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PERSEVERATION AND PROBLEM SOLVING IN INFANCY

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I. Introduction

One of the hallmarks of human problem solving is its *efficiency*. When solutions to problems are known and easily retrieved from memory, we prefer retrieving them over computing them anew. As an illustration, consider the following situation. A college student participating in an experiment is asked the answer to the problem "122 × 11." After a few seconds, the subject answers "1342." On the next trial, the subject is again given the problem "122 × 11" and immediately answers "1342." Rather than laboriously recomputing the problem's solution, the subject swiftly and efficiently retrieves it from memory.

Despite its many obvious advantages, our tendency to retrieve past solutions from memory has at least one potential drawback. Past solutions can be helpful only if they are indeed appropriate for the problems at hand. To return to our example, consider what would happen if the subject was given the problem "122 × 13" in a later trial and mistakenly assumed that this was the same problem as before. The subject would once again retrieve the solution "1342," yielding a perseverative error. In this chapter, *perseveration* is defined as the retrieval of a familiar solution in a context in which a significant change has been introduced so that the familiar solution is no longer appropriate; for the subject to succeed, a novel solution must be computed.

Infants, like adults, produce perseverative errors, and developmental researchers have long been interested in understanding infants' perseverative tendencies. In this chapter, we summarize the research we have been conducting over the past 5 years on the perseverative responses of infants aged 6.5 to 11 months in a variety of tasks. The central perspective of our work, as illustrated by the preceding comments, is that perseveration is best understood as efficient problem solving gone awry. Familiar solutions are retrieved where novel solutions should have been computed.

Before describing our research, we briefly discuss prior work on infant perseveration. For the most part, this work has involved very different tasks from our own and has yielded very different answers to the riddle of infants' perseverative errors. After outlining these differences, we introduce our research and outline the plan of this chapter.

II. Perseveration in Memory-and-Motor Tasks

A. TRADITIONAL MEMORY-AND-MOTOR TASKS

Most of the research on infants' perseverative errors has focused on tasks that require infants (a) to update and remember information about objects and (b) to use this information to select appropriate motor responses. For ease of reference, we will refer to tasks with this dual requirement as "memory-and-motor" tasks.

The first infant memory-and-motor task was developed by Piaget (1954, pp. 44–46) to examine infants' ability to search manually for an object hidden in one of two locations. This task has been used extensively by developmental researchers (for reviews, see Bremner, 1985; Diamond, 1985; Harris, 1987; Sophian, 1984; Wellman, Cross, & Bartsch, 1986). For example, in a classic longitudinal study, Diamond (1985) tested infants every 2 weeks from 6 to 12 months of age. On each trial, a toy was hidden in one of two identical wells, which were then covered with cloths. Next, a delay was introduced; the length of the delay was slowly increased across testing sessions. During the delay, the experimenter used a verbal distractor (e.g., counting aloud) to attract the infants' attention and thus prevent them from simply staring at the correct well throughout the delay. Following the delay, the infants were allowed to search for the toy. Side of hiding was reversed three to five times in each session. Of particular interest were reversal trials (termed B trials) that followed correct trials (termed A trials): would the infants search at the correct well on the B trials, or would they perseverate, returning to the (now empty) well they had searched successfully on the A trials? Two main results were obtained. First, all of the infants produced perseverative errors on the B trials. Second, longer delays were necessary with age to elicit perseverative errors: thus, whereas delays of less than 1 s produced errors at 7.5 months, 3-s delays were needed at 8 months, 6-s delays at 9 months, 8-s delays at 10 months, and over 10-s delays at 12 months.

B. NOVEL MEMORY-AND-MOTOR TASKS

A number of experiments with novel memory-and-motor tasks have added significantly to our understanding of the conditions under which perseverative errors occur in these tasks (e.g., Diedrich, Thelen, Corbetta, & Smith, 1998; Hofstadter & Reznick, 1996; Munakata, 1998; Smith, McLin, Titzer, & Thelen, 1995). To illustrate this point, two such experiments are described next, one by Hofstadter and Reznick (1996) and one by Smith et al. (1995).

Hofstadter and Reznick (1996) examined 5-month-old infants' *visual search* for an object hidden in one of two locations. As in Diamond's (1985) experiment, a toy was lowered in one of two identical wells, which were then covered with cloths. Next, a transparent and an opaque screen were raised, hiding the wells. After a 3-s delay, the opaque screen was lowered, leaving the transparent screen in place (to prevent manual search responses). Visual search on the A and B trials was measured by the direction of the infant's first gaze toward a well. The results indicated that, on the B trials, the infants had a significant tendency to gaze first at the well that was correct on the preceding A trial, thus producing a perseverative error.

Smith et al. (1995) examined whether 8-month-old infants would still make perseverative errors if *no toy* was hidden. The infants sat in front of two identical wells covered with lids; one lid was labeled the A lid and the other the B lid. In each test trial, an experimenter grasped and waved one of the lids before returning it to its initial position. After a 3-s delay, the infants were allowed to reach. The A lid was used for two test trials (A trials) and the B lid for two additional trials (B trials). The results indicated that the infants had a significant tendency to reach for the A lid on the B trials. Perseverative errors were thus observed despite the fact that no toy was hidden and the infants simply watched the experimenter wave one of the lids covering the wells.

Although the tasks devised by Hofstadter and Reznick (1996) and Smith et al. (1959) differ from the Piagetian two-location search task in several key respects, both are still memory-and-motor tasks according to the two criteria listed earlier: in each task, success on the B trials depended on the infants being able (a) to update and remember information (e.g., to remember in which of the two wells the object had been hidden or which of the two lids had been cued) and (b) to use this information to select one or two alternative motor responses (e.g., to direct their gaze to the left or right well or to reach for the left or right lid).

Not surprisingly, current accounts of perseveration in memory-and-motor tasks (e.g., Ahmed & Ruffman, 1998; Diamond, 1991; Diedrich et al., 1998; Hofstadter & Reznick, 1996; Marcovitch & Zelazo, in press; Munakata, 1998; Smith et al., 1995; Zelazo & Zelazo, 1998) typically refer to limitations in (a) infants' ability to update and maintain information in working memory across trials, and/or (b) infants' ability to use this information to select a novel motor response over a previously successful but no longer appropriate response. Decreases with age in perseveration are generally attributed to improvements in these two abilities with neurological maturation and (primarily motor) experience.

III. Perseveration in Tasks Other Than Memory-and-Motor Tasks

A. NONMEMORY-AND-MOTOR TASKS

1. Previous Tasks

In the mid 1990s, we began exploring the nature and causes of infants' perseverative errors in tasks *other* than memory-and-motor tasks. We were aware that perseverative errors had been reported in a number of detour tasks (e.g., Lockman & Pick, 1984; Mackenzie & Bigelow, 1986; Rieser, Doxsey, McCarrell, & Brooks, 1982). These tasks were similar to memory-and-motor tasks in that infants had to select one of two alternative motor responses on each trial; the tasks differed from memory-and-motor tasks, however, in that infants did not need to update and remember information to determine which of the two motor responses was appropriate, because the necessary information was perceptually available.

To illustrate, Lockman and Pick (1984) examined 12- and 18-month-old infants' ability to use the shortest route to reach their mothers. The infants and their mothers were positioned on opposite sides of an 8-foot-long barrier, near the left or right end; the two ends were used on alternate trials. The barrier was short enough for the infants to see their mothers clearly, but too tall for the infants to climb over it. The results indicated that on the initial trial, the infants in both age groups almost always went to their mothers by the shortest route (e.g., around the right end of the barrier if they stood near that end). On subsequent trials, however, only the 18-month-olds changed their response and used the shortest route to reach their mothers; the 12-month-olds tended to repeat their first response, going to their mothers via the same route across trials. The younger infants thus perseverated even though their mothers were clearly visible above the barrier so that the infants had no need to update and remember their mothers' position across trials.

2. *Our Own Tasks*

In our research, we used two novel series of tasks. The tasks in the *first* series (Aguiar, 1998; Aguiar & Baillargeon, 1999b; Aguiar, Rives, & Baillargeon, 1997) were similar to those of Lockman and Pick (1984), Mackenzie and Bigelow (1986), and Rieser et al. (1982) in that infants had to select one of two motor responses based on information that was perceptually available rather than stored in memory. Our tasks were adapted from Piaget's (1954, pp. 180–183) support task. In this task, a toy is placed on the far end of a support such as a cloth, and infants must pull the near end of the cloth to bring the toy within reach. In our tasks, infants aged 7, 9, and 11 months were shown two clothes placed side by side; one had a toy on its far end and one had a toy beyond it (the oldest infants were tested with a somewhat more complex arrangement of the cloths and toys). After infants succeeded at retrieving the toy, the location of the two cloths was reversed; the question of interest was whether, in the reversal trial, the infants would (a) pull the correct cloth and retrieve the toy or (b) perseverate, pulling the cloth on the same side as the cloth they had pulled on the preceding trial.

