems of manual search by measuring infants' visual response to object occlusions. Infants' preferential looking to novelty after habituation/familiarization has been used to investigate object permanence by

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comparing infant looking times to scenes in which permanence is apparently violated with control scenes in which it is not. An assumption of such studies is that, if infants treat objects as permanent, an event that violates permanence will recruit longer looking. A host of studies has been conducted using this approach (e.g. Baillargeon, 1987; Baillargeon & Graber, 1987; Spelke, Breinlinger, Macomber & Jacobson, 1992). Typically, these findings are interpreted as showing that infants as young as 3.5 to 5 months of age, and perhaps from birth, exhibit object permanence (e.g. Baillargeon, 1993; Spelke *et al.*, 1992).

Recently, the deeper inferences about object permanence based on looking-time studies have also been questioned (Haith, 1998, Meltzoff & Moore, 1998; Spelke, 1998). The debate is whether these studies have over-attributed object permanence to young infants. The present authors have suggested that infants' representational capacity itself, even in the absence of permanence, would be sufficient to generate the looking response (Meltzoff & Moore, 1998). Infants could encode the visible pre-hiding situation and compare its representation with the visible post-hiding situation to detect change on dimensions other than the permanence violation. Such changes or pre–post discrepancies would recruit increased looking without requiring an understanding of the object's existence behind the occluder while it is out of sight. A number of preferential looking studies have been reinterpreted along these lines (Bogartz, Shinskey & Speaker, 1997; Meltzoff & Moore, 1998; Munakata, McClelland, Johnson & Siegler, 1997). A second query considers what responses should be expected when a fundamental construal of the infants' world such as permanence is violated. Adults might withdraw, seeking to avoid the conflicting evidence; infants might also. In some studies infants have shown aversion to permanence violations, which led to less looking at the conflicting display (e.g. Meltzoff & Moore, 1998; Moore, Borton & Darby, 1978; Rosser, Narter & Paullette, 1995).

This study returns to manual search and tries to improve it as a diagnostic tool for assessing infant object permanence. A principal goal is to assess whether search success is based on permanence while providing controls for diagnosing the meaning of a failure to search. Most previous studies have focused more on the determinants of search error and construed development as changes in means–ends understanding, memory, the inhibition of perseverative responses, spatial coding, etc. (e.g. Bremner, 1994; Butterworth & Jarrett, 1982; Diamond, Cruttenden & Neiderman, 1994; Harris, 1987; Munakata, 1998; Sophian & Yengo, 1985; Wellman, Cross & Bartsch, 1987). The procedures developed in this study take these factors seriously by controlling for them, which assists in using infants' search to diagnose their underlying understanding of permanence.

In the studies reported here, infants are shown two different types of total occlusion in which the *same* toy is hidden in the *same* place behind the *same* screen.[1] If young infants systematically solve one hiding but not the other, this task differentiation cannot be attributed to differences in toy preference, motor skill, or means–ends coordination, because the same response in the same spatial location is needed to find the toy in both.

[1] The search tasks are drawn from a longitudinal study that found infants solving hidings-by-screen about 4 months earlier than hidings-by-hand (Moore, 1973, 1975; see tasks 3.2 and 3.4 in Moore & Meltzoff, 1978, p. 176).

Moreover, such a task differentiation would demonstrate that search is not a generalized removal of all screens whenever objects disappear. If that were the case, both tasks should be solved if one could be solved.

Experimental procedures were used to clarify the inferences that could be drawn from successful search. The value of using a search measure in the first place is that it seems to imply that infants' are seeking the absent object in its invisible location. The mere act of removing occluders, however, is not conclusive evidence of permanence, since they can be displaced for a variety of reasons. Because of this, previous researchers have striven to distinguish intentional search for an object from, for example, playing with occluders that fortuitously reveals the hidden object (e.g. Appel & Gratch, 1984; Bremner, 1978*a*; Butterworth, 1977; Willatts, 1984). The current experiments adopted three criteria for isolating permanence-governed search.

First, infants were precluded from reaching until the occlusion was complete. If search is based on permanence (the representation of an absent object as continuing to exist in a hidden location), infants should be able to initiate search after the disappearance event is complete. Search acts that start before occlusion is complete do not necessitate permanence, because they could be planned and launched from direct perception. Secondly, a rigorous criterion for the form of the search act was adopted. If infants represent a hidden object as spatially localized, for example under a cloth, the aim of search should be to uncover that space, and thus the object. Pointing at or even touching the occluder does not unequivocally index a hidden location; it may simply mark where the last perceptual change occurred in the visual field as the object disappeared. Thus, displacement of the occluder sufficient to uncover the hidden object was required. Thirdly, the infants' gaze during the act of uncovering was measured. If search is permanence-governed, the infant's gaze should be directed toward the hidden location as uncovering begins, supporting the inference that infants located the object as being under the occluder. The last two points help to prevent the error of interpreting infant play with occluders as permanence-governed search.

Expt 1 examined task differentiation in a developmental study of 10-, 12- and 14-month-old infants seated at a table. The results showed that one type of object occlusion was solved earlier than another. Expt 2 used a different setting where 10-month-olds crawled across the floor to find a hidden toy. Thus, a different response system, locomotion, was interposed between occlusion and the uncovering response. The results replicated Expt 1 suggesting that a deeper level of analysis is needed to account for task differentiation than the type of motor response used to recover invisible objects.

It is argued that object permanence is not innately specified, but develops. The theory proposed here is that object permanence is an attainment that grows from a developmentally prior understanding of object identity—the spatiotemporal criteria that infants use to predict a future encounter with an object and re-identify it as the same one again after a break in perceptual contact. Identity criteria allow infants to parse observed disappearance–reappearance transformations as involving one and the same individual. The maintenance of identity over disappearance transforms is a necessary foundation for the acquisition of object permanence from real-world experience. It is further argued that the two types of occlusions presented here differ markedly in their identity demands and that this is why one develops later than the other. The findings suggest that the young infants' understanding of permanence is not an all-or-none phenomenon, but a work in progress during infancy. At first it is constrained to specific types of occlusion transformations; with development it is understood as a general property of material objects regardless of the type of occlusion in which they participate.[2]

EXPERIMENT 1: A DEVELOPMENTAL STUDY

Method

Participants

The participants were 72 normal infants: 24 each at 10 months old (M = 43.54 weeks, SD = .51 weeks), 12 months old (M = 52.06 weeks, SD = .71 weeks) and 14 months old (M = 60.77 weeks, SD = .62 weeks). Half of the participants at each age were female. The participants were recruited by telephone from the university's computerized participant pool, containing names of families who had returned a recruitment card soon after the birth of their child. Pre-established criteria for admission into the experiment were that infants be of normal birth weight (2.5 to 4.5 kg), normal length of gestation (40 ± 3 weeks), and have no known visual, motor or mental handicaps. Because the study used hand movements that could be communicative to infants learning American Sign Language (ASL), infants whose parents acknowledged teaching ASL were not admitted. Of the participants, 69 were White; one participant was from each of the following ethnic groups: Black, Hispanic and Asian. All of the participants came to the laboratory without siblings so as to avoid distractions. Ten additional infants were tested but were dropped from the study because of persistently throwing toys off the table or refusing to pick up any toys (three), not watching the whole disappearance event (six), or experimenter error (one).

