Inability of Five-Month-Old Infants to Retrieve a Contiguous Object: A Failure of Conceptual Understanding or of Control of Action?

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Infants of 5 to 6 months of age can retrieve a free-standing object, but fail to retrieve the same object from atop a slightly larger object. The accepted explanation has been that the infants do not understand that an object continues to exist independently when placed upon another. Predictions based on that explanation were tested against the hypothesis that infants' problem consists of lack of precision in visually guided reaching and lack of ability to inhibit reflexive reactions to touch. Twelve infants each at 5 and 7 months of age were tested on 16 trials. More 5-month-olds succeeded, in less time, and with fewer touches to an edge of the base, on trials more forgiving of an imprecise reach than on less forgiving trials. Success in retrieving objects close in size and fully contiguous with their bases was seen even at 5 months when the demands on skill in reaching were reduced. It is proposed that when 5-month-old infants fail to retrieve one object placed upon another, it is not because of a lack of conceptual understanding, but because they lack the skill to reach to the top object without accidentally touching an edge of the base en route.

INTRODUCTION

Piaget theorized that infants 5 to 6 months old do not understand the concept of contiguity, i.e., they do not realize "that two objects can be independent of each other when the first is placed upon the second" (Piaget, 1937/1954, p. 177). This view has been echoed by developmental psychologists ever since (see e.g., Bower, 1977, pp. 116–117; Spelke, 1988, p. 207). We offer an alternative hypothesis here: Infants even as young as 5 months *do* understand contiguity. Their problem lies instead in getting their hands accurately to the desired object without touching the edge of the neighboring object, for when they touch an edge they react reflexively by grasping it or withdrawing their hands. The cognitive competence is present by at least 5 months of age; it is the control of action needed to demonstrate that competence that develops later.

Contiguous and "behind." Bower (1977, pp. 116–117) extended Piaget's initial observations of one object on top of another to other conditions of contiguity: "If infants are presented with an object that lacks a boundary of its own—whether top, bottom, front, or back—they will not attempt to grasp the object until they are 9 or 10 months of age. . . . Evidently, it is the common boundary that is critical." Bower (1974) was the first to report that young infants will successfully retrieve a small object when it is placed several inches behind a screen but fail to retrieve that same object when it is directly behind and touching the screen. In 1989, Diamond and Gilbert replicated that finding but went on to demonstrate that infants of 7 months successfully retrieve a small object contiguous with another (the front wall of a small, open-top box) when (1) the con-

tiguous object borders the wall from the front, (2) the object is the same height as the wall, (3) the contiguous object extends behind the wall farther than one half the screen's height, and (4) the box is tipped forward toward the infant (see Figure 1). These are all conditions of contiguity, yet infants of 7 months consistently succeed. In addition, Diamond and Gilbert (1989) found that when an object is *not* contiguous with the front wall of the small box but extends behind the wall a distance less than one half the wall's height, infants of 7 months fail to retrieve the object but succeed if the object is placed farther behind the wall (see Figure 1).

Diamond and Gilbert (1989) concluded that 7-month-old infants *do* seem to understand the concept of contiguity as evidenced by the many conditions of contiguity under which they succeed. The problem appears to be motor rather than conceptual. Diamond and Gilbert designed their experimental conditions to test their hypothesis that 7-month-old infants' problem is twofold. *The first part of the problem is that their visually guided reaching is imperfect. When an arched, or two-directional, reach (over the wall and then back for the toy) is needed, 7-month-old infants often do not get cleanly to their target (the toy); they often accidentally touch the edge of the wall en route to their goal.* (A simple, direct reach is sufficient when the box is tipped forward or when any portion of the goal object is (1) farther behind the wall than one half the wall's height, (2) the same height as the wall, or (3) in front of the wall.) In-
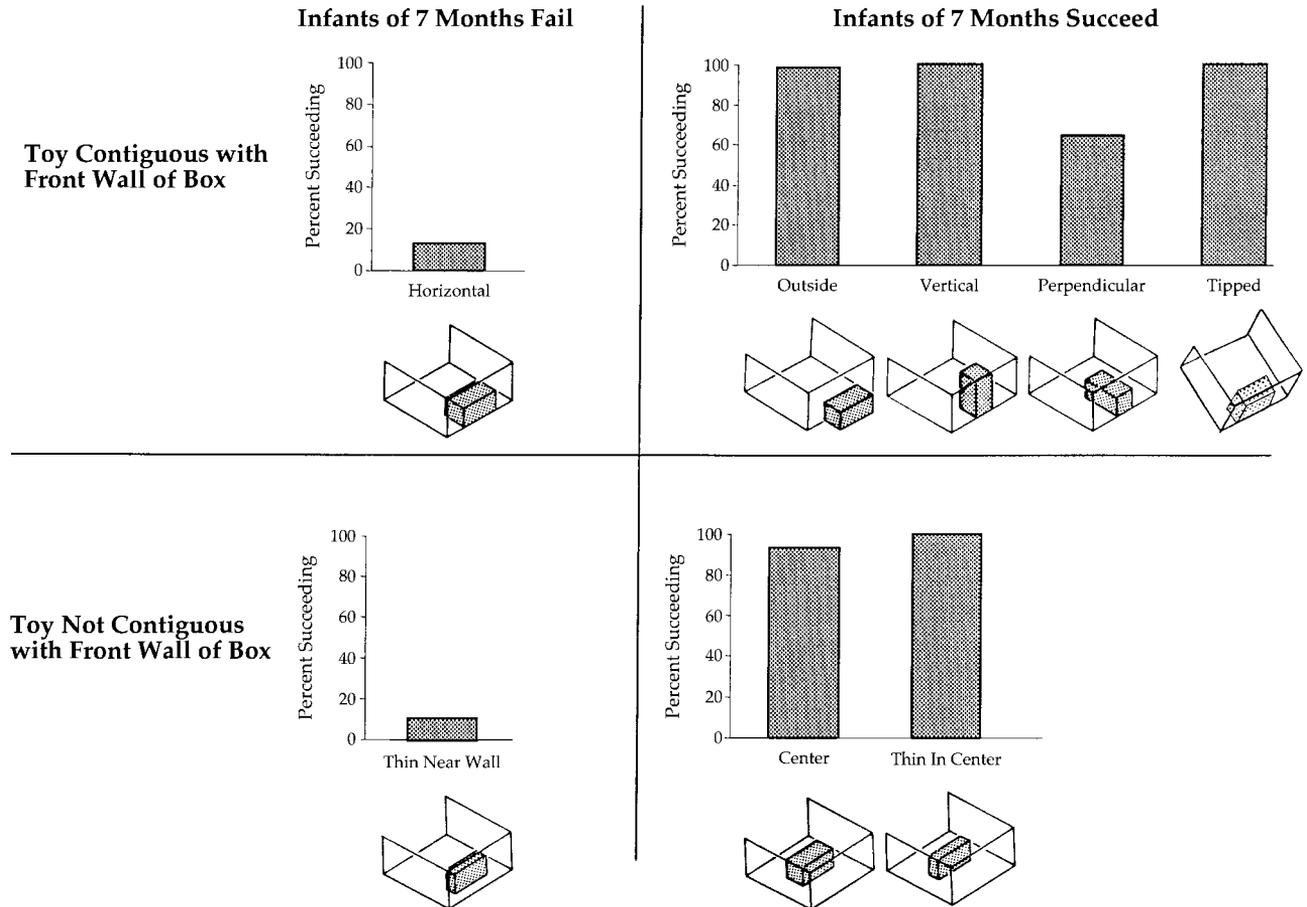
Figure 1   In Diamond & Gilbert's (1989) examination of two contiguous objects, one behind the other, they found that 7-month-old infants succeeded in several conditions where the objects were contiguous and failed in a condition where they were not contiguous. The variable that determined whether the infants would succeed was whether they could retrieve the goal by a straight reach or whether they would have to reach over the front wall of the box and then curve their hand around to retrieve the object.

deed, Diamond and Gilbert found that infants of 7 months touched the front wall over three times as often when a two-directional reach was required as when the toy could be obtained by a unidirectional reach.

This, by itself, would not prevent infants from succeeding were there not a second problem. When an adult's hand grazes a neighboring object, the adult simply continues on to the goal object; infants of 7 months do not. *The second part of the problem for infants of 7 months is that the reflexive reactions of the hand to contact (the grasp and avoidance reflexes; Twitchell, 1965, 1970), are not yet fully inhibited, especially when the goal of an action is to grasp an object.* Hence, when infants of 7 months touched the front wall of the box en route to the toy, they reflexively grasped the front wall (the more typical reaction) or reflexively pulled their hands back in the avoidance reaction. These reflexive reactions, in and of themselves, would not prevent in-

fants from succeeding were their reaches sufficiently accurate to avoid touching the wall. It is the conjunction of imprecision in executing complex reaches and inadequate inhibition of the primitive reflexes of the hand that cause 7-month-olds to often fail to retrieve an object bordering, and directly behind, a small wall or screen. Thus, Diamond & Gilbert (1989) demonstrated that the critical variable is the complexity of the route to the object, not whether the goal object is contiguous with another object or not.