Our *second* series of tasks (Aguiar, 1998; Aguiar & Baillargeon, 1996, 1998, 1999a, 1999c) differed maximally from memory-and-motor tasks in that infants not only did not have to update and remember information about objects but also did not have to select one of two alternative motor responses. Tasks in this second series involved the violation-of-expectation paradigm (e.g., Baillargeon, 1995, 1998). In this paradigm, infants typically see an expected event, which is consistent with the belief or expectation under examination, and an unexpected event, which violates it. With appropriate controls, longer looking at the unexpected than at the expected event provides evidence that infants detect the violation in the unexpected event. In our tasks, infants aged 6.5, 7.5, and 8.5 months were shown containment events. During the familiarization trials, infants saw an object being lowered into a much wider container. During the test trials, the same object was lowered into two novel containers, one slightly larger (large-container event) and one smaller (small-container event) than the object. Past research (Sitskoom & Smitsman, 1995) has shown that by 6.5 months of age, infants realize that a rigid object can be lowered into a container that is wider but not narrower than the object. Our containment tasks examined whether infants would (a) detect the violation shown in the small-container test event or (b) perseverate, carrying forth the same expectation ("the object will fit into the container") they had formed during the familiarization trials.

Infants in both our support and containment tasks produced perseverative errors. To account for these results, together with those of Lockman and Pick (1984), Mackenzie and Bigelow (1986), and Rieser et al. (1982), we have been developing a model of perseveration in nonmemory-and-motor tasks. As might be expected, this model differs radically from current accounts of perseveration in memory-and-motor tasks (e.g., Ahmed & Rufman, 1998; Diamond, 1991; Diedrich et al., 1998; Hofstadter & Reznick, 1996; Marcovitch & Zelazo, in press; Munakata, 1998; Smith et al., 1995; Zelazo & Zelazo, 1998). As mentioned earlier, these accounts typically refer to limitations in (a) infants' ability to update and remember information about objects and (b) infants' ability to select a new motor response over a previously successful but no longer appropriate alternative response. Because neither of these limitations could be used to explain the perseverative errors observed in our containment tasks, we opted for a very different approach focused on limitation in infants' problem-solving abilities.

B. ORGANIZATION OF THE CHAPTER

The rest of this chapter is divided into four sections. In the first, we describe our problem-solving model of perseveration in nonmemory-and-motor tasks. In the second and third sections, we describe the results of our support and containment experiments and discuss how these results provide evidence for our model. Finally, in the fourth section, we return to the perseverative errors that have been observed in memory-and-motor tasks and explore ways in which our problem-solving model can be elaborated to account for these errors. Our hope is that a single model can eventually be developed that accounts for errors in *both* memory-and-motor and nonmemory-and-motor tasks and thus offers a unified account of perseveration in infancy.

IV. A Problem-Solving Model of Infant Perseveration in Nonmemory-and-Motor Tasks

Before describing our model of infant perseveration in nonmemory-and-motor tasks, we make two comments about its domain of application. First, our model focuses primarily on tasks of the following format: to start, infants receive one or more trials (termed the A trials) in which they are given the same problem; next, infants receive one or more trials (termed the B trials) in which they are given a problem that is largely similar to the initial problem except that a crucial feature has been changed so that the original solution is no longer valid; for infants to succeed, a new response must be produced. Second, our model applies only to tasks that infants are capable of solving: perseveration on the B trials is never due to infants lacking the knowledge and cognitive skills necessary to detect the change introduced or to respond to it appropriately.

A. THREE ASSUMPTIONS

Our model rests on three main assumptions which are described in turn.

1. *First Assumption*

The first assumption is that at the start of each A and B trial in a testing session, infants conduct an *initial analysis* of the problem before them to categorize it as novel or familiar; that is, they judge whether the problem is one they are encountering for the first time in the session or one they have encountered earlier in the session. If infants conclude that the problem is novel, they perform a *further analysis* of the problem and compute its solution. In contrast, if infants conclude that the problem is familiar, they do not conduct a further analysis of the problem but instead simply retrieve their previous solution (for related ideas, see Baillargeon, 1993; Logan, 1988; Suchman, 1987).

2. *Second Assumption*

The second assumption is that infants perseverate on the B trials when their initial analysis of the problem is too incomplete to allow them to detect the crucial change that has been introduced. As a result, infants mistakenly categorize the problem as similar to that on the preceding A trials. Instead of computing a novel solution, infants retrieve their prior solution, resulting in a perseverative error.

3. *Third Assumption*

The third assumption, which is depicted in Figure 1, is that whether infants perseverate or respond correctly on the B trials depends to a large extent on their level of expertise at the task. We believe that *novice* infants (i.e., infants with little experience at the task) are more likely to perseverate on the B trials than are *expert* infants (i.e., infants with more experience at the task).

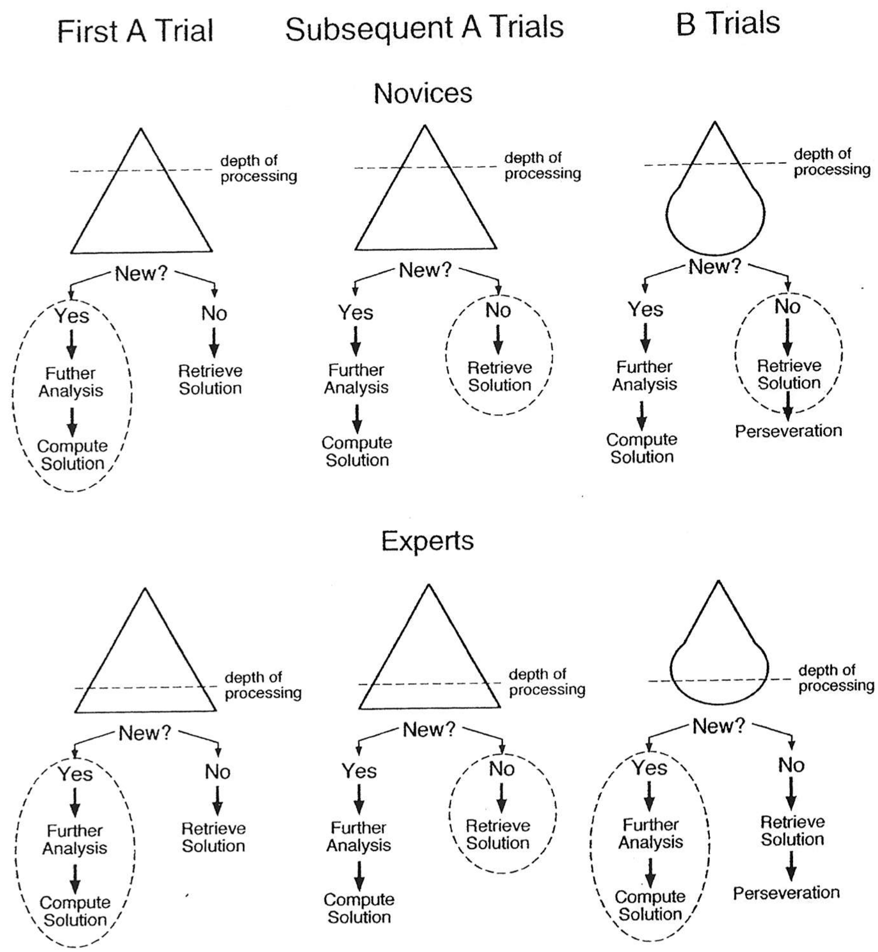

Fig. 1. Schematic description of the third assumption of our perseveration model.

a. Novice Infants. When categorizing a problem, novice infants tend to engage in a shallow analysis of the problem that bypasses many of its crucial features. On the first A trial, this shallow analysis is sufficient to yield a correct categorization of the problem as novel; because infants are encountering the problem for the first time in the test session, a correct categorization would be expected on almost any analysis, however superficial. Having categorized the problem as novel, novices then conduct a further analysis of the problem and compute its solution. On the subsequent A trials, novice's shallow initial analysis is again sufficient to yield a correct categorization of the problem as familiar; because the problem is in fact the same as that on the preceding A trials, a correct categorization would again be expected on almost any analysis. Having categorized the problem as familiar, infants do not conduct any further analysis but instead simply retrieve and execute their prior solution.

Novices' shallow initial analysis is thus sufficient to lead them to perform correctly on all of the A trials. Difficulties arise only on the B trials, when the change in the problem involves a feature that typically falls outside the set of features that novices spontaneously attend to when performing their (shallow) initial analysis of the problem. Because they fail to detect the change introduced, novices mistakenly categorize the problem as familiar and hence retrieve their previous solution, resulting in a perseverative error. Novices' difficulties on the B trials constitute the primary focus of this chapter.

b. Expert Infants. In contrast to novices, expert infants tend to engage on both A and B trials in a deeper initial analysis of the problem that takes into account a greater number of its crucial features. As a result, experts are more likely to detect the change introduced in the B trials and hence to categorize and respond to the problem correctly.

4. *Summary of Assumptions*

In summary, we believe that the key to perseveration in nonmemory-and-motor tasks lies in problem categorization: infants perseverate when they mistakenly categorize a novel problem as familiar and thus go on to retrieve their previous solution rather than compute a new one. In turn, the key to problem categorization lies in problem analysis: infants mistakenly categorize a novel problem as familiar when their initial analysis of the problem is too shallow to allow them to notice that a crucial feature has been changed. When discussing the findings of our support and containment experiments, we will attempt to flesh out our claims about problem categorization and analysis. We believe that these claims are important not only for the insights that they may yield about infant perseveration, but also, more generally, for the light that they may shed on infant problem solving. As mentioned at the start of this chapter, our view is that perseveration is best understood as efficient problem solving gone awry; from this perspective, perseveration provides a fascinating window through which to explore the strengths and limitations of human problem solving from its origins onward.