Test environment and apparatus

Testing took place within a two-room suite. One room was a waiting area where parents could feed and change their infants; the other contained a three-sided test chamber. The walls and ceiling of the chamber were lined with grey paper. The rear wall had a small hole to allow for videotaping. The chamber was illuminated by fluorescent lights on the ceiling behind the infant plus one 75-watt incandescent spotlight aimed at the centre of the table from 90° to the infant's right. The infant sat on the parent's lap facing the rear wall and across a table from the experimenter. The tabletop was 125 cm × 90 cm and made from matte black Formica. In the middle of the infant's side, a 25 cm × 20 cm 'notch' was cut so the infant was enclosed on three sides when sitting at the table. The infant's reactions were videotaped with an image from the top of the infant's head to the centre of the table. The experiment was electronically timed by a character generator that inserted elapsed time on the video record and also displayed a digital clock to the experimenter.

Test materials

The objects that were hidden were: an orange rubber bear (7.5 cm × 7 cm × 5 cm); a flesh-coloured rubber baby wearing a blue diaper (10 cm × 5 cm × 4 cm); or a plastic finger puppet in the shape of a clown's head (5 cm × 4.5 cm × 5.5 cm). They were occluded by one of two white washcloths made from thin Terry cloth (30 cm × 25 cm). The long side of the cloths was oriented to the width of the table on which they were centred 25 cm apart.

Design

The study used a repeated measures design in which each infant was presented with two occlusion tasks, and thus each infant acted as his or her own control. For each infant, the same object was hidden in the same

[2] Other events, such as burning, dissolving and exploding annihilate objects—but note that these are not 'occlusions' *per se*, although they result in disappearance.

location (left or right) for both tasks. Task order, sex of participant, and side of hiding were counter-balanced within each age group; six infants (three of each sex) were randomly assigned to each Order × Side cell in each age group.

Procedure

Acclimatization and warm-up procedure. Upon arriving at the laboratory, infants were taken to a waiting room and given a toy telephone to play with while their parents filled out consent and birth information forms. After a period of acclimatization, usually within 5–10 min, the parents carried them into the test chamber and placed them on their laps. The parent was seated on a chair with wheels which could be rolled back from the test table, or rolled forward until the infant's stomach was touching the forward edge of the 'notch' (see Fig. 1). Both positions were shown to the parents, and they were instructed to hold their infants securely upright when rolled away from the table. To accommodate differences in the size of infants, a graded set of foam pads was available that could be placed in the parent's lap to bring the infant's navel level with the table top.

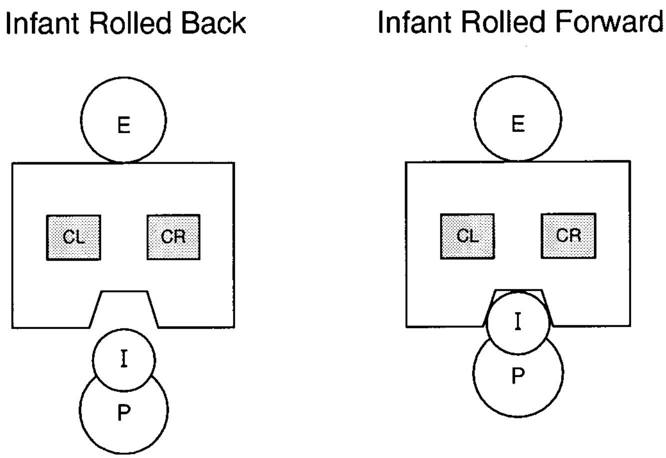

Figure 1. Arrangement of the table, cloths, and participants in Expt 1. The left side shows the situation when the occlusion is shown to the infant. The infant is rolled back from the table, out of reach of the cloths. The right side shows the situation after the occlusion is complete. The infant is rolled up to the table, and the response period is timed. E = experimenter; I = infant; P = parent; CL or CR = cloths to the infant's left or right.

Once at the table, a warm-up period commenced. It was designed to familiarize the infants with the test chamber and a turn-taking game with the experimenter. First, the experimenter demonstrated something interesting that could be done with one or more of the rings of a stacking-ring set while the infant was rolled away from the table; then he would say 'It's your turn', and leave the ring(s) on the table and the infant would be rolled forward to play with them. The experimenter would then say 'Watch' and take the ring(s) back and repeat the process. 'It's your turn' and 'Watch' were signals to the parent to roll forward and back. When the infant would willingly release the rings to the experimenter, the cloth screens were introduced. One of the objects to be hidden was placed between the cloths on the experimenter's side of the table, while the infant was focused elsewhere. When the infant noticed the toy, it was pushed within reach. If accepted, the toy was deemed a sufficiently attractive object to hide; if not, the process was repeated until an attractive one was found. The rings were then removed by holding them in the air and dropping them over the edge of the table while saying 'Bye-bye rings'. To equate for differences in reach and to ensure that the infant was out of reach when the hidings occurred, the toy was pushed in slowly until the infant could just touch it. For hidings, the cloths were positioned to have their nearest edge about 3 cm inside this limit.

Test procedures. After this warm-up and calibration period, the object occlusion tasks were administered. For both hiding tasks, the following procedures were the same. The infants were rolled back 20 cm out of reach and held securely under the arms by the parent so they could not lunge forward or launch a reach before the object disappeared. The parent was not signalled to roll the infant forward to the table until after the hiding was finished and the experimenter's empty hand had returned to the centre of the table. The 10 s response period was timed starting from the moment the infant was rolled forward sufficiently that his or her stomach touched the table edge. If infants removed the correct cloth during the response period, they were allowed to pick up and play with the object. If they did not search, or removed the wrong cloth during the first response period, both the cloths and the hidden object were removed from the table without revealing the object. They were then returned to the table using the same procedure by which they had initially been introduced. The infant was allowed to pick up and play with the object before the next task presentation began.