Contiguous and "on top of." Diamond and Gilbert's explanation for the failure of 7-month-old infants in the "behind" condition cannot account for the failure of younger infants in the "on-top-of" condition. In the latter condition a simple, direct reach will suffice. Perhaps infants of 5 months do not understand the concept of contiguity, although the results of Diamond and Gilbert (1989) suggest that by 7 months they do.

We hypothesize, however, that the problem at 5 months, like that at 7 months, is fundamentally in motor execution, not in conceptual understanding. At 5 months, skill in executing even a simple, direct visually-guided reach is sufficiently imperfect that if the supporting object is slightly larger than the target object, 5-month-old infants are likely to touch the edge of the base en route to their goal. Such a touch elicits the grasp reflex. Imprecision in reaching at 5–6 months has been known since at least 1932 when Richardson documented that whereas infants of 6 months can retrieve a freestanding object, they fail to do so if they have to reach through a grill.

To test between the understanding-contiguity and skill-in-reaching explanations of why 5-month-old infants fail to retrieve one object placed on top of another object, the two explanations must be clearly specified. According to at least one version of the understanding-contiguity hypothesis (Bower, 1977, p. 117), "it is the common boundary that is critical." Infants should fail when two objects share a common boundary and succeed when they do not. When they fail it is not because of difficulty in reaching but because of erroneously conceiving of the two contiguous objects as "a single unit" (Spelke, 1988, p. 207). Understanding-contiguity theorists have allowed for a few exceptions to a strict interpretation of this: Infants of 5–6 months can retrieve the object on top if it stands out clearly from its support (as in the case of a narrow, deep goblet on top of a book (Piaget, 1937/1954, p. 177). Infants can succeed, according to Piaget (1937/1954, p. 178) if the goal object is on top of "a surface large enough to be likened to simple neutral bases" (such as a large cushion or coverlet).

Our skill-in-reaching hypothesis makes specific predictions about conditions of contiguity under which infants of 5 months should succeed. Regardless of whether two objects are contiguous or not, infants of 5 months should fail when one would predict that a slightly imprecise reach, or a reach with fingers spread wide open, would be likely to contact one or more edges of the bottom object, especially if the edges of the bottom object are readily graspable by an infant. They should succeed when, even if their aim is slightly off, they are not likely to contact a graspable edge of the base en route to the goal object.

To make this a clear test between the skill-in-reaching and understanding-contiguity positions, in many of the conditions where we predict success the goal object and base share a boundary and the goal object and base are fairly similar in size, the goal object does not stand out well from the base, and the base is not so large as to serve as a neutral base. These conditions of contiguity, where we are predicting success, meet all the criteria that have been specified thus far by conceptual-understanding theorists for predicting failure. Such conditions include when a base only slightly larger than the object on top does not provide an easily graspable edge (for example, when the base is a solid rectangle lying flat on the tabletop) or when the base is a small cushion, with no hard edges to elicit the grasp reflex.

We also predict that 5-month-old infants should succeed when the goal object is slightly larger than the base (because the edge of the goal object is likely to be contacted before an edge of the base) even if the base provides an easily graspable edge and even if goal object and base are quite close in size. Here, the goal object and base are as close in size, and as contiguous, as when the base is slightly larger than the goal object. We predict success, however, with the goal object larger than the base and failure with the base larger than goal object. These two predictions are based solely on the likelihood of contacting an edge of the base en route to the object on top. We also predict that if you take a condition where most 5-month-old infants fail (goal object and base close in size, fully contiguous along the top of the base and bottom of the goal object) and simply place the base-with-goal-object-on-top very close to the infant, significantly more 5-month-olds will succeed (because with the objects very close, the infant is likely to reach from above and thus grasp the goal object before contacting the base, whereas if the objects are further away, the infant is likely to approach the objects from the front and thus is likely to touch the protruding base before gaining the goal object). In the series of trials described below we have independently varied degree of contiguity between the goal object and base and the likelihood of contacting a graspable edge of the base en route to the goal object.

Before undertaking an extended series of tests between the predictions that one might generate from the conceptual understanding and motor execution hypotheses, we first sought to replicate (by using a small wooden block and a slightly larger wooden block) Piaget's (1937/1954, p. 177) classic observation of Laurent's failure to retrieve a matchbox on a small book: "At 0;6(22) Laurent tried to grasp a box of matches. When he is at the point of reaching it I place it on a book; he immediately withdraws his hand, then grasps the book itself." Our 5-month-olds succeeded; we could not replicate Piaget's observation. Piaget was a brilliant, utterly reliable observer of behavior; we were probably doing something wrong if we obtained different results. We made our base more "book-like," introducing an indentation on three sides to mimic the way a book's pages do not extend as far as the cover. When we presented infants the

same condition we had presented before (the "binding" side of the base turned toward the infants), 5-month-olds again succeeded. When the base turned around, so that the "pages" faced the infants, presenting an easily graspable edge (i.e., the edges of the top "cover" of our wooden "book"), the infants failed, exactly as Piaget had observed, and precisely in the way Piaget had observed them to fail (by showing the grasp or avoidance reactions). Although Piaget never reported the orientation in which he presented the book, it is our suspicion that Piaget held the book by its back binding and placed the matchbox on the book with the pages facing his infant son.

METHODS

Participants. Twenty-four healthy, term infants (12 male, 12 female) were tested in our infant laboratory. Half of the infants were 5 months of age (*M* = 23 weeks, 4 days; *range* = 21 weeks, 5 days–25 weeks, 2 days), and half were 7 months of age (*M* = 32 weeks, 4 days; *range* = 31 weeks, 3 days–33 weeks, 6 days). All came from middle class homes and all were from European American backgrounds. The mothers of about half the infants were working outside the home and 42% of the infants had at least one sibling. In addition to the 24 infants whose data are reported, 7 infants (6 at 5 months and one at 7 months) came to our laboratory but could not be included. Four infants of 5 months became too frustrated with our task and refused to continue reaching for the objects. Experimenter errors occurred in the remaining three sessions.

Procedure. Infants sat on their parents' laps at a wooden table (68.75 cm high, with a tabletop 50 cm × 61 cm) across from the experimenter (AD). At the outset of every trial, the experimenter attracted the infant's attention to the goal object. With the other hand, the experimenter placed the base on the table. Then the experimenter placed the goal object on top of the base and slid the base, with the goal object on top of it, within reach of the infant. The infant was encouraged to retrieve the goal object. All bases, except for a red cushion, were made of wood and painted with nontoxic tempera paint. A variety of goal objects were used to maintain a high level of interest; many were brightly colored, or filled with coins, or both. A trial ended when the infant succeeded in retrieving the goal object or refused to try any longer. The experimenter held onto the two rear corners of the base during each trial. A total of 16 trials were administered where (1) degree of contiguity between the goal object and base and (2) the likelihood of contacting a graspable edge of the base en route to the goal object were independently varied. One 5-month-old would

not work at our task after Trial 12; another 5-month-old refused to try on Trials 9, 14, and 15; otherwise, all infants received all 16 trials in the same order. All sessions were videotaped for detailed analyses using two cameras. One camera filmed from over the rear right corner of the testing table; the other filmed from over the rear left corner.

The series of trials was designed to provide 10 pairings where two trials differed in only one detail that critically affected the probability of contacting a graspable edge of the base. We predicted that if we had designed our trials correctly, on one trial in each of these 10 pairings, infants of 5 months would touch and grasp an edge of the base more often than on the other trial in the pair. We further predicted that on the trials where infants touched and grasped the edge of the base more often, fewer infants of 5 months would succeed and trial durations would be longer. On half of these 10 pairings, infants encountered the trial we predicted would be easier first.

For 8 of these 10 pairings, a prediction based on the degree of contiguity between the goal object and base (the variable Piaget and Bower considered critical) is different from the prediction based on our hypothesis (that the critical variable is whether an imprecise reach might contact a graspable edge of the base); see Figure 2.

The independent measures were the age and sex of the infant, the degree of contiguity between the goal object and base, and the likelihood of contacting a graspable edge of the base in the process of trying to retrieve the goal object. The dependent measures were (1) whether or not the goal object was retrieved, (2) trial duration, (3) number of touches to an edge of the base (an edge being defined as the intersection of two planes), and (4) percentage of touches to an edge of the base that were followed immediately by grasping that edge. Whether or not the infant succeeded in retrieving the toy, trial duration, number of touches to the base, location of each touch, and the infant's reaction to each touch were coded from the videotape.

Our predictions were as follows: (1) Infants of 7 months would perform better (i.e., more would succeed on each trial and in less time) than infants of 5 months and this age difference would be greater the more likely a slightly imprecise reach for the goal object would be to contact a graspable edge of the base. (2) Infants of 7 months would be less likely to touch an edge of the base than infants of 5 months, and this age difference would be greater the more likely a slightly imprecise reach for the goal object would be to contact a graspable edge of the base. (3) Infants of 5 months would perform better, and be less likely to touch an edge of the base, on those trials where a

PREDICTIONS FOR PERFORMANCE OF FIVE-MONTH-OLDS
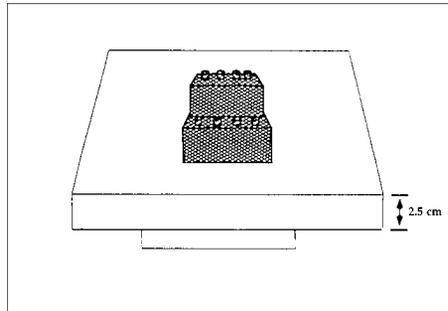
Variable of Interest based on Understanding Contiguity:	Variables of Interest based on Skill in Reaching:
Degree of contiguity between the goal object and base	If the reach to the goal object is slightly off the mark, is it likely that the base will be touched? If the base is touched, is it likely that it will be grasped?