B. SUPPORTING EVIDENCE FROM RELATED LITERATURES

Findings from several research areas outside infancy provide evidence for our problem-solving model of perseveration in nonmemory-and-motor tasks. Below we briefly describe three sets of such findings.

1. *Distinction between Computation-Based and Retrieval-Based Problem Solving*

A number of neuropsychological findings support the distinction between computation-based and retrieval-based problem solving (e.g., Murthy & Fetz, 1992; Posner & Raichle, 1994). In one experiment, Posner and Raichle (1994, pp. 105–129) used positron emission tomography (PET) to examine adults' brain activity during a verb-generation task. The participants were asked to read a list of 40 nouns and after each noun to produce a verb that represented an appropriate use of the noun (e.g., hammer–pound). The PET images revealed that the pathway activated when the subjects were computing their responses included the left frontal cortex, the anterior cingulate cortex, the left posterior temporal cortex, and the right cerebellum. However, when the subjects were tested with the same list of nouns following 15 min of practice, so that they were now simply retrieving their previous responses, no activation was observed in these areas; instead, a different pathway was activated that included the buried insular cortex in both hemispheres. The computation of new responses and retrieval of old responses thus produced activation in two different brain pathways.

2. *Perseveration Produced by the Miscategorization of a Problem*

Results from the traditional problem-solving literature provide evidence for the notion that perseveration occurs when subjects mistakenly categorize a problem as similar to one encountered earlier in a testing session. In the classical experiments of A. S. and E. H. Luchins (e.g., Luchins, 1942, 1946; Luchins & Luchins, 1950), adults and elementary school children solved two sets of five pencil-and-paper problems in which they were asked how to obtain a specific volume of liquid from a large tank using any or all of three empty jars (A, B, and C). The volume of liquid to be obtained and the capacity (measured in quarts) of the three jars changed from problem to problem. The first set of problems was solved most efficiently by the formula $B - A - 2C$. All but one of the problems in the second set could be solved by this formula or more efficiently by simpler formulas such as $A - C$ or $A + C$; the remaining problem could be solved only by the $A - C$ formula. Most adults and children continued to use the formula they had generated for the first set of problems when solving the second set. Indeed, the participants' perseverative tendency was so robust that most failed to notice that the original formula actually led to an incorrect answer in the $A - C$ problem. Consistent with our hypotheses about categorization and perseveration, the authors observed in additional experiments that only participants "who treated each problem as possessing individual requirements" (Luchins & Luchins, 1950, p. 295) tended to show little or no perseverative tendency.

3. *Distinction between Novices' and Experts' Problem Categorization*

Many results from the adult literature on expertise are consistent with our hypothesis that infants who are novices or experts at a task consider different information when categorizing problems (e.g., Anderson, 1987; Cheng, 1985; Chi, Feltovich, & Glaser, 1981; Ericsson & Charness, 1994; Johnson & Mervis, 1994; Reimann & Chi, 1989). For example, Chi et al. (1981) asked physics experts (Ph.D. students in physics) and novices (undergraduate students who had just completed a mechanics course) to categorize 24 problems from a standard physics textbook. Analysis of the participants' sorts indicated that the experts categorized the problems based on principles of mechanics, whereas the novices categorized the problems based on the concrete objects (e.g., springs and pulleys) mentioned in the problems.

V. Perseveration in Support Tasks

In this section, we review experiments conducted with three support tasks of increasing difficulty. As mentioned earlier (in section III), these tasks resembled memory-and-motor tasks in that infants were required on each trial to perform one of two alternative motor responses (i.e., pull on a left or a right cloth). These tasks differed from memory-and-motor tasks, however, in that infants did not need to update and remember information on each trial to decide which motor response was appropriate: all of the information necessary to make this decision was perceptually available. Our three tasks and their results are described in turn.

A. TOY-ATTACHED TASK

Several researchers have reported that infants less than 8 months of age typically do not pull on the near end of a cloth to bring within reach a toy placed on the far end of the cloth (e.g., Aguiar, 1997; Kolstad & Aguiar, 1995; Matthews, Ellis, & Nelson, 1996; Piaget, 1952; Willatts, 1984). However, Kolstad and Aguiar (1995) found that infants as young as 6.5 months of age will pull on a cloth to bring a toy within reach if they are first shown that the toy is *attached* to the cloth. Kolstad and Aguiar concluded that when the toy and cloth are separate, young infants are unable to think of an appropriate solution for retrieving the toy; the solution of pulling on the cloth to bring the toy within reach is not yet in their repertoire and does not occur to them. When the toy and cloth are attached, however, infants view them as a single, composite object; because they already know how to act on one portion of a composite object to make possible an action on a different portion of the object (e.g., grasping a nursing bottle and bringing its nipple to the mouth), in-

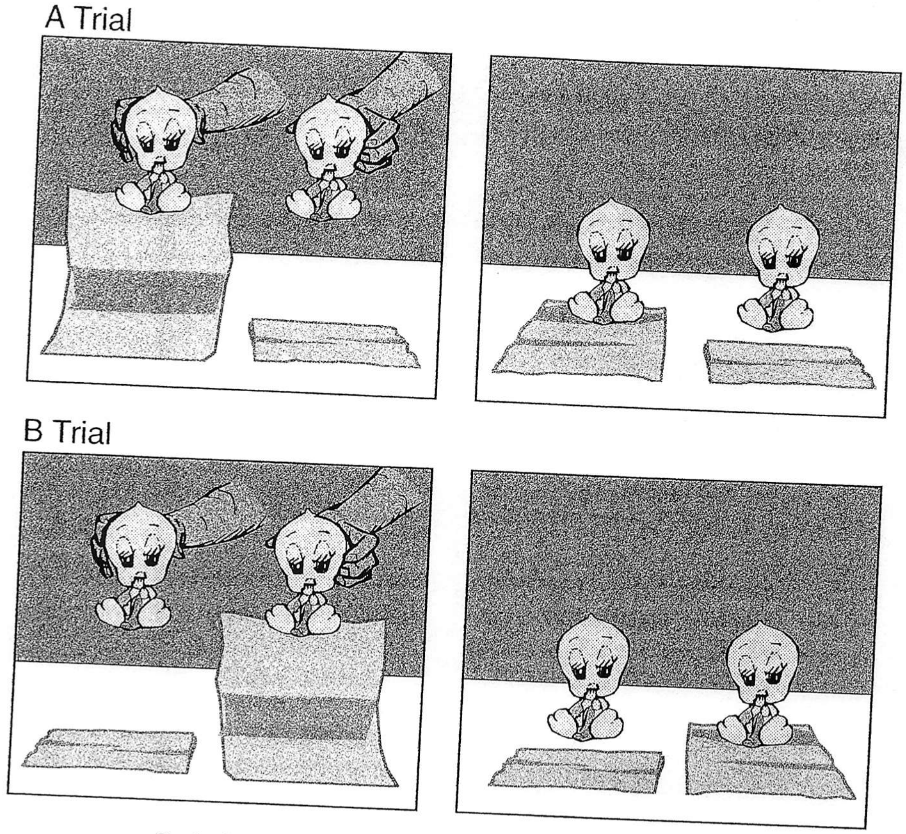

Fig. 2. Schematic drawing of the test trials in the toy-attached task.

fants have no difficulty determining what action to perform to retrieve the toy attached to the cloth.

Our first support task was based on this result (Aguiar, 1998; Aguiar & Baillargeon, 1999b; Aguiar et al., 1997). In the task, 7- and 9-month-old infants were shown two cloths lying side by side. As depicted in Figure 2, one cloth had a toy attached to its far end and the other cloth was folded in half and had an identical toy placed beyond it. After the infants succeeded in retrieving the attached toy on two trials, the location of the two toy-cloth pairs was reversed. The question of interest was whether the infants would pull the cloth with the attached toy or would perseverate, pulling the cloth on the same side as the cloth they had pulled in the preceding trials.

1. Procedure

Participants were tested using a two-phase procedure that consisted of a pretest and a test phase. Infants' actions during both phases were videotaped and later coded through frame-by-frame analyses.

During the *pretest* phase, each infant sat on a parent's lap at a table across from an experimenter. To start, the infants received pretest trials with a single toy and cloth. These trials were designed to introduce the task to the infants, and also to ensure that the infants could solve single toy–cloth problems. The toy was a bright attractive toy such as a Tweety Bird doll (throughout the experiment, new toys were introduced as needed to maintain the infants' interest). The bottom of the toy was velcroed to the far end of a cream-colored felt cloth. At the start of the first trial, the experimenter held up the toy and cloth, calling the infant's attention to each of them. Next, the experimenter placed the cloth and toy on the table in front of the infant; the near end of the cloth was within the infant's reach, but the toy was not. Next, the infant was encouraged to retrieve the toy (e.g., "Can you get it?"). The parent was instructed to restrain the infant while the cloth and toy were being placed on the table and to release him or her when the experimenter asked the infant to retrieve the toy. If the infant failed to pull on the cloth and retrieve the toy, the trial was repeated up to two times, usually with a different toy; if the infant still failed to retrieve the toy after three trials, the session was terminated. If the infant succeeded in retrieving the toy, then he or she received two additional pretest trials that were identical to the initial one, with one exception: after depositing the cloth and toy on the table, the experimenter placed a large opaque screen on the table between the infant and the cloth and toy; the screen was then immediately removed. The reason for this procedure is explained below.