Hiding-by-screen was one of the object occlusions shown to infants (Fig. 2). In this task, a stationary object was occluded on the table by the movement of a screen. To administer this task, infants were rolled back, the object was placed between the cloths and their attention attracted to it. The experimenter then folded the cloth laterally in half, carried the object in the palm of his hand to the place on the table exposed by folding the cloth, and deposited it there. The object was then occluded by slowly folding the cloth back to its original position. The interval from disappearance beginning to total occlusion was M = .77 s, SD = .34 s. The hiding event was terminated by the carrying hand returning to the centre of the table, palm up (the interval from its leaving the cloth until coming to rest between the cloths was M = 1.77 s, SD = .41 s). When the infant had looked at the empty hand there, the experimenter said 'It's your turn', and the infant was rolled forward.[3]

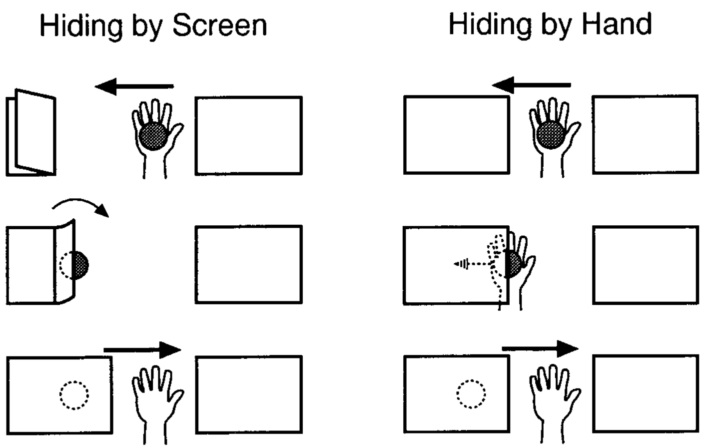

Figure 2. Schematic of two types of object occlusions. The left column depicts hiding-by-screen and the right column depicts hiding-by-hand. Hiding-by-screen began with the experimenter carrying the object to a place on the table next to the folded cloth and depositing it there. The occlusion occurs by unfolding the cloth over the object. The experimenter's hand then returns to the starting point, in the centre of the table. Hiding-by-hand began with the experimenter carrying the object toward the cloth. The occlusion occurs as the object goes under the cloth; it is then deposited on the table. The experimenter's hand returns to the starting point, in the centre of the table.

Hiding-by-hand was the other object occlusion shown to the infants (Fig. 2). In this task, the object is carried under a stationary screen on the palm of the hand and deposited there; then the hand emerged empty. To administer this task the infants were rolled back, the object was placed between the cloths, and

[3] Folding the cloth was accomplished by lifting both corners such that the experimenter's hand ipsilateral to the side of hiding picked up the corner nearest to him. The object was carried to its hiding place by the contralateral hand.

their attention attracted to it. The experimenter then put the object in the palm of his hand, lifted the inside edge of the designated cloth with his other hand, and carried the object under the cloth and deposited it there. The interval from disappearance beginning to total occlusion was controlled to be the same as the previous task (M = .77 s, SD = .21 s). As in the other hiding task, the hiding event was terminated by the carrying hand returning to the centre of the table, palm up (the interval from its leaving the cloth until coming to rest between the cloths was M = 1.78 s, SD = .47 s). When the infant had looked at the empty hand there, the experimenter said 'It's your turn', and the infant was rolled forward.

Operational definitions and scoring

The video records of all 144 trials (3 ages × 24 participants each × 2 trials) were edited in a random order to produce a scoring tape (with the restriction that trials from the same infant could not be adjacent). The occlusion event was not visible on the videotape, and each video segment for scoring began and ended in the same way. It began with experimenter's empty hand resting in the centre of the table (see Fig. 2, last step) and continued to the end of the 10 s response period. Thus, there was no information on the scoring tape as to which task was used. A microanalytic scoring procedure was used in which a scorer viewed the video segments in real time, slow motion, and frame-by-frame at her choosing. The scorer, who was naïve to the structure of the experiment, to the hypotheses, and without listening to the video soundtrack, provided a dichotomous yes/no judgment of whether an act of uncovering occurred in each response period. The scorer also coded whether it was the left or right cloth that was uncovered and the direction of the infant's gaze as uncovering began.

'Uncovering' was defined as the first manual act that displaced a cloth from its initial location such that at least half of the area under the cloth was revealed. To be scored, uncoverings must have begun, as indicated by movement of the cloth, within the 10s response period. Successful search was defined as an uncovering that occurred where the object was hidden.

The 'direction of visual expectation' associated with an act of uncovering was defined as the spatial direction of the infant's gaze occurring simultaneously with the start of uncovering (i.e. gaze direction during the interval beginning when the cloth was first moved up to, but not including, when the toy became visible or the place was half uncovered). Mutually exclusive and exhaustive codes for direction of visual expectation were: (a) the hidden location (as the cloth was moved, infants stared at the table where the cloth had been or followed the edge of the cloth); (b) the experimenter's hand; (c) the floor beside the infant; (d) off the table to the left or right side; or (e) no expectation (infants looked at the experimenter's face, or looked at (and may have put their head down on) the table between themselves and the cloth).

Intra- and interscorer agreement was assessed by rescoring a randomly selected 20% of the trials. There were no intra- or interscorer disagreements on the uncovering measure. Intra- and interscorer agreement was high on the visual expectation code (kappas of .80 and .82 respectively).

Results and discussion

The experiment was counterbalanced for sex, task order and side of hiding. For all the analyses that follow the data were collapsed across these factors, because a three-way analysis of variance (ANOVA) conducted on infants' overall success score (0, 1, 2) using Sex (female/male) × Task order (first/second) × Side of hiding (left/right) found no significant main effects or interactions, with all Fs $<$ 1.0 and ps $>$ .40. Infants were given two tasks with dichotomous outcomes, and each infant falls into one cell of a 2 × 2 table. Infants either solve: both tasks, neither task, the hiding-by-screen but not hiding-by-hand, or the hiding-by-hand but not hiding-by-screen. Such 2 × 2 tables are appropriately analysed by the McNemar test (Siegel, 1956). The criterial cells of the McNemar test for task differentiation fall on the diagonal, showing a change in performance from one task to the other. If the hiding-by-screen task is easier and solved at a younger age than the hiding-by-hand task, there should be more infants who solve hiding-by-screen and fail hiding-by-hand than the converse.

The results demonstrate that there is a significant difference in infants' success on the two occlusions (Table 1). In the cells bearing on differentiation, 15 infants solve hiding-by-screen but not hiding-by-hand vs. only 1 infant who does the converse ($p < .001$, McNemar test). The effect is strong regardless of which task was administered first. For infants who saw hiding-by-screen as their first task, the relevant data are 8 vs. 0; and for infants who saw hiding-by-hand first, the data are 7 vs. 1 (these are the subcomponents of the 15 vs. 1 effect).

Table 1. Expt 1: Number of infants succeeding/failing as a function of occlusion type

	Hiding-by-hand	
Hiding-by-screen	Fail	Succeed
Succeed	15	36
Fail	20	1

Note. $N = 72$ infants. McNemar test, $p < .001$.