Trial 1   Tall object A centered on larger base, no rim

Goal Object = blue plastic Lego (6.3 × 3.1 × 4.2 cm)[a]; Base = red wooden platform (22.5 × 12.5 × 3.8 cm)

| Predicts success because the goal object stands out well from the base.	Predicts success because the goal object stands out well from the base so that even an imprecisely executed reach would be likely to reach the goal object without touching the base.
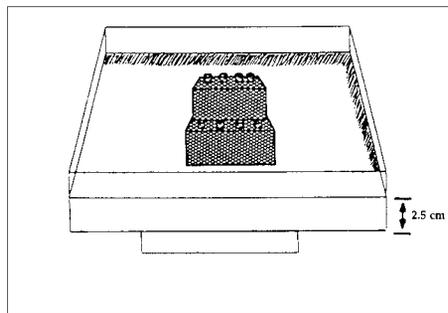
Trial 2   Tall object A centered on larger base with rim

Goal Object = Trial 1; Base = same as on Trial 1, but with rim 1.9 cm high

| Predicts performance should be comparable on Trial 2 to that on Trial 1 because the degree of contiguity is the same; infants should succeed because the goal object stands out well from the base.	Predicts performance should be worse on Trial 2 than on Trial 1 because, although the degree of contiguity is the same, the lip around the base makes it likely that if infants are not precise in aiming their reach, their hands will touch the base en route to the goal object.
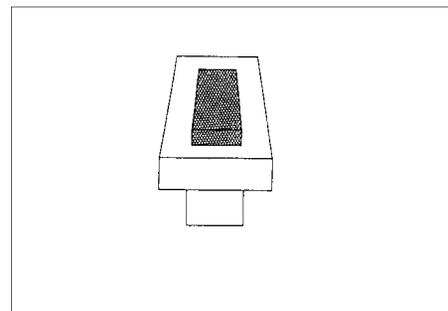
Trial 3   Object B centered on base

Goal Object = rectangular cardboard box covered with silver foil (10.0 × 3.8 × 1.2 cm); Base = red, wooden platform (12.5 × 7.5 × 4.4 cm)

| Predicts failure because here the goal object is on top of a slightly larger base, fully sharing one boundary of the goal object.	Predicts failure because if infants are slightly imprecise in aiming their reach, they are likely to touch the base in the course of reaching for the goal object.
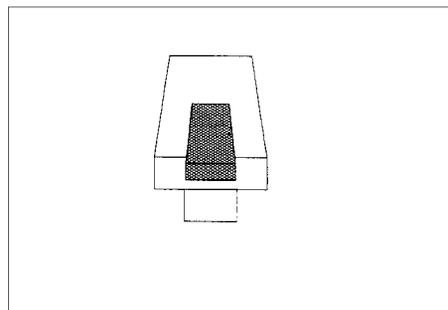
Trial 4   Object B extending over front of base

Goal Object and Base = those on Trial 3, with object extending over front of base

Predicts that Trial 4 should be easier than Trial 3 because object and base are only partially contiguous.	Predicts that Trial 4 should be easier than Trial 3 because even an imprecise reach would be likely to arrive at the goal object without touching the base.

Figure 2   Illustration and description of the trials administered to the infants, grouped in sets of trials differing in only one variable, with that variable affecting the likelihood of a slightly imprecise reach touching a graspable edge of the base. The predictions generated by our skill-in-reaching hypothesis are contrasted with the predictions generated by an understanding-contiguity hypothesis. [a] Measurements are given in length × width × height.
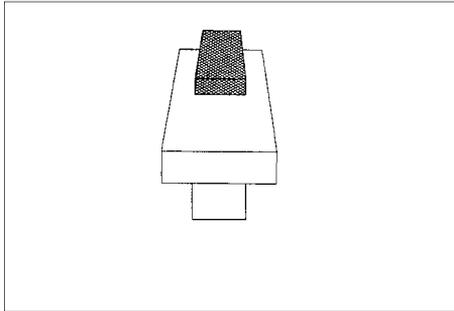
Trial 14   Object B extending over back of base

Goal Object and Base = those on Trials 3 and 4, with object extending over back of base

Predicts performance on Trial 14 should be comparable to that on Trial 4, because the degree of contiguity is the same, and better than on Trial 3, because the degree of contiguity is less.

Predicts performance should be worse on Trial 14 than on either Trial 3 or Trial 4, because infants should be most likely to touch the base en route to the goal object on Trial 14.
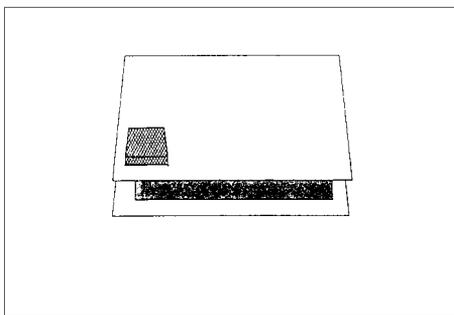
Trial 5   Object C near front corner of much larger base

Goal Object = square metal box with picture of cat (3.5 × 3.5 × 0.8 cm); Base = yellow wooden "book" (12.5 × 15.6 × 2.5 cm) with object at front, left corner of base

Predicts infants should succeed on Trial 5 because the base is much larger than the goal object on top.

Predicts infants should fail because the goal object is near two edges of the base. Infants who are imprecise in aiming their reach should be likely to touch an edge of the base en route to the goal object.
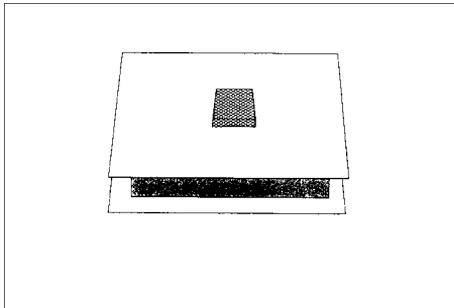
Trial 10   Object C centered on larger base

Goal Object and Base = those on Trial 5, with object centered on base

Predicts performance should be comparable to that on Trial 5, because the degree of contiguity is the same. Infants should succeed because the base is much larger than the goal object on top.

Predicts performance should be better than on Trial 5. Infants should succeed because even an imprecise reach is unlikely to result in contact with an edge of the base.
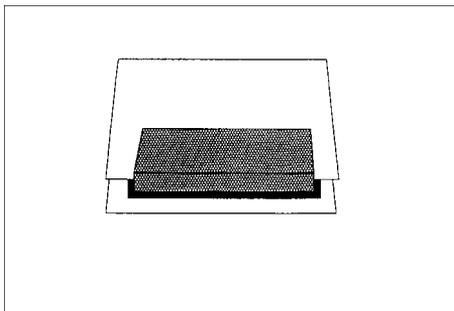
Trial 6   Object D extending over front of base

Goal Object = stack of index cards covered with silver foil (12.5 × 7.5 × 1.6 cm); Base = red wooden "book" (15.6 × 12.5 × 2.5 cm) with object extending over front of base

Prediction is unclear because goal object and base are partially contiguous, yet partially not contiguous.

Predicts success because even an imprecise reach would be likely to arrive at the goal object without touching the base below.

Figure 2   (Continued)
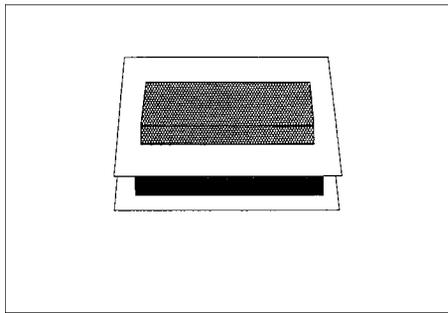
Trial 7   Object D centered on base

Goal Object and Base = those on Trial 6, with object centered on base

Predicts Trial 7 should be harder than Trial 6 because on Trial 7 the goal object and base are fully contiguous, whereas the degree of shared boundary is less on Trial 6.

Predicts Trial 7 should be harder than Trial 6 because on Trial 7 if infants are slightly imprecise in aiming their reach, they are likely to touch the base in the course of reaching for the goal object.
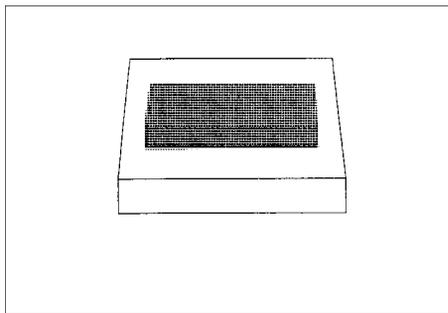

Trial 13   Object D centered on base, "binding" toward infant

Goal Object = those on Trials 6 and 7; Base = same as on Trials 6 and 7, but with no indentation on the sides facing infant; object centered on base

Predicts performance on Trial 13 should be comparable to that on Trial 7; goal object and base are equally contiguous on the two trials.