Following the pretest phase, the *test* phase began. At the start of the first test trial, the experimenter placed one cream-colored cloth on the table to one side of the infant's midline and then folded the cloth in half, toward the infant. Next, the experimenter introduced two identical attractive toys, such as Tweety Bird dolls (see Figure 2). One toy was held above and beyond the folded cloth; the other toy, which was held on the opposite side of the infant's midline, had a cloth attached to its bottom. The experimenter squeaked the two toys, placed them down on the table, and then tapped them simultaneously until the infant had looked at each of them. For half of the infants, the attached toy–cloth pair was on the right and the unattached toy–cloth pair was on the left; for the other infants, the positions of the two pairs were reversed. Next, as in the last two pretest trials, the screen was placed between the infant and the toy–cloth pairs for a brief interval; this procedure was adapted from that of Hofstadter and Reznick (1996) and was intended to prevent the infants from simply reaching for whichever toy–cloth pair they happened to look at last when the experimenter tapped them. After the screen was removed, the infants were encouraged to reach, as in the pretest trials. The first trial was repeated until the infants succeeded in retrieving the attached toy on two consecutive trials, termed the A trials. The infants typically took two to six trials to complete these trials. Infants who did not complete two successful A trials (with the same toy) within six trials were eliminated from the sample. The infants who succeeded on two consecutive A trials were given one additional trial, termed the B trial, that was identical to the A trials except that the position of the two toy–cloth pairs was reversed.

The infants' responses on the B trial were assigned to one of two main categories. Infants were said to have produced a *correct* response if they pulled the cloth in the attached toy–cloth pair while focusing primarily on the toy (as opposed to, say, the cloth itself, the experimenter, and so on). Infants were said to have produced a *perseverative* response if they pulled the cloth in the unattached toy–cloth pair while again attending to the toy. In rare instances where the infant pulled both cloths simultaneously, the toy the infant looked at was used to determine which cloth was being pulled intentionally.

2. *Results and Interpretations*

As shown in Table I, the results of the B trial revealed a reliable difference between the responses of the 7- and 9-month-old infants: whereas most of the younger infants produced perseverative responses by continuing to pull the cloth on the same side as they had pulled on the A trials, most of the older infants produced correct responses, pulling the cloth with the attached toy.

Consistent with our model, we assume that the 7-month-old infants perseverated because their initial analysis of the B-trial problem was too shallow to allow them to register the change in the location of the two toy–cloth pairs. As a result, the infants categorized the B-trial problem as similar to that on the preceding A trials. This miscategorization in turn led the infants to retrieve their previous solu-

TABLE I

7-, 9-, and 11-Month-Old Infants' Performance in the Support Tasks

Task	Response on the B trial: Pull cloth at previous location (perseverate)	Response on the B trial: Pull cloth at new location (succeed)
Toy-attached		
7 months	×	
9 months		×
Toy unattached		
9 months	×	
11 months		×
Gap		
11 months	×	

tion, leading to a perseverative error. In contrast, the 9-month-old infants engaged in a more complete initial analysis of the B-trial problem. This analysis enabled the infants to notice the change in the location of the two toy–cloth pairs. Accordingly, the infants categorized the B-trial problem as distinct from that on the preceding A trials and proceeded to analyze the problem further and compute a new appropriate solution.

Why did the 7-month-old infants engage in a shallow and the 9-month-old infants in a deeper initial analysis of the B-trial problem? We believe that the answer to this question has to do with infants' level of expertise at solving problems involving the retrieval of composite objects—objects that are made up of different parts such as a nursing bottle, a rattle, and the attached toy–cloth pair in our task. As mentioned earlier, 6.5-month-old infants readily pull on the near end of a cloth to bring within reach a distant toy when they are shown that the toy is actually attached to the far end of the cloth, thus forming a single composite object (Aguiar, 1997; Kolstad & Aguiar, 1995). However, pilot data collected with infants aged less than 6 months indicated that these younger infants were less likely to succeed at retrieving the attached toy. One implication of these results is that, although the 7-month-old infants in the present experiment were able to solve problems involving the retrieval of composite objects, this ability was still a relatively new acquisition. By contrast, the 9-month-old infants had about 2 months additional practice at retrieving composite objects. It is plausible that as a result of such practice infants come to automatically encode more detailed information about composite objects in their initial analysis. After all, one can gain access to a distant portion of a composite object by acting on a nearer portion that is *attached* but not *disjoint* (e.g., one can gain access to the nipple of a nursing bottle by acting on the bottle only if the bottle and nipple are actually attached at the time). It would make sense that with experience infants would come to closely and routinely attend to the arrangement of the portions of a composite object prior to acting on it. Such an encoding would have helped the 9-month-old infants in our experiment track the location of the attached toy–cloth pair on each trial, thereby facilitating their successful performance.

We are not suggesting that 7-month-old infants never attend to the arrangement of the distinct portions of composite objects. If this were the case, it would be difficult to explain the 7-month-old infants' performance on their first successful A trial. Our suggestion is that the infants attended to the arrangement of each toy–cloth pair only in their *further* analysis of the problem when they were computing its solution. In the B trial, the infants never carried out this further analysis because they miscategorized the problem as familiar, and thus simply retrieved their previous, A-trial solution.

What information did the 7-month-old infants include in their shallow initial analysis of the B-trial problem? The present data do not allow us to offer a precise answer to this question. One possibility is that the infants focused on the global context of the problems and were swayed by the overall similarities across trials in the testing room, experimenter, procedure, stimuli, and so on. Another possibility is that the infants' initial analysis was more limited in scope and that, like the physics novices in the experiment of Chi et al. (1981), the infants attended primarily to the concrete entities involved in the problems ("yep, toys and cloths, same old thing").

B. TOY-UNATTACHED TASK

Our second support task (Aguiar, 1998; Aguiar & Baillargeon, 1999b; Aguiar et al., 1997) was similar to our first with one important exception: in the attached toy-cloth pair, the toy was no longer velcroed to the cloth but simply rested on it (see Figure 3). This difference was perceptible only when the experimenter held up the

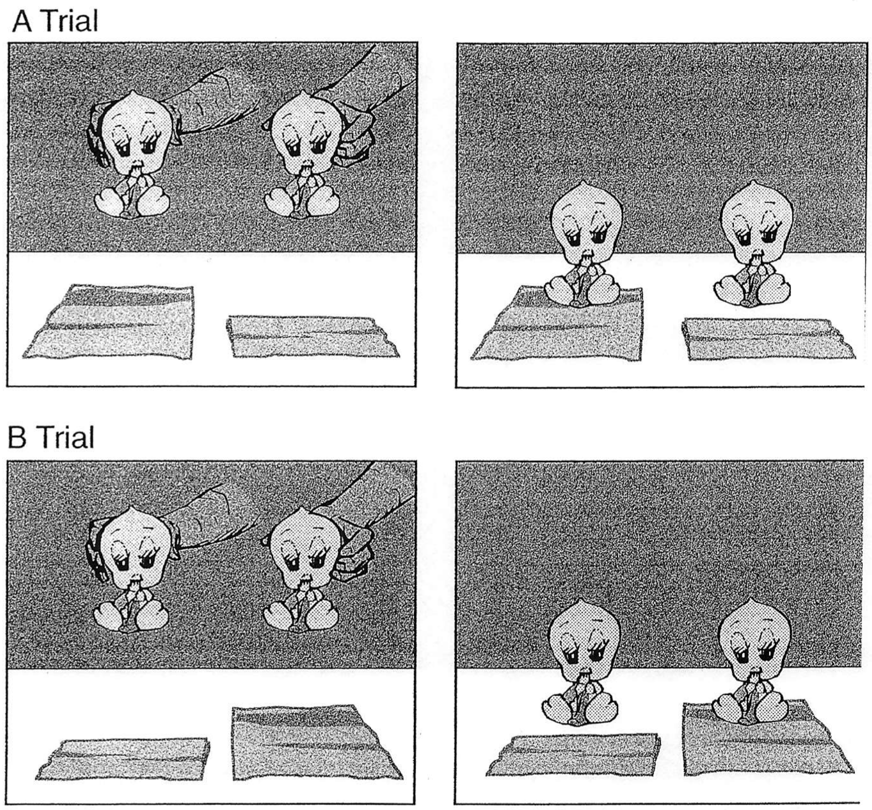

Fig. 3. Schematic drawing of the test trials in the toy-unattached task.

toy; when the toy and cloth were on the table, they were indistinguishable from the attached toy–cloth pair in our first task.

1. Procedure

Participants were 9- and 11-month-old infants. The infants were tested using the same procedure as in the toy-attached task, with a few exceptions. First, the single toy and cloth used in the three pretest trials were no longer attached. Second, at the start of each test trial, the experimenter placed the two cloths simultaneously on the table, on either side of the infant's midline, and then folded one of the cloths in half. Next, the experimenter introduced the two toys, and the procedure then continued as in the toy-attached task.

2. Results and Interpretations

The results revealed a reliable different between the responses of the younger and older infants on the B trial: whereas most of the 9-month-old infants perseverated and pulled the cloth on the same side as the cloth they had pulled on the A trials, most of the 11-month-old infants responded correctly and pulled the cloth on which the toy rested (see Table I).