Table 2 breaks down the overall effect by age, providing one McNemar table for each. The differentiation effect is significant at 10 months (7 vs. 0, $p < .05$) and 12 months (8 vs. 0, $p < .01$) of age, but not at 14 months of age (0 vs. 1). By 14 months of age, most of the infants solve both tasks. This is to be expected with developmental phenomena; at some age infants will solve the more difficult task, and there will no longer be any differentiation.

Table 2. Expt 1: Number of infants succeeding as a function of age and occlusion type

	Hiding-by-hand					
	10-month-olds		12-month-olds		14-month-olds	
Hiding-by-screen	Fail	Succeed	Fail	Succeed	Fail	Succeed
Succeed	7	7	8	10	0	19
Fail	10	0	6	0	4	1

Note. $N = 24$ infants at each age. McNemar tests, *p*s $< .05$ for 10-month-olds, $< .01$ for 12-month-olds, and n.s. for 14-month-olds.

Table 3 displays the number of infants searching successfully at each age on each task. On the hiding-by-screen, a majority of the infants succeed at every age (58%, 75% and 79% of 10-, 12- and 14-month-olds respectively), and there was no significant difference in success as a function of age ($\chi^2(2, 72) = 2.82, p > .24$). On the hiding-by-hand, it was not until 14 months of age that a majority of infants were successful (29%, 42% and 83%

of 10-, 12- and 14-month-olds respectively), and there was a significant difference in success as a function of age ($\chi^2(2, 72) = 15.46, p < .001$).[4]

Table 3. Expt 1: Number of infants succeeding/failing on each task as a function of age

Age	Hiding-by-screen			Hiding-by-hand		
	Succeed	Fail	% Succeed	Succeed	Fail	% Succeed
10-months	14	10	58	7	17	29
12-months	18	6	75	10	14	42
14-months	19	5	79	20	4	83

Note. For hiding-by-screen, $\chi^2(2,72) = 2.82$, n.s. For hiding-by-hand, $\chi^2\ (2,72) = 15.46, p < .001$.

The infants' acts of uncovering were analysed. They were accompanied by visual expectation at the previously hidden location. The data showed that 93 of the 95 uncoverings were accompanied by visual expectation. The two exceptions were looks to the experimenter. Thus, the form of search act found here was a coordination between manual uncovering and visual expectations of reappearance consistent with an infant notion of a hidden location for the unseen object. No reaches toward the cloths began before the object's disappearance was complete, and no infants were rolled forward before they had seen the empty hand.

The results showing task differentiation are clear (15 vs. 1), but one might also try to relate the current search data to the overall success/failure rate in past literature on manual search. At first, the infants might seem to have more search problems than would be expected for infants at this age (it is often assumed that the A hidings of the A-not-B tests are easy, but see Munakata (1997) for results showing that infants of this age have difficulties at A). The present authors believe that the current success rate was obtained because of the familiarization procedures used and the stringent task administration adopted. Procedurally, it is important that infants did not receive partial hiding tasks as warm-up trials to prompt search at A, as was done in many previous manual search studies. Further, the task administration required that infants were out of action until the hiding was complete, so that they could not simply be continuing a reach that began while the object was still perceptually present. The fact that 93 of the 95 manual search acts were accompanied by visual inspection of the spot previously obscured by the cloth lends support to the present hypothesis that the search obtained was based on 'permanence' rather than magical procedures or fortuitous cloth pulling.[5]

[4] The text reports the age effects using the complete data set, comprising the data from both trials. The same age effects were also found using the first trial data only. On the hiding-by-screen, the percentage of infants succeeding at 10-, 12- and 14-months-old was respectively 58%, 83% and 83%, and there was no significant difference in success as a function of age ($\chi^2(2,72) = 2.67, p > .25$). On the hiding-by-hand, the pattern was 17%, 50% and 83%, and there was a significant difference in success as a function of age ($\chi^2(2,72) = 10.67, p < .005$).

[5] The reader might be interested in a microanalysis of the trials in which infants were scored as exhibiting unsuccessful search. Of the total of 56 trials scored as unsuccessful search, there were 7 with search at the wrong cloth and 49 with no search. Of the 49 trials scored as no search, there were 6 trials in which infants simply touched a cloth but did not meet the critierion for displacing it.

In sum, the data suggest that these acts of uncovering, even those of 10-month-olds, warrant description as search for an invisible object while it resides in a hidden location. The results showed that not all total hidings are the same. Infants do not seem to solve search tasks in an all-or-none fashion. There was a significant difference between the two occlusion events even though the same uncovering act that solved the easier task would have solved the harder task; performance factors were equated. What notion of object permanence would yield successful search on one task but not the other? Expt 2 examines the generality of this difference between the tasks and what it might mean.

EXPERIMENT 2: CRAWLING THROUGH SPACE

Expt 1 found a developmental difference between two types of total occlusion tasks. Would this task differentiation generalize to a new situation? Suppose infants watched an object's disappearance from a distance and then had to traverse 3-D space before searching? Successful search in this case would demonstrate that infants are not limited simply to leaning forward and reaching (e.g. 'viewer-centred reach space'), but can use the hiding event to specify a spatial location as the goal for locomotion before executing the uncovering act. This would suggest both a stable representation of the hidden object and flexibility in the use of means to an end—locomotion to the hiding place and manual search once there.

Expt 2 used the two tasks from Expt 1, but the objects were hidden under different screens (semi-rigid pillows), and infants had to move themselves through space (by crawling) and uncover the objects while sitting on the same surface as the object (the floor). In addition, a different set of objects was used. Ten-month-olds were chosen to participate in order to test the youngest possible age. If the previously found difference in task success held in these circumstances, such generality would suggest that a more abstract, structural description of the tasks exists than describing them solely in terms of the degree of occlusion or the particular manipulative skills used in recovery. Characterizing this *task structure* would be an important step toward an account of task differentiation.

Method

Participants

The participants were 24 normal 10-month-old infants (M = 42.76 weeks, SD = .62 weeks). Half of the participants were female. The recruitment procedure and pre-established criteria for admission into the study were the same as in Expt 1. As in the first experiment, all the participants came to the laboratory without siblings to avoid distractions. Of the 24 participants, 22 were white and 2 were Asian. One infant was dropped from the study because of equipment failure, and two for failing to crawl during a warm-up period in which infants were required to crawl across the room to obtain visible toys.

Test environment and apparatus

Testing took place in a laboratory room that was furnished like an ordinary living-room with a couch, two large chairs, a changing table with mobile above it and pictures on the walls. The infants sat on the edge of a chair between the parent's legs and across the room from the experimenter, who sat on the floor. Their reactions were videotaped by a camera located behind the experimenter and equipped with a wide-angle lens yielding an image from the top of the infants' head when they were sitting in the chair to the pillows on the floor. The seat of this chair was 42 cm off the floor; its front was 90 cm from the nearest edges of the pillows. The experiment was electronically timed by a character generator that displayed a digital clock to the experimenter.