Predicts that Trial 13 should be easier than Trial 7 because whereas infants are equally likely to touch the base en route to the goal object on both trials, the base on Trial 13 presents a less graspable edge.
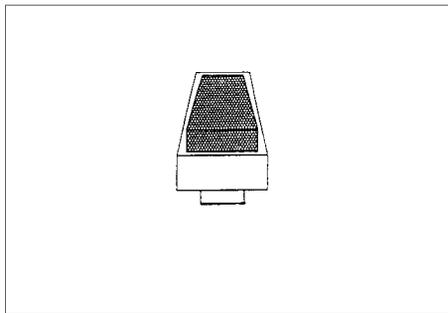
Trial 8   Object E on slightly larger base

Goal Object = multicolored rice candy box (8.8 × 4.4 × 1.6 cm); Base = yellow wooden platform (9.4 × 6.0 × 3.1 cm)

Predicts failure because the goal object and base are close in size and fully contiguous.

Predicts failure because if infants are slightly imprecise in aiming their reach, they are likely to touch the base in the course of reaching for the goal object.
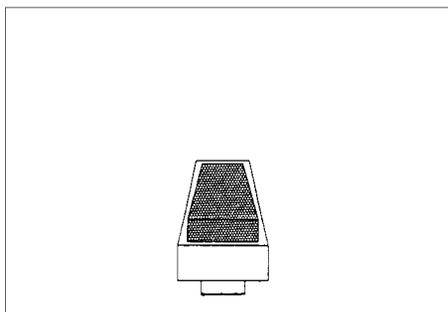
Trial 9   Object E on slightly larger base, at front edge of the table

Goal Object and Base = those on Trial 8, with object and base very close to infant

Predicts performance should be comparable on Trial 9 to that on Trial 8, since the conditions are identical except that the stimuli are closer to the infant on Trial 9.

Predicts better performance on Trial 9 than on Trial 8 because the infant's reach is more likely to come from directly above the display on Trial 9 rather than start forward of the display, and so is less likely to contact the base en route to the goal object.

Figure 2   (*Continued***)**
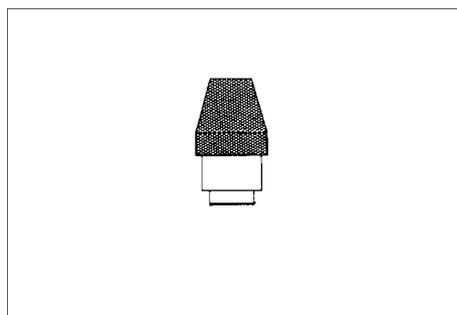
Trial 12   Object E on slightly smaller base

Goal Object = those on Trials 6 and 7; Base = slightly smaller yellow wooden
platform (8.1 × 4.0 × 3.1 cm)

Predicts performance should be comparable on Trial 12 to that on Trial 8; on both trials the goal object and base are close in size and are fully contiguous along one side.

Predicts infants should perform better on Trial 12 than on Trial 8 because on Trial 12 the goal object overhangs the base on all sides and hence infants should be unlikely to come in contact with the base en route to the goal object.
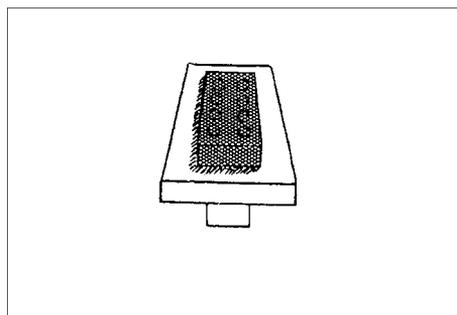
Trial 15   Object F centered .5 inch above base

Goal Object = yellow plastic Lego (8.8 × 3.8 × 2.3 cm); Base = red wooden platform (17.9 × 8.8 × 3.5 cm) with protrusion (2.5 × 1.5 × 1.2 cm)

Predicts success on Trial 15 because the goal object and base are not contiguous. (The goal object sits on a small, thin ridge hidden beneath the goal object.)

Predicts success because it is easy to grasp the goal object without touching the base. The space below the goal object makes it easy to get a hand around the goal object to grasp it.
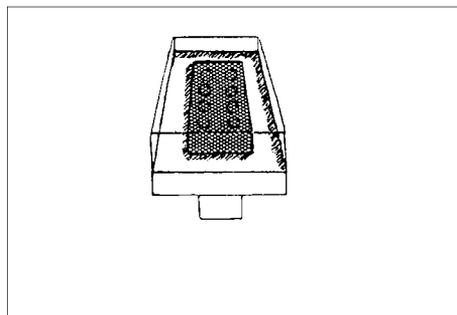
Trial 16   Object F centered .5 inch above base, with rim

Goal Object = Trial 15; Base = same as on Trial 15 but with rim 2.7 cm high

Predicts performance on Trial 16 should be comparable to that on Trial 15 because the goal object and base are still not contiguous.

Predicts performance should be worse than on Trial 15 because the lip around the base makes it likely that if infants are not precise in aiming their reach, their hands will touch the base en route to the goal object.
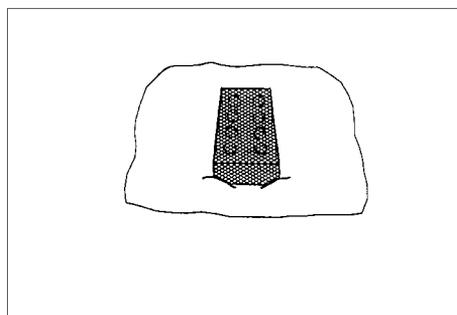

Trial 11   Object F centered on cushion

Goal Object = that on Trials 15 and 16; Base = red cushion (17.5 × 16.3 × 3.1 cm)

Predicts failure on Trial 11 because a goal object is on top of a slightly larger base, fully sharing a boundary.

Predicts infants should succeed because the base has no hard edges to elicit the grasp reflex.

Figure 2   (*Continued*)

slightly imprecise reach was less likely to come in contact with a graspable edge of the base than on trials less forgiving of an imprecise reach. (4) Infants of 5 or 7 months would react to touching an edge of the base by grasping the base or by withdrawing their hand in the avoidance reaction. Because the reflexes of the hand disappear during the first year of life, infants of 7 months would show these reactions less often than 5-month-olds.

We also constructed a 5-point scale of level of difficulty based on the likelihood of the infant contacting a graspable edge of the base in the process of reaching for the goal object. Trial 14, where the goal object was partially on top of the base and partially overhanging the back of the base, received a score of 5 (most difficult) because such a large proportion of the base lay in front of the goal object that the likelihood of touching some edge of the base (front, left, or right) before getting to the goal object was very high.

The trials that we predicted would be next most difficult (Trials 2, 3, 5, 7, 8, and 16) received a score of 4. On Trials 2 and 16 there was a lip around the base. We predicted it would be difficult for infants to avoid the lip when reaching for the goal object, even though on Trial 2 the goal object stood out some distance from the base and on Trial 16 the base and goal object appeared not to be contiguous at all. (This was accomplished by attaching a small protrusion to the top of the base, which was completely concealed when the goal object was placed on top of the protrusion, which gave the appearance that the goal object was suspended in midair.) On Trials 3, 7, and 8, the goal object sat atop a slightly larger base; it did not stand out from the base and the top of the base presented an easily graspable surface. On Trial 5, a small goal object was placed on top of a much larger base, but the goal object was placed near the front left corner, that is, near two graspable edges of the base.

We predicted that Trials 9, 10, and 13 would be intermediate in difficulty (Level 3). Trials 9 and 13 presented the goal object on top of a slightly larger base. On Trial 9, however, the goal object and base were placed extremely close to the infant. We hypothesized that the infant might reach straight down from on top of the goal object and hence might be more likely to contact the goal object without touching the base than on the comparable trial with the base and goal object further from the infant (Trial 8). On Trial 13, the base did not present an easily graspable edge; hence, we predicted it would present less difficulty than the comparable trial with a more easily graspable base (Trial 7). For Trial 10, a small goal object was placed on top of a much larger base. The goal object and base were the same as on Trial 5; however, on Trial 5 the

goal object was near two edges of the base, whereas the goal object was now placed in the center of the base, far from the edges.

We predicted that Trials 1, 4, 6, 12, and 15 would be easier for infants (Level 2) because they would be unlikely to touch the base en route to the goal objects. Trial 1 presented a goal object that stood out some distance from its base (as on Trial 2, but with no lip around the base). Trials 4 and 6 presented goal objects only partially on top of their respective bases, overhanging the front of the base. Trial 12 presented a goal object atop a slightly smaller base; no edge of the base extended beyond the goal object. Trial 15 presented a goal object that did not appear to be contiguous with its base at all but rather appeared to be suspended in air above the base (as on Trial 16, but with no lip around the base). Finally, Trial 11 was predicted to be the easiest trial (Level 1) because the base, being a cushion, provided no hard edges that would elicit the grasp or avoidance reactions.

Half of the trials in six sessions were coded twice from the videotape, once early in the study and again after roughly half the videocoding was completed. Intracoder reliability was >.90 (α coefficient) for all items (success/failure, trial duration, number of touches to the base, location of each touch on the base, and reaction to each touch of the base). The coder was blind to the hypotheses and aims of the experiment until late in the study. Another person blind to the hypotheses also coded two of the last sessions. Intercoder reliability for those two sessions was ≥.95 (α coefficient) for success/failure, trial duration, and number of touches to the base, and it was ≥.86 for location of each touch on the base and reaction to each touch of the base.