Consistent with our model, we believe that the 9-month-old infants perseverated in the toy-unattached task because (a) their initial analysis of the B-trial problem was too shallow to enable them to register the change in the location of the two toy–cloth pairs; (b) they consequently miscategorized the problem as similar to that on the preceding A trials; (c) this miscategorization in turn led them to retrieve their previous solution, resulting in a perseverative error. In contrast, the 11-month-old infants succeeded at the task because (a) they engaged in a deeper and more complete analysis of the two toy–cloth pairs that allowed them to detect the change in the location of the toy–cloth pairs; (b) they accordingly categorized the B-trial problem as novel; and therefore (c) they went on to compute its solution.

Why did the 9-month-old infants engage in a shallow and the 11-month-old infants in a deeper initial analysis of the B-trial problem? We believe that the answer to this question has to do with infants' level of expertise at solving problems involving the retrieval of objects resting on supports. As mentioned earlier, it is not until infants are about 8 months of age that they spontaneously pull on the near end of a support to bring within reach a toy placed on the far end of the support (e.g., Aguiar, 1997; Kolstad & Aguiar, 1995; Matthews et al., 1996; Piaget, 1952; Willatts, 1984). These findings suggest that although the 9-month-old infants in the present experiment were able to solve problems involving the retrieval of supported objects, this ability was still a relatively new acquisition. By contrast, the 11-month-old infants had about 2 months additional practice at retrieving supported objects. It seems reasonable to suppose that as a result of such practice infants come to automatically encode more detailed information about object-support pairs; after all, one can retrieve an object by pulling on a support when the object rests *on* but not *beyond* the support, and it makes sense that with experience infants come to closely and routinely attend to whether an object is on or beyond a support before acting on it. This more detailed encoding would have helped the 11-month-old infants in our experiment track the location of the supported toy on the initial analysis of each of the trials, thereby contributing to their successful performance.

Why did the 9-month-old infants perseverate in the toy-unattached but not the toy-attached task? In accordance with our model, we believe that the answer to this question has to do with infants' initial analysis of the B-trial problem in each task. We suggested earlier that, by 9 months of age, infants automatically encode detailed information about composite objects. In the toy-unattached task, however, there were *no* composite objects. If the infants simply noted in their initial analysis of the B-trial problem in the unattached-toy task that there were two distinct objects, a toy and a cloth, on either side of the midline, without attending particularly to whether the toy in each pair was on or beyond the cloth, then they would have lacked the necessary information to judge that the B trial was indeed different from the preceding A trials and called for a novel solution.

Once again, we are not suggesting that 9-month-old infants never attend to the arrangement of objects and their supports. Clearly, the 9-month-old infants in the toy-unattached task had to do so on their first successful A trial. However, we believe that these infants attended to the arrangement of the toy and cloth in each pair only in their *further* analysis of the problem when they were computing its solution. In the B trial, the infants never carried out this further analysis because they miscategorized the problem as familiar and therefore simply retrieved their previous, A-trial solution.

C. GAP TASK

Our third support task (Aguiar, 1998; Aguiar & Baillargeon, 1999b; Aguiar et al., 1997) was similar to our toy-unattached task, with one important exception: the toy–cloth pair involving a toy standing behind a folded cloth was replaced with a new toy-two-cloths pair (see Figure 4). In this pair, two smaller cloths, separated by a gap, were laid on the table; the toy rested on the farther of the two cloths. The total length of the two cloths and gap equalled that of the single cloth in the toy–cloth pair.

1. *Procedure*

Participants were 11-month-old infants. The infants were tested using the same procedure as in the toy-unattached task, with the following exception. At the start of each test trial, the experimenter placed the single cloth and two small cloths on the table, on either side of the midline. Next, the experimenter introduced the two toys, and the procedure continued as in the toy-unattached task.

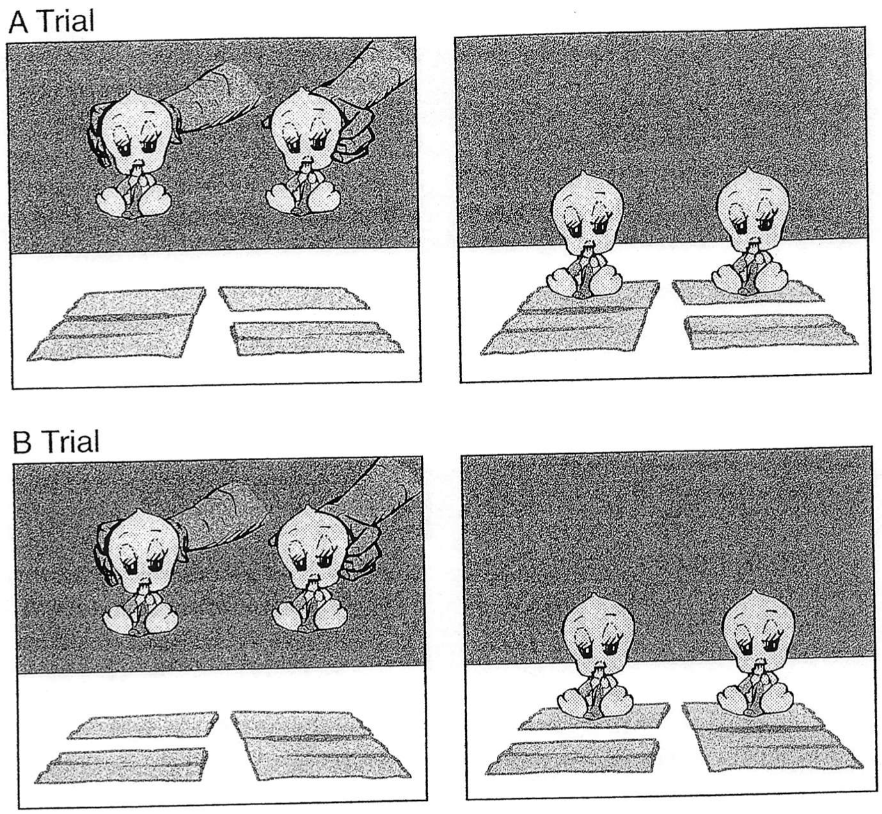

Fig. 4. Schematic drawing of the test trials in the gap task.

2. *Results and Interpretations*

Comparison of the B-trial responses of the 11-month-old infants in the toy-unattached and gap tasks revealed a reliable difference: whereas most of the infants in the toy-unattached task had responded correctly, most of the infants in the gap task perseverated, pulling the cloth on the same side as the cloth they had pulled on the preceding A trials (see Table I). In accordance with our model, we assume that the infants in the gap task perseverated because their initial analysis of the B-trial problem was too shallow to enable them to register the change that had been introduced. As a result, the infants miscategorized the problem as similar to that on the preceding A trials. This miscategorization in turn led the infants to retrieve their previous solution, resulting in a perseverative error.

Why did the 11-month-old infants perseverate in the gap but not the toy-unattached task? We suggested earlier that the 11-month-old infants in the toy-unattached task, who were experienced at retrieving supported objects, might have included in their initial analysis of the B-trial problem information as to whether each toy was on or beyond its support. Such information was sufficient, in the toy-unattached task, to help the infants track the location of the two toy–cloth pairs and hence correctly categorize the B-trial problem and avoid perseveration. In the gap task, however, each toy rested *on* a cloth; therefore, an initial analysis that simply checked whether a toy was on or off a support would not have provided sufficient information to correctly track the location of the toy–cloth and toy–two-cloths pairs. A more detailed analysis was required that also included information about whether the portion of cloth on which the toy rested was effectively connected to the portion of cloth within reach. Presumably, with practice at solving gap problems such as the one used here, infants would come to include more detailed support information in their initial analyses of the problems, thereby avoiding perseveration.

D. PRIOR EVIDENCE OBTAINED WITH A DIFFERENT SUPPORT TASK

It might be objected that our results are inconsistent with those of experiments conducted with a different support task (Matthews et al., 1996; Willatts, 1985), which yielded no evidence of perseveration. Matthews et al. (1996) tested infants every 4 weeks between 7 and 15 months of age in the following support task: two identical cloths lay side by side on a table, and a toy was placed on the far end of one of the cloths. After the infants successfully retrieved the toy on two or three trials (A trials), the toy was moved to the other cloth (B trials). The results indicated that the infants produced few perseverative errors across all testing sessions. Willatts (1985) found no evidence of perseveration in a similar task with 9-month-old infants.

How can we reconcile these results with our own? Our experiments indicated that more complex support tasks were needed with age to elicit perseverative errors: the 7-month-old infants perseverated in the toy-attached task, the 9-month-old infants perseverated in the toy-unattached but not the toy-attached task, and the 11-month-old infants perseverated in the gap but not the toy-unattached task. Our interpretation of these results was that with experience, infants routinely encode information about more and more crucial features in their initial analysis of support problems, and as a result are more likely to detect changes in these features on B trials. In the task used by Matthews et al. (1996) and Willatts (1985), the infants were given problems involving a *single* toy. Therefore, as long as the infants' initial analysis of the problem on each trial included the toy's location, they could categorize the problem correctly and know whether to retrieve their previous solution or compute a new one. In all our tasks, in contrast, the infants were given problems involving *two* toys. Hence, more information had to be included in the infants' initial analyses of the problems to differentiate between the two toy–cloth pairs and achieve correct categorizations.

The results of Matthews et al. (1996) and Willatts (1985), rather than being inconsistent with our own, thus provide further evidence that the more complex the support task, the more information must be included in infants' initial analyses of the problems for perseveration to be avoided, and hence the older the age at which infants are likely to succeed at the task.