Experimental design and test materials

The design was the same as Expt 1 except that only 10-month-olds were tested. Each infant was presented with both occlusion tasks, acting as his or her her own control. For each infant, the same object was hidden in the same location (left or right) for both tasks. Task order, sex of participant and side of hiding were counterbalanced. The objects were brightly coloured wooden and plastic toys. They were hidden under one of two semi-rigid, patterned blue pillows (40 cm $\times$ 40 cm $\times$ 10 cm) placed 40 cm apart on the golden carpeted floor.

Procedure

The acclimatization and warm-up procedures were identical to those in Expt 1 except as noted below. Instead of 'rolling back' for the hiding presentations, the infant was picked up by the parent and placed on the chair between her legs until the hiding was completed (object totally occluded and palm returned to the centre). At that point the experimenter said 'It's your turn', and the infant was placed on hands and knees on the floor between the parent's feet and allowed to crawl to the rings (warm-up) or the pillows (test). Toys were stored in a box behind the experimenter and were removed from play by dropping them in the box while saying 'Bye-bye'.

The hidings were conducted as in Expt 1 except as follows. The disappearance of the object when hidden by movement of the pillow was accomplished by the experimenter grasping the pillow's centre with his nearer hand and rotating as though it were hinged at the back edge and then lowering it again. For the hiding-by-hand, the pillow was moved as though hinged from the front, so the object could be carried beneath it. A 30s response period was timed from when the infant's hands and knees touched the floor.

Operational definitions and scoring

The scoring definitions differed in two minor ways from Expt 1 in order to accommodate the new occluders. First, because the pillows were larger and more rigid than the cloths, uncovering was also scored if the infant tilted the pillow up off the toy (the operational definition of tilting the pillow was raising it 60° or more). Secondly, the codes for direction of visual expectation were identical to Expt 1, save that the visual expectation categories of 'off the table' and 'on the floor' were replaced with 'on the floor beyond the pillows'.

The video records of all 48 response periods (2 trials $\times$ 24 participants) were edited to produce a randomized scoring tape as in Expt 1. Each video segment on the tape began when the experimenter's empty hand was resting between the pillows and continued to the end of the 30 s response period. Thus, there was no clue for which type of object occlusion had been shown to any infant. Intra- and interscorer agreement was assessed by rescoring a randomly selected 20% of the trials. There was 100% agreement for the intrascorer coding of uncovering and direction of visual expectation. Interscorer agreement was high for both uncovering and visual expectation, as evaluated by kappa (1.00 and .85 respectively).

Results and discussion

The experiment was counterbalanced for sex, task order and side of hiding. For all of the analyses that follow, data were collapsed across these factors, because a three-way ANOVA conducted on infants' overall success score (0, 1, 2) using Sex $\times$ Task order $\times$ Side of hiding found no significant main effects or interactions (all Fs < 1.6 and ps ranging from .23 to .81).

The results showed the same task differentiation as was found in Expt 1. As shown in Table 4, nine infants solved hiding-by-screen, but not the hiding-by-hand; no infants exhibited the converse ($p < .005$, McNemar test). The acts of uncovering were coincident with infant visual expectation directed to the hidden location. There were 21 uncoverings accompanied by accurate visual expectation vs. 2 that were not. One of the exceptions was looking at the experimenter's hand; the other was looking at his face.[6]

Table 4. Expt 2: Number of infants succeeding/failing as a function of occlusion type

	Hiding-by-hand	
Hiding-by-screen	Fail	Succeed
Succeed	9	6
Fail	9	0

Note. $N = 24$ infants. McNemar test, $p < .005$.

Over two experiments, testing a total of 48 10-month-old infants, the results were quite systematic. There were 16 infants who solved hiding-by-screen but not by hand, and no infants showing the reverse pattern ($p < .001$, McNemar test). Moreover, the same task differentiation was obtained in two disparate tests recruiting different motor performances, one involving sitting at a table and pulling cloths and the other involving self-generated movement through space and then displacing a semi-rigid barrier.

ANALYSIS OF AFFECTIVE REACTIONS TO OCCLUSION

Why would infants who succeed at finding an object given one type of total occlusion fail on another type? One strategy in seeking an answer is to develop an additional measure such as affect. Understanding an occlusion might be indexed by smiles; lack of understanding might lead to conflict and avoidance.

Behavioural codes were created to assess avoidance. A scorer naïve to the hypothesis coded the response periods, using the same edited tapes described previously. Since 10-month-olds were used in both experiments, their data were combined across the studies to provide a large, age-controlled sample to assess affective responses ($N = 48$).

Operational definitions

There was little fussing in these studies. The measured affect concerned infants' active avoidance of the hiding event. Avoidance was scored as a dichotomous yes/no code for each trial. Because the infants could move on their own volition in Expt 2, avoidance was defined as a head turn $\geq 90°$ away from the straight line between the infant's chair and the mid-point between the pillows. The head turn had to occur before the infant reached the far edge of the pillows or began to search by manually lifting or displacing a pillow. The criterion for a head turn of 90° was seeing the infant's head in profile with the ear directed

[6] The length of time it took infants to crawl across the room, the interval from complete disappearance to uncovering, is noteworthy ($M = 11.03$ s, $SD = 5.92$). Success after this memory delay, and the insertion of crawling between disappearance and removal of the occluder, support the argument that search in this experiment is permanence governed.

toward the experimenter. In Expt 1, because infants were constrained to sit in the parent's lap at the table, avoidance was defined as the infant's head tipped forward with the eyes directed down toward the table between the infant and the cloths, plus any one of the following: (a) pushing away from the table and squirming; (b) turning away from the table; (c) putting the head down on the table; or (d) manually rubbing on the table in front of the cloths. Criteria (a)–(d) were designed to capture both the aversive and the displacement aspects of avoidance. Intra- and interscorer agreement was assessed by rescoring a randomly selected 20% of the trials. Agreement was satisfactory for both Expts 1 and 2 as evaluated by kappa (.87 and .78 for intra-, and .79 and .74 for interscorer agreement).

Results and discussion

The results show that avoidance is differentially associated with one of the object occlusions. As shown in Table 5, 17 avoided the hiding-by-hand but not the hiding-by-screen; only 1 showed the opposite pattern ($p < .001$, McNemar test).[7]

Table 5. Number of infants avoiding as a function of occlusion type

	Hiding-by-hand	
Hiding-by-screen	Avoid	Not avoid
Not avoid	17	27
Avoid	3	1

Note. $N = 48$ 10-months-olds from Expts 1 and 2 combined. McNemar test, $p < .001$.