RESULTS

No significant sex difference was found; all results are reported collapsed across gender. As predicted, infants of 7 months performed better than infants of 5 months. The mean percentage of correct retrievals across all 16 trials was 95% for infants of 7 months but only 58% for infants of 5 months; linear regression: $F(1, 375) = 90.89$, $p < .001$; $R^2 = .20$. The mean trial duration was only 3.7 s for infants of 7 months but 14.5 s for infants of 5 months; linear regression using the log of trial duration because of unequal variances in the two age groups: $F(1, 375) = 206.82$, $p < .001$; $R^2 = .36$. Infants of 7 months were less likely to touch the base underneath the goal object than were infants of 5 months. The mean number of touches to an edge of a base per trial over the 15 trials where the bases had edges was 1.4 for 7-month-olds and 3.0 for 5-month-olds; linear regres-

Table 1 Performance of both Age Groups on Each Trial, Trials Ordered by Level of Difficulty

Trial	Percent Correct			Mean Trial Duration			Mean Number of Touches to an Edge of the Base		
	Age 5 Months	Age 7 Months	Difference	Age 5 Months	Age 7 Months	Difference+	Age 5 Months	Age 7 Months	Difference+
Easiest trial									
T11: Small cushion as base	100	100	0 ns	5.5	2.5	3.0 $F = 9.17$ $p < .005$	n/a	n/a	n/a
Easy trials									
T1: Object standing well out from base	100	100	0 ns	7.4	3.3	3.1 $F = 3.32$ $p < .04$	.9	.4	.5 $F = 4.09$ $p < .03$
T4: Object extending over front of base	92	92	0 ns	13.2	2.7	10.5 $F = 14.17$ $p < .001$	1.8	.6	1.2 $F = 6.58$ $p < .01$
T6: Object extending over front of base	88	92	4 $F = .12$ ns	13.2	2.7	10.5* $F = 11.19$ $p < .002$	1.2	.5	.7 $F = 5.17$ $p < .01$
T12: Object slightly larger than base	83	100	17 $F = 2.20$ ns	7.2	1.8	5.4* $F = 33.61$ $p < .0001$	1.1	.5	.6 $F = 6.10$ $p < .01$
T15: Object not contiguous with base ($N = 11$ at 5 months)	100	100	0 ns	4.4	2.2	2.8* $F = 9.85$ $p < .003$	1.2	.5	.7 $F = 5.22$ $p < .01$
Intermediate trials									
T9: = T8 but very near infant ($N = 11$ at 5 months)	73	100	27 $F = 4.11$ $p < .03$	6.1	2.9	3.8 $F = 3.97$ $p < .03$	1.2	1.2	0 ns
T10: Small, thin object on large base	33	92	59* $F = 12.53$ $p < .001$	19.2	3.7	15.5* $F = 27.02$ $p < .0001$	4.1	1.1	3.0* $F = 22.46$ $p < .0001$
T13: "Binding" side of base presented ($N = 11$ at 5 months)	64	92	28 $F = 2.74$ ns	15.9	4.3	11.7 $F = 8.58$ $p < .004$	3.9	1.3	2.6* $F = 15.07$ $p < .0001$
Difficult trials									
T2: Rim around base	67	100	33 $F = 5.50$ $p < .01$	25.6	5.3	20.3* $F = 28.65$ $p < .0001$	5.2	.8	4.4* $F = 29.20$ $p < .0001$
T3: Object slightly smaller than base	17	100	83* $F = 55.00$ $p < .0001$	20.2	4.8	15.4* $F = 26.71$ $p < .0001$	5.1	1.3	3.8* $F = 27.35$ $p < .0001$

T5: T10's object near front corner of base	29	100	71* $F = 29.71$ $p < .0001$	13.3	3.3	6.8* $F = 18.95$ $p < .0002$	4.1	1.4	2.7* $F = 19.52$ $p < .0001$
T7: "Pages" side of base presented	17	92	75* $F = 28.74$ $p < .0001$	24.5	5.5	19.0* $F = 31.51$ $p < .0001$	5.2	1.8	3.4* $F = 26.42$ $p < .001$
T8: Object slightly smaller than base	33	100	67* $F = 22.00$ $p < .0001$	13.9	3.1	10.8* $F = 42.57$ $p < .0001$	3.5	1.1	2.4* $F = 14.69$ $p < .0005$
T16: Rim around base ($N = 10$ at 5 months)	30	92	62* $F = 13.75$ $p < .0001$	20.1	4.7	15.0* $F = 22.84$ $p < .0001$	4.3	1.8	2.5* $F = 16.04$ $p < .0003$
Hardest trial									
T14: Object extending over back of base ($N = 10$ at 5 months)	0	75	75* $F = 27.27$ $p < .0001$	24.4	6.5	16.1* $F = 26.85$ $p < .0001$	3.5	2.6	.9 $F = 7.42$ $p < .01$
Summary									
Easiest trial (Trial 11)	100	100	0 *ns*	5.5	2.5	3.0 $F = 9.17$ $p < .005$	n/a	n/a	n/a
Easy trials (Trials 1, 4, 6, 12, 15)	95	97	2 $F = 0.08$ *ns*	8.9	2.6	6.6* $F = 49.28$ $p < .0001$	1.3 *range* = 0–3	.5 *range* = 0–1	.8 $F = 9.67$ $p < .004$
Intermediate trials (Trials 9, 10, 13)	58	94	36* $F = 25.21$ $p < .0001$	14.1	3.6	10.0* $F = 23.06$ $p < .0001$	3.1 *range* = 0–5	1.2 *range* = 0–2	1.9* $F = 21.34$ $p < .0001$
Difficult trials (Trials 2, 3, 5, 7, 8, 16)	31	97	66* $F = 148.05$ $p < .0001$	19.6	4.4	15.2* $F = 165.69$ $p < .0001$	4.5 *range* = 1–6	1.3	3.2* $F = 148.71$ $p < .0001$
Hardest trial (Trial 14) ($N = 10$ at 5 months)	0	75	75* $F = 27.27$ $p < .0001$	24.4	6.5	16.1* $F = 26.85$ $p < .0001$	3.5 *range* = 1–6	2.6 *range* = 1–4	.9 $F = 7.42$ $p < .01$

Note: Level of difficulty was determined solely by the likelihood of contacting a graspable edge of the base en route to reaching for the goal object atop the base. Number of subjects = 12 unless otherwise noted. The number of 7-month-old participants was 12 on every trial. Degrees of freedom = 1, 22 when the N at 5 months = 12; df = 1, 21 when the N at 5 months = 11; df = 1, 20 when the N at 5 months = 10.

* Difference in performance between infants of 5 and 7 months was statistically significant. Because 16 comparisons were run for each dependent measure above, the usual statistical significance level of $p = .05$ was divided by 16. Hence, only p values < .003 are considered statistically significant.

+ Log transformations were used for analyses of differences in trial duration and number of touches to an edge of the base because of unequal variances in the two age groups.

sion using the logarithmic transformation of number of touches to the edge of the base because of unequal variances: $F(1, 375) = 275.87$, $p < .001$; $R^2 = .44$.

We hypothesized that at 5 months, infants are less accurate in aiming their reaches than they are 2 months later at 7 months. Hence, we predicted that the more unforgiving the conditions of a trial to a slight inaccuracy in aiming the reach, the greater the age difference would be in performance. Trials with a low level of difficulty were trials where even if the reach were inaccurate, an edge of the base would probably not be touched. For each trial we ordered infants of the same age from the best to the worst on each dependent variable. Then we calculated the difference between the performance of the infant of 5 months and the infant of 7 months at each rank for each trial and each dependent measure and performed linear regressions on those difference scores. Our predictions were confirmed. There was a greater age difference in percentage of successful retrievals as trials increased in their likelihood that a graspable edge of the base would be contacted, $F(4, 180) = 26.46$, $p < .001$, $R^2 = .37$. Similarly, there was a greater age difference in trial duration the more unforgiving the conditions were to a slight inaccuracy in the reach, $F(4, 179) = 14.27$, $p < .001$, $R^2 = .24$. The disparity in the number of touches to the edge of the base between infants of 5 months and infants of 7 months was also greater on the more difficult trials than on the trials we predicted would be easier, $F(4, 179) = 10.4$, $p < .001$, $R^2 = .18$. (See Table 1.) Predictions 1 and 2 were thus confirmed.

We hypothesized that the reason infants of 5 months fail to retrieve an object placed on top of a slightly larger object is *not* because the infants do not understand that these objects are still two separate objects but rather that they lack the skill to reach accurately to the goal object without touching the base en route, and if they touch an easily-graspable edge of the base, the grasp reflex is triggered by that accidental touch. Thus, Prediction 3 was that infants of 5 months would perform worse on those trials where a slightly inaccurate reach for the goal object was more likely to contact a graspable edge of the supporting object, independent of the degree of contiguity between the two objects. Indeed, 5-month-olds were less likely to retrieve the goal object on trials where it was more likely that a graspable edge of the base might be touched while reaching for the goal object; regression: $F(1, 183) = 101.37$, $p < .001$, $R^2 = .37$. Trial durations were also longer the greater the likelihood of touching a graspable edge of the base; regression with logarithmic transformation: $F(1, 182) = 56.93$, $p < .001$, $R^2 = .24$. Empirical confirmation of the validity of the 5-point scale of the likelihood of contact-

ing a graspable edge of the base can be seen by the strong relationship between the number of touches to an edge of the base and the trial's score on our scale; regression with logarithmic transformation: $F(1, 182) = 87.42$, $p < .001$, $R^2 = .37$.