E. TOY-UNATTACHED TASK REVISITED

One way of construing the results reported so far is that infants who have little experience at solving support problems can be prevented from perseverating on B trials by being given simpler problems for which they routinely include change-relevant information in their initial analyses of the trials. Thus, we could say that 9-month-old infants who perseverate in the toy-unattached task can be helped either by attaching the toy that rests on the cloth *to* the cloth (as in our toy-attached task), or by using a single toy (as in the task of Matthews et al., 1996, and Willatts, 1985). Could infants be prevented from perseverating in other ways? We conducted additional experiments to address this question.

The point of departure for these experiments was the intuition that, although infants might focus primarily on the arrangement and location of the toys and cloths in their initial analyses of support problems, they might also encode some information about the global context of the problems. This intuition suggested that the introduction of a *salient contextual change* in the B trials might be detected by infants, leading to correct categorization and responding.

In one experiment (Aguiar, 1998; Aguiar & Baillargeon, 1999b), 9-month-old infants were tested with a procedure similar to that of our original toy-unattached task, with one important exception: one experimenter tested the infant in the A trials and a different experimenter tested the infant in the B trial. At the end of the A trials, the A experimenter stepped behind a large curtain, and the B experimenter then emerged from behind this curtain to continue the infant's testing.

Comparison of the responses on the B trial of the 9-month-old infants in our original toy-unattached task and in the two-experimenters version of the task yielded a significant difference: unlike the infants in our original task, most of the infants in the two-experimenters task responded correctly on the B trial. Further experiments are planned to establish exactly how having a second experimenter test the infants in the B trial prevented their perseverating. For example, did the infants succeed because they knew that different people often behave differently and hence realized that the B experimenter might well give them a different problem than the A experimenter? Did the infants become distracted by the change in experimenter and essentially forget the A trials? Or was it simply that the change in experimenter was perceptually highly salient for the infants and had the same effect that might be expected from any other salient contextual change, such as a drastic change in the appearance of the test rooms?

Whatever the final outcome of these future experiments, two conclusions can already be drawn from the results of our two-experimenters task. First, having two different experimenters administer the A and B trials helps prevent 9-month-old infants from perseverating in the toy-unattached task. Second, infants' initial analyses of support problems include information about not only objects and their supports but also about more global contextual features of the problems, since changes in some of these features can lead infants to categorize problems as novel.

F. SUMMARY OF FINDINGS IN SUPPORT TASKS

The results of our support tasks are easily summarized. First, infants at each age produced perseverative errors. Second, the older the infants, the more complex the task needed to be in order to elicit errors. Thus, the 7-month-old infants perseverated in the toy-attached task, the 9-month-old infants in the toy-unattached but not the toy-attached task, and the 11-month-old infants in the gap but not the toy-unattached task. Finally, infants were less likely to produce perseverative errors if different experimenters administered the A and B trials.

These results are consistent with our model of infant perseveration and suggest that as infants gain experience with support problems, they routinely encode more and more crucial features in their initial analyses of the problems. Thus, the 9- but not the 7-month-old infants in the toy-attached task encoded in their initial analysis of the problem on each trial the location of the attached toy–cloth pair. Similarly, the 11- but not the 9-month-old infants in the toy-unattached task encoded the location of the toy–cloth pair in which the toy rested on as opposed to beyond the cloth. These more detailed encodings enabled the infants to detect the location change introduced in the B trial; as a result, they correctly categorized the problem as novel and computed a new solution, thereby avoiding perseveration.

VI. Perseveration in Containment Tasks

In this section, we review experiments conducted with two containment tasks of increasing difficulty. Both tasks involved a violation-of-expectation paradigm rather than an object-manipulation paradigm. As mentioned earlier, the tasks differed maximally from memory-and-motor tasks in that infants (a) had no need to update and remember information about objects and (b) were not required to select and perform one of two alternative motor responses across trials: infants simply looked at the event they were presented on each trial. The two tasks and their results are described in turn.

A. BALL TASK: CONTAINER AND NO-CONTAINER CONDITIONS

Our first task was based on the results of an experiment by Sitskoorn and Smitsman (1995). These results, which are described in more detail later, suggested that

6- but not 4-month-old infants realize that the width of an object relative to that of a container determines whether the object can be lowered into the container. In our task, 6.5-month-old infants first received familiarization trials (A trials) followed by test trials (B trials). During the familiarization trials, the infants saw a large ball being lowered into a much wider container. During the test trials, the infants saw the same ball being lowered into two novel containers, one slightly larger (large-container event) and one considerably smaller (small-container event) than the ball (Aguiar, 1998; Aguiar & Baillargeon, 1996, 1999a). The question of interest was whether the infants would (a) detect the violation shown in the small-container event, and hence look reliably longer at this event than at the large-container event, or (b) perseverate by carrying forth the same expectation ("the ball will fit into the container") they had formed during the familiarization trials, and hence look about equally at the two test events.

A second group of 6.5-month-old infants was tested in a control condition (no-container condition) identical to the container condition, with one exception: during the familiarization trials, the wide container was absent and the ball was simply lowered to the apparatus floor. We reasoned that because these infants (a) could not form an expectation during the familiarization trials that the ball would fit into the container and hence (b) could have no such expectation to apply to the test trials, they should detect the violation in the small-container test event and hence should look reliably longer at this event than at the large-container test event.

1. Procedure

The infants in the container and no-container conditions were tested using a two-phase procedure that included a familiarization and a test phase (for brevity's sake a prefamiliarization phase involving a single trial is not described here; see Aguiar & Baillargeon, 1998, for details). During the *familiarization* phase, the infants in the container condition received three trials (see Figure 5). At the start of each trial, a large ball attached to the lower end of a rod was held directly above a very wide and shallow container, so that their widths could be visually compared. After a few seconds, a screen hid the ball and container. The ball was briefly raised above the screen and then lowered back behind the screen into the container. Finally, the screen was removed to reveal the ball resting on the bottom of the container. The infants in the no-container condition saw identical familiarization trials, except that the wide container was absent and the ball was simply lowered to the apparatus floor (see Figure 5).

During the *test* phase, the infants in the two conditions received four test trials. On alternate trials, the infants saw two test events identical to the familiarization event except that a different container was used (see Figure 6). In one event (large-container event), the container was taller and slightly wider than the ball; in the other event (small-container event), the container was taller but only half as wide as the ball. When the screen was removed, at the end of each test event, the infants saw the ball's rod protruding above the container's rim, suggesting that the ball

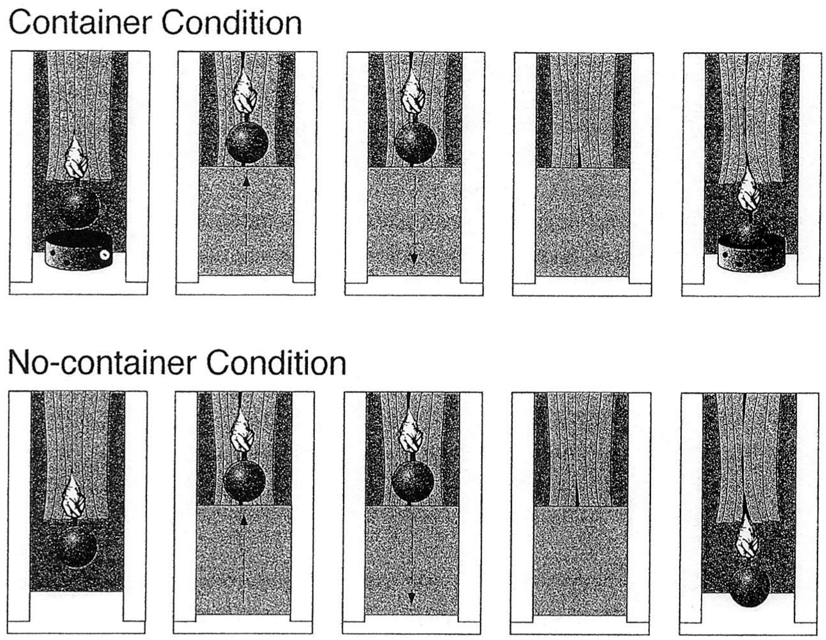

Fig. 5. Schematic drawing of the familiarization events in the container and no-container conditions of the ball task.

was inside the container. The order of presentation of the two test events was counterbalanced across infants.

Within each familiarization and test trial, the event was repeated continuously until the trial ended. This occurred when the infant either (a) looked away from the event for 2 consecutive seconds after having looked for at least 11 cumulative seconds (the duration of one event cycle) or (b) looked at the event for 60 cumulative seconds without looking away for 2 consecutive seconds.

2. Results and Interpretations

As shown in Table II, the results of the no-container condition indicated that the infants looked reliably longer at the small- than at the large-container test event. These results suggested that the infants (a) understood that the width of the ball relative to that of each container determined whether the ball could be lowered into the container; (b) determined that the ball could fit into the large but not the small container; and hence (c) were surprised in the small-container event when the screen was removed to reveal the rod protruding from the container's rim. These results confirmed those of Sitskoorn and Smitsman (1995) and provided further evidence that, by 6.5 months of age, infants realize that an object cannot be lowered into a narrower container.