One might wonder whether the avoidance of hiding-by-hand simply reflects the infants' frustration at not finding the object. This can be tested by examining only the infants who failed both tasks (since, on this hypothesis, they should be equally frustrated on both). For these infants, nine avoided hidings-by-hand but not by screen and one did the opposite ($p < .05$, McNemar test). (The remaining cells are that three infants avoided both hidings and six avoided neither.) Thus, frustration about not finding the toy is not sufficient to explain the differential pattern of results. Infants' avoidance of hiding-by-hand appears to be a reaction to this type of occlusion, unmediated by search consequences.[8]

In preferential looking to novelty studies, it is commonplace to describe infants'

[7] The same pattern of avoidance was also found in the first trials alone, showing that it was not built up over multiple trials, but obtained on the infants' first contact. These first trial data can be cast as a 2 (Hide-by-screen/Hide-by-hand) × 2 (Avoid/Not avoid) table. The results show that 46% of the 24 infants shown hiding-by-hand on the first trial avoided it, whereas only 13% of the 24 infants shown hiding-by-screen event avoided it ($\chi^2(1,48) = 4.94, p < .05$).

[8] The data in the text control for age, reporting 24 10-month-olds from each experiment. However, the same pattern of results obtains if one collapses across all the infants in both experiments regardless of age ($N = 96$). The criterial cells in the overall McNemar test were 23 vs. 2, $p < .001$. The corresponding first-trial data were 29% vs. 8%, $\chi^2 (1,96) = 5.54, p < .05$.

response to permanence violations as indicating 'surprise'. To date, however, these studies have not directly measured surprise or other affective behaviour (Haith, 1998; Meltzoff & Moore, 1998). The findings reported here are among the first to show that affective responses vary as a function of occlusion events, thus adding to the tools for diagnosing infants' understanding of permanence.

What can account for such strong differential reactions to the two hidings (17 vs. 1), considering that they were both total occlusions of an object? As noted, the reaction cannot be attributed to frustration at not finding the toy, and the pattern of results points to the nature of the hiding-by-hand event itself. Further empirical study examining the underlying cause of the affect is needed, but the present interpretation is that the post-occlusion empty hand had a different meaning for infants after seeing one type of hiding vs. the other. For the hiding-by-screen, the table (or floor) was the place in which the object disappeared and, when uncovered, reappeared. For the hiding-by-hand, the hand was the place of disappearance. After depositing the object under the screen, the hand emerged empty. Only the hiding-by-hand forced infants to confront the fact that the place the object disappeared is now empty. The authors' speculation is that infants expected to see the object in the place it disappeared (the hand) and seeing the empty hand violated their understanding of permanence. This idea is expanded upon below.

GENERAL DISCUSSION

The results show that not all object occlusions are treated in the same way by young infants. This has implications for theories of development in object permanence. The 'hiding-by-screen' task was systematically solved before the 'hiding-by-hand' task. This finding of task dissociation cannot be explained in terms of motivational or performance variables such as toy preference, motor skill, or means–ends coordination. In both tasks the *same* toy was hidden in the *same* place under the *same* screen and required the *same* uncovering response. Moreover, the task dissociation generalizes over different recovery means—removing cloths while seated at table (Expt 1) and crawling through space to displace occluding pillows (Expt 2). Qualitatively, the nature of the infants' search meets criteria for being permanence-governed: the uncoverings were initiated after task presentations were finished and were coordinated with visual expectation at the place of reappearance as uncovering began. Some development in object permanence *per se* seems to occur between 10 and 14 months of age.

This section (a) considers the results in light of existing theories, (b) hypothesizes that object identity is a developmental precursor to object permanence and underlies the obtained task dissociation, and (c) draws some broader implications for developmental theory in general.

Task dissociation and existing theories of object permanence

The findings are not in accord with strong theories of innate object permanence. One such position derives permanence from object perception. Spelke (1990) argues that permanence is a property of objects ensuing from the perceptual system's initial segregation of perceived surfaces into coherent, whole objects. The object knowledge embodied in this processing is expressed as the principle of continuity—an object traces one continuous path through space and time; there are no gaps in this path. Permanence is seen as 'core knowledge', available from birth. A related argument contends that young infants can draw inferences about invisible objects and events using the principle of continuity (Spelke & Van de Walle, 1993). Similarly, Baillargeon argues that infants reason in terms of object permanence by 3.5–5.5 months of age, if not earlier (Baillargeon, 1987, 1994*a*; Baillargeon & DeVos, 1991).

As currently articulated, these positions have difficulty accounting for why the hiding-by-hand is harder than the hiding-by-screen when performance factors have been equated. If permanence is a perceptual property of physical objects, there would be no task dissociation because the same object and screens are involved in both tasks. If young infants can reason on the basis of permanence or the principle of continuity, infants shown hidings-by-hand should have little difficulty finding the object. They observed the object's path as it was carried under the screen and then did not emerge with the hand. From the Spelke and Baillargeon viewpoint, infants should be able to reason that 'since hand and object go under the screen and only the hand comes out, the object remains under the screen; therefore, search there' (see Baillargeon, 1994*b*, for similar reasoning). The results are not in accord with this view and suggest that a more developmental view may be in order.

These findings cannot be explained by Piaget's particular developmental theory. For Piaget (1954), total hidings in one location are first solved at stage 4 because the coordination of secondary circular reactions enables infants to use the act of screen removal as a means to recover the hidden object. At stage 5 infants can solve total hidings in more than one location, coping with visible changes in hiding locus by searching 'behind the obstacle where the object was last seen disappearing'. Search tasks are analysed solely in terms of their location, degree of occlusion and the actions required for recovery. Piaget's theory, therefore, has no easy explanation for how total hidings in one place, solved by the same recovery act, can be developmentally different.

Munakata *et al.* (1997) have proposed a developmental, but not Piagetian, view of infant search. In one empirical study, they found that 7-month-olds can use a trained response to recover objects behind transparent screens but fail to use that same response to recover objects hidden behind opaque screens. They therefore conclude that difficulties with means–ends coordination *per se* are insufficient to account for search failures on total hidings, because infants were trained to have the means–ends abilities at their disposal. The present results extend this argument in two ways. First, they show that means–ends difficulties do not account for failure on hiding-by-hand with infants older than 7 months, because these same infants manifest the necessary means–ends coordination on hiding-by-screen. Secondly, this effect is not dependent on training the recovery response and can be obtained using the infant's spontaneous search acts.

However, Munakata *et al.*'s (1997) particular theoretical account of infant search is not easily extended to explain the task dissociation obtained here. They believe that success on total occlusions is the product of a 'gradual strengthening' of infants' representation of the hidden object until it can compete with their perception of the visible occluder. It is difficult to see how an incremental strengthening of the object's representation can account for solving one task but not the other. Presumably, if representation is strong enough to support search after total occlusion on one of the tasks administered here, it would also support search on the other. The following section proposes that changes in object search reflect qualitative shifts in infants' understanding, rather than a 'gradual strengthening' of representation.