An alternative interpretation of our findings that 5-month-olds were more likely to grasp the base and not retrieve the goal object than were 7-month-olds might be that 5-month-olds were actually reaching for the base rather than the goal object. Evidence arguing against that interpretation is as follows: (1) The goal objects were more attractive than the bases. (2) Infants of both ages tended to keep their eyes fixed on the goal object even when they grasped the base. (3) Infants reacted to touching and grasping the base by pulling their hands back and trying the reach again. (4) Most telling, 5-month-olds retrieved the same goal objects from the same bases on trials where it was easier to physically reach to the goal object without touching the base en route (e.g., Trial 3 versus 4 and Trial 8 versus 9).

Besides being less accurate in aiming their reach, infants of 5 months are also more likely to reach with their hand wide open and fingers spread wide (see Figure 3)—a good strategy when one's aim is imprecise. The imprecise aim of their reach and their open, finger-spread hand position combined to increase the likelihood of accidentally touching the base in the course of reaching for the goal object. Sometimes a single finger would be hooked on the base while the rest of the hand grasped the goal object. Sometimes their palm hit an edge of the base and all their fingers curled around the edge. Note also in Figure 3 that the first hand the infant reached with contacted and grasped the base, though the infant's eyes remained fixed on the goal object. The attention of all infants appeared to be centered on the goal object, even when they grasped the base instead.

Importantly, our results provide four instances of contiguity (Trials 9, 11, 12, and 13) that met all of the stated criteria of understanding-contiguity theorists for when infants of 5–6 months should fail. We found that most 5-month-old infants succeeded in retrieving the goal object from its support on each of those four trials. Thus, most 5-month-olds retrieved a goal object from a slightly larger base when the base did not afford an easily graspable edge (64%), when the base and goal object were very close to the infant (73%), and when the base was a small cushion (100%). Most 5-month-olds also retrieved the goal object when it was on a base slightly smaller than the goal object (83%). On each of these four trials, the percentage of 5-month-olds succeeding was not significantly different from that of the 7-month-olds tested. On the other hand, on trials where it was difficult to retrieve the goal object without contacting a graspable edge of
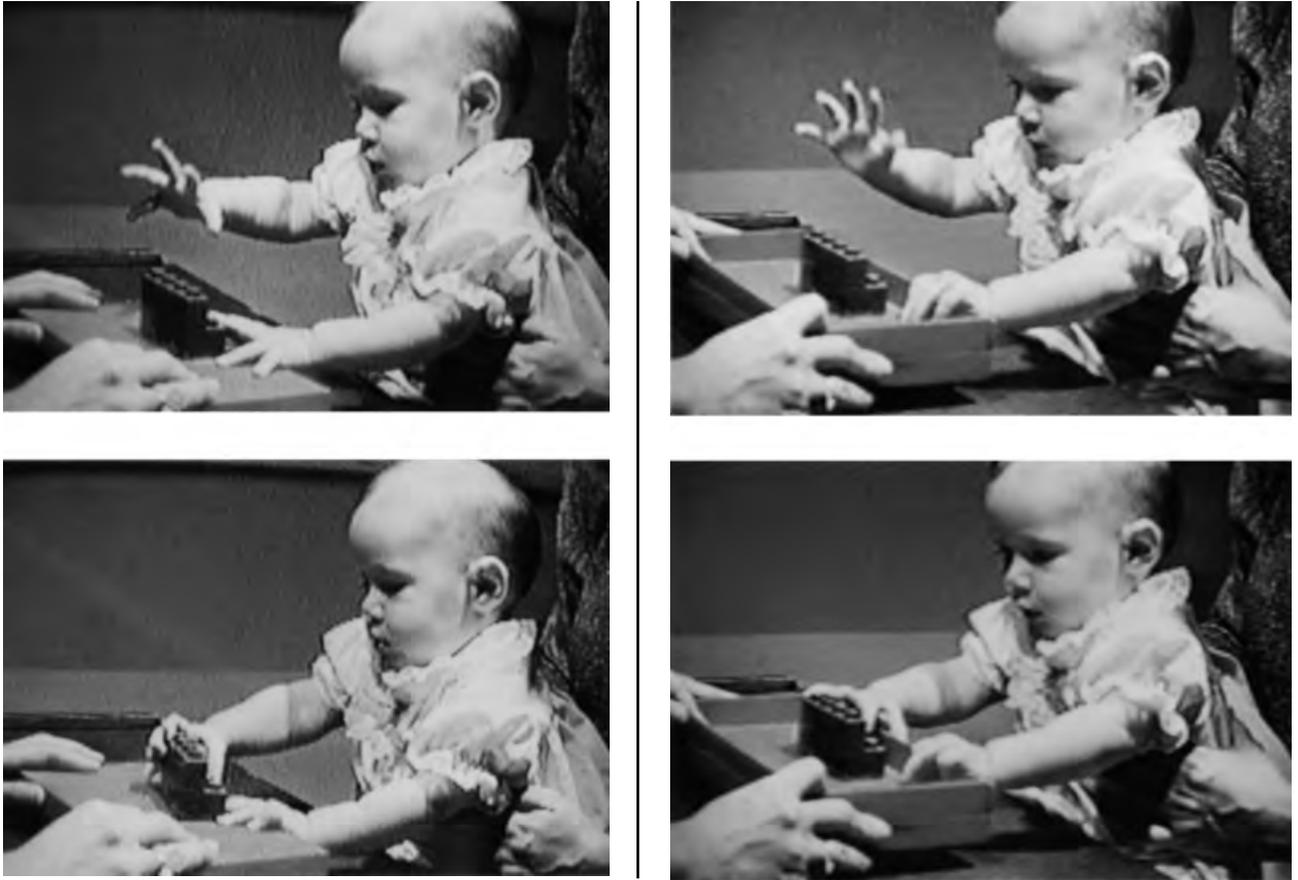
Figure 3   Example of an infant reaching for the goal object of Trial 1 (left) and Trial 2 (right). The first hand with which the infant reached (her left hand) grasped the base on both trials. Her second succeeded in getting cleanly to the goal object on Trial 1, but the thumb of her right hand got snagged by the lip of the base on Trial 2. She was not able to succeed in retrieving the goal object on Trial 2, although on that trial, as on Trial 1, her attention appeared to be focused on the goal object.

the base, infants of 5 months performed significantly worse than infants of 7 months.

Performance on the 10 pairings of trials. On Trials 1 and 2 the degree of contiguity between goal object and base was identical, and the same goal objects and bases were used (except that the base on Trial 2 had a lip around it; see Figure 2). We predicted that infants of 5 months would perform worse on Trial 2 than Trial 1, and they did. On Trial 2 they took significantly longer and fewer succeeded (although with the correction for multiple tests the latter did not reach statistical significance; see Table 2). They also touched an edge of the base significantly more often on Trial 2. Trials 15 and 16 provide a similar comparison (they differed only in the presence of a lip around the base on Trial 16). On these two trials the goal object and base did not appear to be contiguous at all. We predicted that infants of 5 months would perform worse on Trial 16 than on Trial 15, and they did (see Table 2). Significantly fewer 5-month-olds succeeded on the

lip-around-base trial, all took longer on that trial than on Trial 15, and 5-month-olds touched the base on Trial 15 significantly more often than on Trial 16.

The goal objects and bases used on Trials 3, 4, and 14 were identical. On Trial 3 the goal object extended partially over the front of the base, on Trial 14 it extended an equal distance over the rear, and on Trial 4 it was centered on the base. (On each of these trials, the goal object and base were easily within reach for the infant. The base was 3–5 cm farther from the infant and the goal object 3–5 cm closer on Trial 3 than on Trial 4. On Trial 14, the base was 3–5 cm closer and the goal object 3–5 cm farther away from the infant than on Trial 4.) The understanding-contiguity hypothesis should lead to predictions of worse performance on Trial 4 (the condition with the greatest degree of contiguity) and equivalent performance on Trials 3 and 14 (which had equal degrees of contiguity). Our skill-in-reaching hypothesis, however, generated predictions that Trial 4 should be least difficult, Trial 3 in-

Table 2   Between-Trial, Within-Subject Comparisons for Five-Month-Old Infants on Trials That Differed in Only One Variable, with That Variable Affecting the Likelihood of a Slightly Imprecise Reach Touching a Graspable Edge of the Base

	Percent Correct		Trial Duration		No. of Touches to an Edge of the Base		
	t	p	t	p	t	p	
Trial 1 versus Trial 2	2.35	<.02	−4.68	<.0004*	−6.75	<.0001*	
Trial 3 versus Trial 4	−5.75	<.0001*	1.14	ns	3.32	<.005*	
Trial 3 versus Trial 14	1.00	ns	−1.70	<.06	−2.13	<.03	(N = 10)
Trial 4 versus Trial 14	9.00	<.0001*	−2.71	<.01[a]	−4.60	<.0004*	(N = 10)
Trial 5 versus Trial 10	−0.32	ns	−1.67	<.06	1.12	ns	
Trial 6 versus Trial 7	5.45	<.0001*	−2.88	<.007[a]	−7.11	<.0001*	
Trial 7 versus Trial 13	−2.89	<.005*	2.04	<.04	2.26	<.02	(N = 11)
Trial 8 versus Trial 9	−2.89	<.005*	3.05	<.005*	2.90	<.007[a]	(N = 11)
Trial 8 versus Trial 12	−2.57	<.01[a]	3.13	<.005*	3.26	<.005*	
Trial 15 versus Trial 16	4.58	<.0005*	−4.84	<.0005*	−4.36	<.0005*	(N = 10)
All 10 Comparisons[b]	9.83	<.0001*	5.95	<.0001*	6.73	<.0001*	
Eight Comparisons[c]	8.47	<.0001*	7.53	<.0001*	8.32	<.0001*	

Note: Ns = 12, unless otherwise noted.