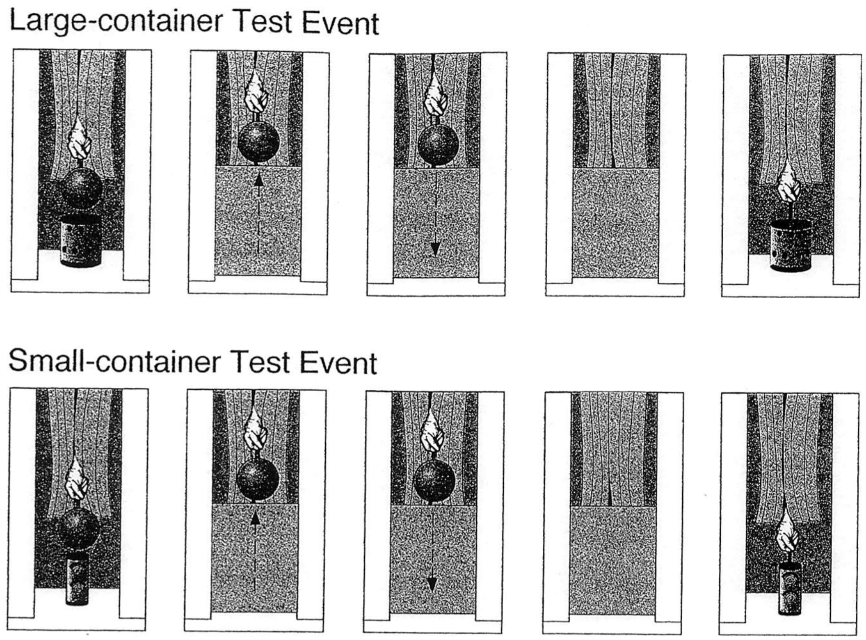

Fig. 6. Schematic drawing of the test events in the container and no-container conditions of the ball task.

In contrast to the infants in the no-container condition, those in the container condition tended to look equally at the small- and large-container test events. Consistent with our model, we believe that the infants responded as they did because (a) their initial analysis of each test event was too shallow to enable them to register the crucial change in the container's width; (b) they miscategorized each test event as similar to the event shown during the familiarization trials; and hence (c) they retrieved the expectation they had formed about the familiarization event ("the ball will fit into the container") and applied it to each test event. Because this expectation was correct for the large- but not the small-container test event, the infants failed to respond appropriately to the latter event.

Why did the infants in the container condition engage in a shallow initial analysis of each test event? In accordance with our model, we believe that the answer to this question has to do with infants' level of expertise at reasoning about the width of objects and containers in containment events. As mentioned earlier, Sitskoorn and Smitsman (1995) found that 6- but not 4-month-old infants succeeded at their task. These findings suggest that, although the 6.5-month-old infants in our task were able to reason about the width of objects and containers (recall that the infants in the no-container condition readily detected the violation in the small-

TABLE II

6.5-Month-Old Infants' Performance in the Ball Task

Condition	Response on test trials: Equal looking times at small- and large-container events (perseverate)	Longer looking time at small- than large-container event (succeed)
Container	×	
No-container		×
Occluder		×
Basket	×	
Reduced-opening		×

container test event), this ability was still a relatively new acquisition. One might predict that with more extensive experience at reasoning about the relative widths of objects and containers, infants come to automatically encode this information in their initial analyses of containment events, thereby avoiding perseveration. Data collected with 8.5-month-old infants using the container condition procedure (Aguiar & Baillargeon, 1999a) support this prediction: these older infants responded with prolonged looking to the small-container test event, even though they saw the ball being lowered into the wide container (rather than to the apparatus floor) during the familiarization trials.

What information did the infants in the container and no-container conditions include in their shallow initial analyses of the test events? We suspect that the no-container infants immediately noticed when watching the test events that the ball, instead of being lowered to the apparatus floor, was now being lowered into a container. This change was sufficient to lead the infants to categorize the test events as novel and consequently to pay careful attention to them as they unfolded. In contrast to the no-container infants, the container infants noted only that the test events, like the familiarization event, involved a ball being lowered into a container. Such limited information was insufficient to enable the infants to categorize and respond to the test events correctly.

B. BALL TASK: OCCLUDER AND BASKET CONDITIONS

Our speculations about the contents of the initial analyses performed by the infants in the container and no-container conditions suggest that the infants focused primarily on the *type* of event occuring in the familiarization and test trials (e.g., Baillargeon, 1995, 1998, 1999). Research on infants' acquisition of physical knowledge indicates that infants form distinct event categories (such as occlusion, containment, collision, and support events), and reason and learn separately about each event category. From this perspective, one could argue that the infants in the no-container condition succeeded (i.e., detected the violation in the small-container test event) because they saw a containment event during the test but not the familiarization trials. The infants detected this change in event category in their initial analyses of the test events, allowing them to categorize and respond to the events correctly. In contrast, the infants in the container condition, who saw a containment event during both the familiarization and test trials, were lulled by this similarity in event category to conclude that they were seeing the same event, resulting in perseverative responding.

These speculations led to two predictions. One was that if the infants were shown an occluder rather than a container during the familiarization trials, they should detect a change in event category—from occlusion to containment—during their initial analyses of the test trials. Like the infants in the no-container condition, the infants should then categorize the test events as novel and respond to them appropriately. The other prediction was that increasing the perceptual distinctiveness of the familiarization and test containers should have little effect on the infants' performance. Like the infants in the container condition, the infants should focus primarily, in their initial analyses of the test events, on the fact that these again involved a containment event, and they should respond perseveratively.

1. Procedure

To evaluate these predictions, 6.5-month-old infants were tested in two conditions (Aguiar, 1998; Aguiar & Baillargeon, 1996, 1999a). In both conditions, the infants saw the same small- and large-container test events as the infants in the container and no-container conditions. Only the familiarization event was different (see Figure 7). In one condition (occluder condition), the bottom and back of the wide familiarization container used in the container condition were removed to form a rounded occluder; the ball was simply lowered to the apparatus floor behind the occluder. This manipulation was derived from work by Hespos and Baillargeon (1999). In the second condition (basket condition), the wide familiarization container used in the container condition was replaced with a wide square wicker basket. In the container condition, the wide familiarization container differed from the test containers in height and diameter, but it resembled these containers in a number of respects: all three containers were cylindrical, were covered with a bright contact paper, were decorated with bright decals, and had their upper and lower edges outlined in black. Compared to the wide familiarization container, the basket was even more different perceptually from the test containers, since it differed from these containers in height and width as well as in shape, texture, color, and pattern.

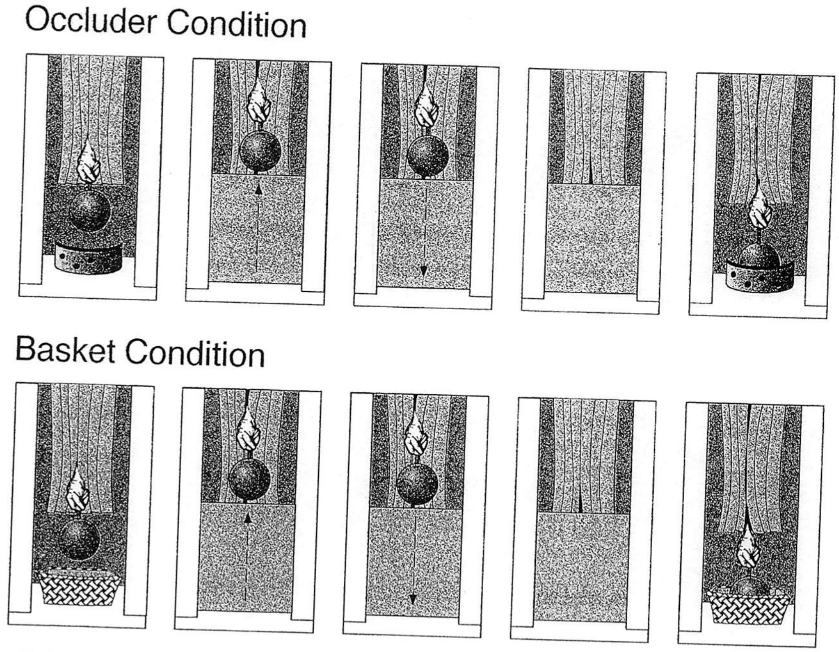

Fig. 7. Schematic drawing of the familiarization events in the occluder and basket conditions of the ball tasks.

2. Results and Interpretations

The results of the occluder and basket conditions supported our predictions (see Table II). Like the infants in the no-container condition, those in the occluder condition looked reliably longer at the small- than at the large-container test event. Furthermore, like the infants in the container condition, those in the basket condition looked about equally at the two test events. Together, these results provide strong evidence that 6.5-month-old infants in our task focus primarily, in their initial analyses of the test events, on whether these events belong to the same or to a different category than the familiarization event. The infants in the no-container and occluder conditions, who saw events from different categories in the familiarization and test trials, succeeded at the task. In contrast, the infants in the container and basket conditions, who saw containment events in both the familiarization and test trials, did not; even salient differences in the width, height, texture, and appearance of the familiarization and test containers had no detectable effect on the infants' initial analysis and categorization of each test event.