Identity-development theory

The results provide four new data points that need to be accounted for: (a) developmental change in search for occluded objects; (b) differential success as a function of type of occlusion within an age; (c) generality of the effects despite alterations in the surface characteristics of the two experiments; and (d) affective responses to occlusions. This section offers a theoretical position accounting for these effects.

First, consider development. The age-related changes in search are not owing to performance factors (motor skills, means–ends understanding, etc.), because they were controlled in these studies. It is suggested here that the age-related changes reflect development in infants' notion of permanence. The problem has always been to describe what such development consists of and how an infant without permanence could ever acquire permanence. It is proposed here that the key to the acquisition problem is object identity. In the authors' view, the maintenance of an object's identity over disappearance–reappearance transformations (this visible object is the *same one* seen before) is a precursor to the acquisition of object permanence. If infants had no means for determining whether the pre- and post-disappearance objects were the same entity, each appearance would be a new individual. Until appearance can be construed as a *re*-appearance of the *same* object again, there is no question of where it was when out of sight. Without some notion of identity, infants' observations of object disappearances–reappearances would not provide experiential leverage for developing permanence. Thus, a theory of object permanence development must begin with infants' understanding of object identity.

What is known about object identity in infancy? For the purposes of this discussion, the term 'object identity' is used to refer to an object's being the self-same individual over different encounters in space and time. This concerns the essential sameness of the individual, not similarities in appearance between two individuals, and it is often called 'numerical identity' in the philosophical literature. Research has shown that infants' earliest and most fundamental criteria for the numerical identity of objects are spatiotemporal, the place or trajectory of an object, although object features come to play a role at some age (e.g., Butterworth, Jarrett, & Hicks, 1982; Meltzoff & Moore, 1998; Moore *et al.*, 1978; Wilcox & Baillargeon, 1998; Xu & Carey, 1996).

The two hiding tasks presented in the present studies pose markedly different identity demands and the authors believe this underlies the obtained task differentiation. In the hiding-by-screen, an object at rest on the table is covered by a cloth. In the hiding-by-hand, an object resting in the palm is carried under the cloth. Both are total occlusions under the same cloth at the same location on the table and require the same actions to recover them. These similarities are why they are not easily differentiated by extant theories. However, the two occlusion events are different from an identity viewpoint. At the ages used here, most infants shown the hiding-by-screen task expect the *same* object to reappear in the place on the table in which it disappeared, because 'place' is their spatiotemporal criterion for identifying objects at rest. The important point to note is that if infants apply such a 'place' notion to the hiding-by-hand, it will lead them to fail. For this task, infants would expect the object to reappear in the hand because the palm of the hand is the place where it disappeared. However, this expected reappearance place is empty when it emerges. The place criterion that enables infants' comprehension of the hiding-by-screen leads to non-comprehension of the hiding-by-hand. When the empty hand emerges in the hiding-by-hand task, infants have no place to search, because there is no other place in the external world for that *same* object to be.[9] Infants using place as their identity criterion for stationary objects would show just the task dissociation obtained. It is thus suggested that useful theoretical terms for describing the hidings are abstract spatiotemporal parameters such as place.[10]

Not only does this help distinguish the two total hidings (by-screen vs. by-hand), but it also explains the generality of the effects. Between Expts 1 and 2 there was a substantial change in many surface characteristics of the tasks. In Expt 2, the occluder was different (cloths vs. pillows), the background was different (table vs. floor), and the recovery response was different (pulling cloths vs. crawling across room in 3-D space). From many theoretical points of view, these salient variations might lead to different results, but according to the viewpoint proposed here, there has been no alteration in the identity structure of the tasks. For example, the hiding-by-screen can be described in the same way in the two experimental set-ups—it is simply an occlusion in *place*, whether on the table top or the floor. Similarly, the identity structure of the hiding-by-hand task remains the same across both experiments—an occlusion in place (the palm), which is then seen to be empty, whether the hiding is done by cloth or pillows, at the table or on the floor. Thus, the generality of the effects is explained by the fact that the identity structure of the tasks remained invariant over the two experiments despite changes in their surface characteristics.

The identity interpretation allows us to examine the acquisition of permanence in a new light. The notion of object permanence involves more than the maintenance of identity across occlusion transformations. Permanence 'fills the gap' between visible encounters with the same object. For infants to treat an object as permanent entails that it has a particular location in the external world between disappearance and reappearance. These studies are interpreted as showing that infants understand permanence when a stationary object is hidden-by-screen but not when the object is hidden-by-hand, successfully searching in one case and not the other, even though performance factors were controlled. (The critical data lie on the diagonals of the McNemar tables, which were 24 vs. 1 across both studies.) Thus, the authors contend that object permanence is not an all-or-nothing acquisition. Rather, they propose that permanence is understood for some types of occlusions before it is understood for others, and infants' understanding of an object's permanence is dependent on the transformational event in which it participates.

Object permanence for the hiding-by-screen develops relatively early because infants

[9] After disappearance, a similar-looking object that appeared in a different place would be interpreted as a different object by the identity criterion of place.

[10] The hypothesis is that *place* is the spatiotemporal criterion infants use to identify a stationary object as the same individual across an occlusion event. Place can be thought of as the object's location in space. At this age, the prototypic example of place for stationary inanimate objects is the footprint on the surface where the object is at rest, and this may be a tabletop, floor, the palm of a hand, etc. Infants' coding of spatial location may change with development along the lines described by Bremner (1978*a*, 1978*b*), Butterworth & Jarret (1982), Butterworth *et al.* (1982) and Piaget (1954), e.g. from a relatively egocentric coding, to a more allocentric coding using landmarks within a visual frame of reference, to 3-D coordinates in Cartesian space.

could understand that there is an invisible place where the object resides while it is out of sight. This follows because the *place* where the object disappeared (the portion of the table top) is located on a surface that is only partially occluded by the screen. At the ages studied here, most infants understand partial hidings (Bower, 1982; Kellman & Spelke, 1983; Piaget, 1954). For infants who understand partial hidings, the now-hidden portion of the table provides an invisible place in the external world in which the object could be located. Hiding-by-screen is thus interpreted as covering the place where the desired object is located, and uncovering the partially hidden surface should reveal the object again. Conversely, hidings-by-hand are solved after hidings-by-screen because the place that the object should be (the hand) is empty. The object is, apparently, not in the external world. Indeed, the empty hand (before alternative locations are imagined) leads infants to interpret this type of hiding transformation as one that does not preserve permanence. At this age permanence is not yet a property of objects. The same object can be interpreted as permanent or not, depending on the occlusion transformation. (Even in the mature state there are disappearance events that do not preserve the permanence of physical objects, e.g. burning, dissolving, exploding, etc., as described in Michotte, 1962.) The present authors' shorthand for this is that the concept of object permanence develops or, more strictly, the range of hidings over which permanence is understood is at first narrow and becomes increasingly comprehensive.