* Difference in performance was statistically significant. Because 10 comparisons were run, for each dependent measure above, the usual statistical significance level of p = .05 was divided by 10. Hence, only p values < .005 are considered statistically significant.

[a] Difference in performance narrowly missed being statistically significant (.005 < p > .01).

[b] All differences were in the direction predicted by the skill in reaching hypothesis, except for the difference in trial duration between Trials 5 and 10. For pooling across comparisons, the absolute values were used except for trial duration, Trial 5 versus Trial 10.

[c] Omitting the comparisons where understanding contiguity and skill in reaching yield the same predictions, that is, omitting the comparisons of Trial 4 versus Trial 3 and Trial 6 versus Trial 7.

termediate, and Trial 14 most difficult because of the likelihood of accidentally contacting an edge of the base en route to the goal object. The skill-in-reaching predictions were confirmed; the understanding-contiguity predictions were not. For example, percentage of correct retrievals by 5-month-olds was 92% on Trial 4, 17% on Trial 3, and 0 on Trial 14.

Similarly, Trials 6 and 7 differed only in that the goal object extended partially over the front of the base on Trial 6, whereas it was centered on the base on Trial 7. Significantly more 5-month-olds succeeded on Trial 6 and they were significantly less likely to touch an edge of the base than on Trial 7 (see Table 2). The base on Trial 13 had the same general dimensions as the base on Trials 6 and 7, but included no indentation. (It resembled the binding side of a book. The base on Trials 6 and 7 resembled the pages side of a hardcover book and presented a much more easily graspable edge.) On Trials 7 and 13 the same goal object was in the same position on the base, but significantly more 5-month-olds succeeded with the base's "binding" side facing them (Trial 13) than with the easily graspable "pages" side facing them (Trial 7; see Table 2). As predicted, infants were more likely to continue their reach after touching the base on Trial 13, rather than having their reach halted by the involuntary release of the grasp reflex.

Trials 5 and 10 differed only in that the goal object was placed near two edges of the base on Trial 5 but far from any edges on Trial 10. We predicted that

5-month-olds would perform worse on Trial 5 because they would be more likely to touch an edge of the base on that trial; our prediction was not confirmed. The degree of contiguity between goal object and base was the same on Trials 5 and 10; hence, an understanding-contiguity hypothesis should yield a prediction of "no difference" in performance on the two trials; no significant difference was found. However, because of the disparity in size between the small goal object and the much larger base, predictions based on understanding contiguity would be that both Trial 5 and 10 should be easy; those predictions were not confirmed. Infants of 5 months performed poorly on both trials. The goal object proved too narrow for the infants to easily pick up.

Trials 8 and 9 differed only in the placement of the stimuli on the table. On Trial 9 the base and goal object were placed almost at the front edge of the table, very close to the infant's body. We hypothesized that on that trial infants might reach from directly above the goal object and so be less likely to touch the base en route. Hence, we predicted that infants would perform better on Trial 9 than on Trial 8. That prediction was confirmed: Significantly more 5-month-olds succeeded and the trial duration was significantly shorter on Trial 9 than on Trial 8. Because proximity to the infant has never been mentioned as a relevant variable by understanding-contiguity theorists, we assume that they would have predicted comparable perfor-

mance on Trials 8 and 9. Trial 12 used the same goal object as on Trials 8 and 9, positioned on the table as on Trial 8 but with a base slightly smaller than the goal object (rather than slightly larger than the goal object as on Trials 8 and 9). We predicted that 5-month-old infants would perform better on Trial 12 because they would be less likely to accidentally touch the base while reaching for the goal object (because no edge of the base extended beyond the goal object). Indeed, trial durations were significantly briefer for Trial 12 and more 5-month-olds tended to succeed (see Table 2). Because the goal object and base were equally close in size and fully contiguous on both trials, we assume that an understanding-contiguity hypothesis would lead to a prediction of comparable performance on Trials 8 and 12.

Instead of looking at each of these individual 10 comparisons of performance on a single trial compared with performance on one other trial, we can look across all 10 comparisons. Here it can be seen, even more strongly than in any single comparison, that infants of 5 months performed better on trials where they were less likely to touch an edge of the base (see Table 2). On 2 of these 10 comparisons, the predictions generated by a conceptual-understanding hypothesis are the same as those generated by our motor-execution hypothesis. If the two comparisons where our predictions agree are omitted, it is still clear that infants of 5 months performed better, and were less likely to touch an edge of the base, on trials we predicted would be easier (see Table 2). On the other hand, infants did not perform better on the trials that should be easier according to the understanding-contiguity hypothesis.

Infants of 5 and 7 months not only differed in how often they touched an edge of the base but also in their reactions to doing so. Touching the base interrupted the reaches of 5-month-olds most of the time (see Table 2). Typically they reacted by grasping the edge and then withdrawing their hands back to their starting position before attempting the reach again. This was repeated many times on each of the more difficult trials. Infants of 5 months were more likely to grasp an edge of the base upon touching it than were 7-month-olds; mean percentage of touches to the base's edge that resulted in grasping the edge across all trials = 62.8% at 5 months, 17.2% at 7 months (see Table 3), $F(1, 120) = 84.02$, $p < .001$, using the Tukey–Freeman transformation because of unequal variances. The other reaction of 5-month-olds was to withdraw their hands in response to touching the base in the classic "avoidance reaction" (Twitchell, 1965, 1970), which Szuman (1927) described as reacting as if they "were afraid." Although the grasp reaction had not fully disappeared by

Table 3 Ability of Five- and Seven-Month-Old Infants to Inhibit Grasping an Edge of the Base Upon Touching It

	Percentage of Touches to an Edge of the Base That Were Followed Immediately by Grasping That Edge	
Trial	Age 5 Months	Age 7 Months
Easiest trial		
T11: Small cushion as base	n/a	n/a
Easy trials		
T1: Object standing well out from base	64.3	0.0*
T4: Object extending over front of base	63.0	0.0*
T6: Object extending over front of base	58.5	0.0*
T12: Object slightly larger than base	50.0	37.5*
T15: Object not contiguous with base (N = 11 at 5 months)	59.0	0.0*
Intermediate trials		
T9: = T8 but very near infant (N = 11 at 5 months)	33.3	30.0
T10: Small, thin object on large base	57.5	25.0*
T13: "Binding" side of base presented (N = 11 at 5 months)	49.2	35.7
Difficult trials		
T2: Rim around base	63.1	16.7
T3: Object slightly smaller than base	84.0	25.0
T5: T10's object near front corner of base	72.0	25.0
T7: "Pages" side of base presented	55.0	27.5
T8: Object slightly smaller than base	76.7	0.0
T16: Rim around base (N = 10 at 5 months)	70.0	22.0
Hardest trial		
T14: Object extending over back of base (N = 10 at 5 months)	85.2	10.2
Mean over all trials	62.8	17.2

Note: Number of subjects = 12, unless otherwise noted.
* Most 7-month-old infants never touched an edge of the base on the starred trials. Hence, on the starred trials, the percentage for 7-month-old infants is based on very few instances.

7 months of age, it was significantly less likely to be elicited at 7 than at 5 months of age.

DISCUSSION

How do our findings compare with the findings and theorizing of Piaget? Our findings are in accord with Piaget's observations but not with his theorizing. Like Piaget, we found that infants of 5 months fail to retrieve an object when it is placed on a slightly larger object (Trials 3 and 8), although they can retrieve an object when it stands out from the base or appears not to be contiguous with the base (Trials 1 and 15 respectively). Wishart and Bower (1984) similarly found that 10 out of 12 infants of 5 months successfully re-

trieved an object that stood out well from its base. We included a number of other conditions, however, that call into question the understanding of Piaget and Bower of why infants perform as they do. We report conditions where the goal object and base were contiguous yet even most 5-month-olds succeeded in retrieving the goal object (Trials 9, 12, 11, and 13: goal object and base fully contiguous; Trials 4 and 6: goal object and base partially contiguous). On the other hand, where the goal object did not appear to be contiguous with the base at all (Trial 16), the goal object stood out well from the base (Trial 2), the goal object and base differed considerably in size (Trials 5 and 10), and the goal object and base were only partially contiguous (Trial 14), most infants of 5 months failed to retrieve the goal object.

How do our findings compare with the findings and theorizing of Spelke? Von Hofsten and Spelke (1985) tested infants of 5 months on two conditions: (A) a block attached to (and hence contiguous with) a slightly larger block behind it, and (B) a thin square object connected by a small protrusion to the slightly larger block behind it, which made the thin object and larger block appear as if they were not contiguous (see Figures 1 and 2 in von Hofsten & Spelke, 1985). Because infants reach preferentially for the closer of two objects, von Hofsten and Spelke reasoned that if infants reached for the larger block, which was farther away, they must have perceived the two objects as being a single unit. Infants of 5 months reached for the edge of the larger block in Condition A (where the larger and smaller blocks were contiguous) but reached for the edge of the thin, seemingly noncontiguous square in Condition B, which led von Hofsten and Spelke to conclude that the infants perceived the contiguous objects as a single unit. The smaller block in Condition A was closer to the infants than the larger block behind it; infants should have been able to get to the smaller block without contacting the larger block en route. Because we have said that infants should succeed if they do not touch the base en route to the goal object, how can we account for the findings of von Hofsten and Spelke?

Differences in the experimental procedures employed here and employed by von Hofsten and Spelke probably account for the differences in the competencies observed in the two studies. Von Hofsten and Spelke took pains to minimize the differences between the two objects. The objects were made of the same material and painted the same colors; our goal objects and bases had different colors and were usually made of different materials. The infant never saw the two objects move independently in von Hofsten and Spelke's experiment. In our experiment, the infants saw the two objects apart from one another and saw the goal object being placed on the base. In the

real world, two objects rarely start out perfectly adjacent to one another from the beginning (e.g., Laurent saw the matchbox first in his father's hand and then placed on top of a book). Finally, von Hofsten and Spelke presented their stimuli at an angle 15° from the vertical. If the researchers had not attached the "top" (i.e., closer) object to the larger block, it would have fallen to the ground. Indeed, Hespos (1999) has recently shown that 5-month-old infants expect horizontal surfaces to support a contiguous object, but they do not expect vertical surfaces to support a contiguous object. This suggests that even 5-month-olds apparently know that were the objects in the von Hofsten and Spelke experiment just contiguous, and not connected, the object in front would have fallen to the ground. In short, in the von Hofsten and Spelke experiment everything was done to maximize the likelihood that participants would conclude that the two adjacent objects were really one object, and hence it is quite possible that 5-month-old infants drew that conclusion.

This account of the differences in our findings and those of von Hofsten and Spelke gains credence from the work of Needham. Needham and Baillargeon (1998) found that 4½-month-old infants indicated through their looking behavior that two adjacent objects were separate objects if they saw one of the two objects alone for only 5 s before seeing them contiguous with one another. Infants in our experiment saw the goal object and base separately for about that long before the start of a trial, and they had even more experience with the objects as separate units when these objects were used on more than one trial. Needham (1998) found that if the objects were simple, infants of 4½ months treated two contiguous objects, differing in color, shape, and the material of which they were made, as separate objects rather than as one unit (as inferred from their looking behavior), even without any prior experience. The stimuli in our experiment as well as in von Hofsten and Spelke's experiment were simple, but our goal objects and bases differed in color and often material (as did Piaget's), whereas von Hofsten and Spelke's did not. Needham's findings and conclusions—that infants of 4½ to 5 months know that two discriminable objects are separate objects even if they share a common boundary—are fully consistent with our own. However, Needham's work does not speak to why 5-month-olds often fail to retrieve a discriminable goal object from on top of a base.

Why do infants of 5 months often fail to retrieve a goal object placed on top of a base? Our work and that of Bresson, Maury, Pieraut-LeBonniec, and de Schonen (1977) indicates that infants even as young as 5 months appear to understand that the goal object continues to exist as a

separate object even when placed upon another object. Needham's work suggests that 4½-month-olds understand the same thing when the objects are next to one another (Needham, 1998; Needham & Baillargeon, 1998). We have proposed that when 5-month-olds fail to retrieve an object placed upon another it is because they have difficulty executing their reach so that it goes precisely to the goal object without accidentally touching the base en route. When their hand touches an edge of the base en route, their reach is interrupted by their reflexively grasping the edge of the base or reflexively pulling their hand back in the avoidance reaction.

In support of this hypothesis we found that infants of 5 months successfully retrieved a goal object fully contiguous with its underlying base under conditions where, even if their aim were imprecise, they were unlikely to contact a graspable edge of the base en route to the goal object. We found that infants failed to retrieve a goal object that appeared not to be contiguous at all with its base when an imprecise reach was likely to contact a graspable edge of the base. Conditions equal in degree of contiguity produced opposite results when they differed in the likelihood of a graspable edge of the base being touched while reaching for the goal object: For example, most 5-month-olds retrieved the goal object when it extended partially over the front of the base but not when it extended an equal distance over the back, and most succeeded when the goal object was slightly larger than the base but not when it was slightly smaller than the base. In addition, more infants succeeded under conditions where the grasp reflex was less likely to be elicited (e.g., when the "binding" side of the base faced the infant) than when the base presented a more easily graspable edge (e.g., when the "pages" side of the base faced the infant). Piaget found that at 6 months of age, his son Laurent could retrieve an object placed on a large cushion. Piaget concluded that the reason for Laurent's success was because of the large disparity in size between the object and cushion. We found, however, that infants of 5 months could retrieve an object placed on a small cushion, close in size to the object. We conclude that they succeeded because the cushion presented no hard edges that when accidentally contacted would elicit the grasping reaction.

The problem at 5 months thus appears not to reside in a lack of conceptual understanding but rather in a lack of skill in executing a visually guided reach that goes directly and accurately to its target and a lack of ability to inhibit reflexive reactions to touch. Five-month-old infants fail because their hand touches the support's edge as they are reaching for the goal object and they react to these touches reflexively, by grasping the edge or by pulling their hand back.

There is one finding for which our theoretical account does not provide a ready answer—infants' poor performance on Trial 10. Here the goal object and base differed considerably in size and the goal object was not near an edge of the base, yet infants grasped the edge of the base anyway, often failing to retrieve the goal object. The goal object was small and difficult for infants to grasp, whereas the thin edge of the base provided an easily graspable surface. Infants probably reached for what they could easily grasp. It may well be that the $12.6 \times 15.6 \times 2.5$ cm base, although much larger than the goal object, was not large enough to be considered a neutral base. As one anonymous reviewer suggested, there may be a minimum absolute size ("perhaps the base must be sufficiently large to be perceived as a two-dimensional surface, such as a tabletop, wall or floor, rather than as an object").

Bresson et al. (1977) offer an alternative way of accounting for performance on Trial 10 and perhaps also for the poor performance on Trial 14 (where the goal object, which extended partially over the back of the base, was several inches from the front edge of the base). They studied infants of 4–9 months as they tried to retrieve a goal object from various supports. (Infants saw the goal objects and bases as separate and observed the goal object being placed on each base). Bresson and colleagues (1977, p. 313) found that "in a great many instances . . . infants did not touch the object, they seized and drew the support toward them while looking at the object." They concluded that infants appeared to understand that the two contiguous objects were separable and appeared to be reaching for the goal object. Bresson and colleagues felt that the problem for infants resided in being presented with two contradictory spatial frames of reference—the boundaries of the goal object and the boundaries of the base. Even when *adults* reach for an object, interference effects are found from a nearby or adjacent object (Tipper, Lortie, & Baylis, 1992). Infants, according to Bresson et al. (1977, p. 318) needed to locate the goal object on the base and at the same time inhibit actions directed at the base:

> The positioning of the first hand on the support . . . is a condition for the other hand to adjust its reaching to the object in a situation where there is conflict between two systems of spatial reference. The positioning of the not-reaching hand would then be a condition for calibrating the program of adjustment. The positioning of the first hand localizes the support, neutralizing the conflict between the two systems of spatial reference.

Thus, whereas we had hypothesized that infants' touching and grasping the base was accidental (the

result of imprecision in executing the reach for the goal object), Bresson and colleagues suggest that infants intentionally reach to the base as a clever and creative way to solve the problem of being attracted both to the edge of the goal object and to the closer edge of the base. Certainly, we observed, as did Bresson and colleagues, that the first hand with which infants reached often arrived at the base and remained there, and then the second hand arrived at the goal object. This would be consistent with the hypothesis offered by Bresson and colleagues. Why, then, do so many infants of 5 months still fail to retrieve the goal object after they have grasped the base with one hand?

If we extend what Bresson and colleagues have said, it may be that infants are "automatically" attracted to edges, so that even if the goal object is some distance from an edge of the base, if infants see the front edge of the base, they are likely to reach toward it. Infants' performance on Trials 10 and 14 is consistent with their reaching toward the closest graspable surface, whether or not that edge belongs to the object they are trying to retrieve. This might be an early bias of the reaching system worth investigating.

In conclusion, it appears that infants of 5 months do not fail to retrieve one object placed upon another because of a lack of understanding that an object continues to exist independently when placed upon another or because the infants misperceive the two objects as a single unit. Apparently, the cognitive competence is present early, but sufficient control of action to demonstrate it comes later. Immaturity in the control or planning of visually guided reaching interferes with the ability of 5-month-old infants to retrieve contiguous objects and masks expression of the cognitive competence.

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ADDRESSES AND AFFILIATIONS

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