Much of the foregoing analysis can be summarized by proposing two developmentally ordered steps in the genesis of object permanence. The earlier understanding is sufficient for solving the hiding-by-screen but leads to failure in the hiding-by-hand. As a rough approximation, the earlier understanding is: A material object that disappears in a place still resides invisibly in that place and can be made to reappear by uncovering the place (disappearance place = reappearance place for stationary, non-self-mobile objects). However, when the place of disappearance is on a carrier that moves behind an occluder, this understanding is violated if the carrier emerges empty. In this case, infants treat the object's absence on the carrier as a violation of permanence, which causes a negative emotional reaction. The eventual solution to hiding-by-hand marks a further step in the development of object permanence. The authors hypothesize that this requires infants to differentiate the disappearance place (on the carrier) from the reappearance place (behind the occluder) and then to coordinate them by means of the trajectory of the carrier-and-object as it disappears. Such differentiation and reintegration enables infants to maintain the object's identity over the transformation; and this spatiotemporal chain links the visible object that disappeared to its representation when invisible and assures that they refer to one and the same object. Understanding such transformations extends infants' notion of object permanence. They now have a new place for the absent object to be—it resides in an invisible place different from its disappearance place while maintaining its identity.[11]

[11] The text describes two developmentally ordered steps in the genesis of object permanence, but it is not thought that these are the only two. For example, infants do not typically solve 'serial invisible displacements' until 18–24 months of age. The authors do not believe their hiding-by-hand task is solved as an invisible displacement at the young ages tested here (10–14 months old). The mature understanding of invisible displacements involves representing the movement of an invisible object as it travels on an invisible trajectory and then is invisibly transferred from one occluder to another. In a typical invisible displacement task, an object travels from one hidden location (say, inside a closed box where it was

Has anything been gained by describing infants' object permanence in this way? It is believed it is helpful in two ways. First, it substantiates the hypothesis that infants' understanding of object permanence is not an all-or-none attainment, but is dependent on the transformations in which the object is involved. Secondly, it points to the abstract terms that might characterize these transformational events—places and trajectories of motion, both visible and invisible. This in turn allows one to predict which variations in the physical world will make a difference in infants' understanding of object occlusions and to generate predictions for novel events.

This account of permanence development might also shed light on the differential affective reactions that were obtained. In the current studies, infants reacted negatively to the hiding-by-hand significantly more than to the hiding-by-screen. This was not frustration owing to lack of success, because the affective difference was found even when infants failed both tasks. Apparently, something about the hiding-by-hand was aversive. Given the foregoing, nothing about the hiding-by-screen should be aversive. The object should reappear in the disappearance place if uncovering occurs; if not uncovered, no conflict is posed by the object's disappearance alone. All is well. However, for the hiding-by-hand, infants see that the disappearance place is empty. Moreover, when hand and object are under the cloth, the arm is still attached to the hand/object, making this a partial occlusion. Failure of the object to return when the hand/object is withdrawn would be a violation of permanence for partial hidings, which infants understand at this age. This violation could explain the negative affect to the hiding-by-hand (see Meltzoff & Moore, 1998, for a further discussion of cognitively-based affect).

Broader implications for theories of development

The goal of this section is to relate these experiments to broader issues for theories of infant development. In the authors' view, understanding object occlusions is an example of a larger problem infants face, which is to maintain stable invariants in the flux of appearances. Infants exhibit (at least) two ways of dealing with this problem. On the one hand, the work on infant categorization shows they are facile at grouping arrays of different objects, events, and sounds into classes. This allows infants to treat the members of a class as equivalent or 'another one of those' because they share certain properties. On the other hand, infants parse multiple appearances as manifestations of a single underlying individual. This notion of unique individuals allows infants to treat encounters as 'this is the same one again'. Both classifying groups of entities and tracing the identity of individuals over time and space are effective in isolating invariants and reducing apparent multiplicity. The authors wish to argue that infants' attempts to maintain the sameness of individuals over occlusion transformations lies at the heart of the development of object permanence.

From this viewpoint, when an object is occluded, the goal of search is quite specific. In searching, infants are seeking the same object that disappeared; no other will do.

previously found) to another hidden location (say, behind a screen). The infant must infer the movement of the already-hidden object as its *occluder* is displaced. The hiding-by-hand task used did not demand such high-level cognition because the object's trajectory to the occluder, and its hiding transformation at the occluder, are both visible. Infants could use the *visible* trajectory of the preoccluded carrier-and-object as an indicator of the hidden location where the object resides.

Successful search reconnects the infant with the pre-disappearance object and maintains order in the infant's cognitive world; failed search confronts infants with disorder which has affective consequences. Their striving to preserve order and coherence in the world generates motivation for hiding games—they are quite willing to play hide-and-seek and peek-a-boo at length.

The findings reported here suggest three hypotheses about object permanence development.

First, *object identity is a developmental precursor to object permanence*. When infants can parse a particular disappearance–reappearance transformation as maintaining the individual's identity, they are in a position to discover that it is permanent in between. Permanence is a cognitive interpretation they impose to make sense of events in the world.

Secondly, what is acquired through experience is structured by the identity-preserving transformations themselves. Infants do not at first understand that material objects, qua objects, are permanent, but rather discover that certain transformations are ones that preserve permanence. For example, the current experiments revealed that infants understood object permanence for hiding-by-screen before they understood it for hiding-by-hand. Infants' level of understanding permanence is general inasmuch as it applies beyond the objects (and occluders) on which it was first discovered. However, it is deeply constrained because it applies to objects only insofar as they undergo specified transformations. The authors summarize this by saying that permanence is *transformationally dependent* in infancy.

Thirdly, object permanence development is a series of ordered steps, two of which were characterized in this study. This development culminates in an understanding of permanence at about 18–24 months old that is occlusion *in*dependent, in the sense that material objects, qua objects, are known to be permanent across any and all occlusions. Infants understand that occlusions prevent perceptual access to objects but do not remove them from the external world.

In sum, it is posited that permanence is initially dependent on the nature of the occlusion; with development, it becomes a property of objects. Even for 10–12-month-olds, object permanence is still a work-in-progress, manifested on one disappearance transformation but not another.

The foregoing identity-development theory can be seen as an exemplar of a more general view of infancy and childhood that has come to be called the 'theory theory' (e.g. Gopnik & Meltzoff, 1997). This view does not see infants' similarity to adults in terms of identical concepts or a 'core knowledge' that remain unchanged from infancy to adulthood, but rather in the fact that infants strive to gain a coherent understanding of their world, including the behaviour of the objects around them. Just as mature scientists are distressed when cherished theories are shown false, the infants in the present studies showed negative emotional reactions to certain hidings—ones providing evidence that their understanding of the world did not hold. Presumably, this conflict engenders reorganization of their understanding to incorporate the observed violation within a more comprehensive framework.

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