3. Related Findings

The finding that the infants in our task were more likely to err when shown familiarization and test events of the same as opposed to different event categories may be related to adults' performance in tasks where they are asked questions with a distorted term, such as "How many animals of each kind did Moses take on the ark?" Most adult participants answer questions of this type without noticing that Noah was replaced by Moses (e.g., Erickson & Mattson, 1981; Reder & Kusbit, 1991). Reder and Kusbit (1991) argued that participants fail to notice this distortion because they make an incomplete match between the representation of the question and their previously stored proposition that contains the answer. However, adults readily pick up the distortion if, for instance, Nixon replaces Noah (Erickson & Mattson, 1981). According to Reder and Kusbit, this result occurs because the participants' partial match process is sensitive to the level of conceptual similarity between the words in the distorted question and the participants' previously stored representation of the answer. Participants overlook substitutions such as Moses for Noah because the two words invoke similar concepts (i.e., Moses and Noah are both biblical characters of the old Testament), but they detect substitutions such as Nixon for Noah because the two words invoke very different concepts.

C. BALL TASK: REDUCED-OPENING CONDITION

We have argued that the infants in the container and basket conditions responded perseveratively to the small- and large-container test events because their initial analyses of these events (a) indicated that they were again containment events and (b) included no information about the relative widths of the ball and container in each event. Could infants be *induced* to include such crucial information in their initial analyses of the test events? The last condition of our ball task was designed to address this question (Aguiar, 1998; Aguiar & Baillargeon, 1996, 1999a).

This condition was based on the intuition that because the wide container used in the container condition familiarization trials was markedly larger than the ball, even a cursory comparison of the widths of the ball and container was sufficient for the infants to ascertain that the one could easily fit into the other. We hypothesized that a task that required the infants to attend more closely to the widths of the ball and container during the familiarization trials might induce them to do the same in the test trials, resulting in a better performance.

1. Procedure

To test this hypothesis, 6.5-month-old infants were tested in a condition (reduced-opening condition) identical to the container condition, with one exception: during the familiarization trials, a cover with a central opening was placed on the wide container (see Figure 8). The cover reduced the opening of the container, so that the ball now fit snugly into the container. We reasoned that the infants would now need to attend more closely to the widths of the ball and container to determine whether the one could indeed be lowered into the other. This more careful

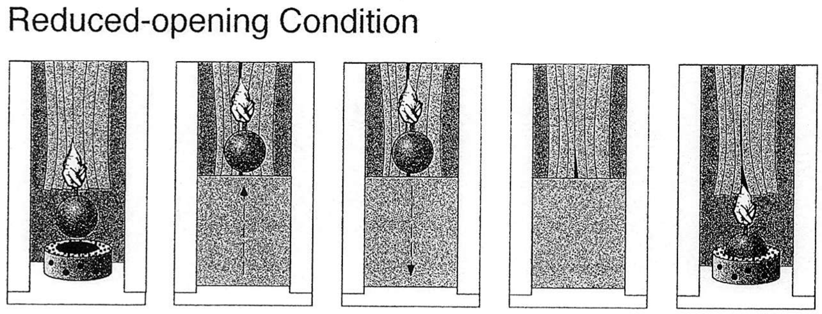

Fig. 8. Schematic drawing of the familiarization event in the reduced-opening condition of the ball task.

comparison might induce the infants to attend similarly to the relative widths of the ball and container during their initial analyses of the test events, resulting in successful performances.

2. Results and Interpretations

The results confirmed our hypothesis: after receiving familiarization trials in which the opening of the wide container was reduced, the infants looked reliably longer at the small- than at the large-container test event (see Table II).

Together, the results of the container and reduced-opening conditions suggest that although the infants did not spontaneously include information about the relative widths of the ball and container in their initial analyses of the test events (container condition), they could be induced to do so if they were given familiarization trials requiring a careful rather than a cursory comparison of the widths of the ball and container (reduced-opening condition). Such trials apparently had the effect of increasing the salience of this comparison process for the infants, making them more likely to include appropriate information about the relative widths of the ball and container in their initial analyses of the test events.

3. Implications for the Results of the No-Container and Occluder Conditions

The results of the reduced-opening condition may also have implications for the results of the no-container and occluder conditions. One might ask why the infants in these conditions did not begin to respond perseveratively across the test trials. That the infants who saw the small-container test event first did not perseverate is not surprising because this event violated their expectations about containment events; this outcome no doubt motivated the infants to pay careful attention to each subsequent event to determine whether it, too, would violate their expectations. However, what of the infants who saw the large-container test event first? Why did these infants not respond perseveratively on the remaining test trials, looking equally at the large- and small-container events?

At least two possibilities come to mind. The first is that infants are unlikely to perseverate if a change is introduced after a single trial: recall that the infants would have seen the large container in the first test trial and the small container in the second one. In the conditions in which perseveration was observed, the infants saw the same object and container (wide container, basket) on three successive familiarization trials prior to the test trials. Although this explanation may seem plausible, pilot data suggest that it is unlikely. These data were obtained in a condition identical to the container condition except that the wide container was introduced only in the *last* familiarization trial; during the first two familiarization trials the ball was simply lowered to the apparatus floor, as in the no-container condition. Despite the fact that the wide container was present for a single trial, the infants still responded perseveratively in the test trials, looking equally at the small- and large-container test events.

A second explanation is that the infants in the no-container and occluder conditions who saw the large-container test event first were in the same position as the infants in the reduced-opening condition: because the ball and large container were very similar in width, the infants had to compare them carefully to determine whether containment was possible. This process in turn increased the likelihood that the infants would include information about the width of the container in their initial analysis of the small-container event, thereby ensuring a successful performance.

The findings discussed in this section are generally consistent with evidence from the literature on adults' skill acquisition that initial training trials influence the kinds of strategies and computations adults use on later trials when processing novel stimuli (e.g., Doane, Alderton, Sohn, & Pellegrino, 1996; Kerr & Booth, 1978; Medin & Bettiger, 1994; Pellegrino, Doane, Fischer, & Alderton, 1991; Schmidt & Bjork, 1992). For example, in a visual discrimination task (e.g., Doane et al., 1996), adults were found to be significantly better at judging whether two random polygon stimuli were similar or different if they were initially trained on pairs of polygons that were highly similar and thus required a precise comparison strategy, as opposed to pairs that were highly dissimilar and thus could be judged by means of a more global comparison strategy.

D. PRIOR EVIDENCE OBTAINED WITH A DIFFERENT CONTAINMENT TASK

It might be objected that our interpretation of the results of the container and basket conditions is inconsistent with the results of Sitskoorn and Smitsman (1995). The 6-month-old infants in their experiment were habituated to two events presented on alternate trials. In both events, a block was repeatedly lowered into and lifted from a box with an opening at the top; one event involved a small block and a box with a small opening, and the other event involved a large block and a box with a large opening. Following habituation, the block and box pairs were rearranged, and the infants saw two test events. In one (large-opening event), the *small* block was lowered into the box with the *large* opening. In the other event (small-opening event), the *large* block was lowered into the box with the *small* opening (the box's side rims were partly collapsible). The results indicated that the infants looked reliably longer at the small- than at the large-opening event. From the perspective of the interpretation proposed in the previous sections, these results are puzzling. Why did the infants not perseverate during the test trials and look equally at the test events they were shown, like the infants in our container and basket conditions? Why did the infants perform instead like the infants in our no-container, occluder, and reduced-opening conditions?

One possible explanation for the discrepancy between our results and those of Sitskoorn and Smitsman (1995) is that these authors changed *both* the object and the container on alternate habituation and test trials. In our task, in contrast, the object—the ball—remained the same throughout the experimental session; only the container was changed. It seems plausible that, when observing containment events in which an object is lowered into a container, infants have a natural bias to attend more to the (moving) object than to the (stationary) container. Such a bias could lead infants to include some information about the features (e.g., width) of the object in their initial analysis of the event on each trial. A change in the object's features would thus be likely to be noticed, and to lead to a correct categorization of the event as novel.

These speculations suggest that 6.5-month-old infants might be less likely to perseverate if tested in a task in which the object rather than the container was changed across trials. For example, infants might see events involving a medium-size container and a small ball (familiarization event), medium ball (medium-ball test event), or large ball (large-ball test event).

E. BALL TASK: RESULTS WITH 7.5-MONTH-OLD INFANTS

We reported earlier that 6.5-month-old infants perseverated in the container condition of our ball task, but that 8.5-month-old infants did not (Aguiar, 1998; Aguiar & Baillargeon, 1996, 1999a). In an additional experiment, we tested 7.5-month-old infants in the same condition (Aguiar & Baillargeon, 1999c). Like the 6.5-month-old infants, these older infants tended to look equally at the small- and large-container test events (see Table III), suggesting that (a) their initial analysis of each test event was too shallow to enable them to detect the change in the container's width; as a result (b) they miscategorized each test event as similar to the familiarization event; and thus (c) they retrieved the expectation they had formed about this event ("the ball will fit into the container") and applied it to each test event.

In our experiments with 6.5-month-old infants, we found that there were at least two ways of preventing perseverative responding in these infants. One way was to

TABLE III

6.5-, 7.5-, and 8.5-Month-Old Infants' Performance in the Ball and Quantitative-Ball Tasks

Condition	Response on test trials: Equal looking times at small- and large-container events (perseverate)	Response on test trials: Longer looking time at small- than at large-container event (succeed)
Ball task		
Container		
6.5	×	
7.5	×	
8.5		×
No container		
6.5		×
7.5		×
Reduced-opening		
6.5		×
7.5	×	
Quantitative-ball Task		
Container		
6.5		×
7.5	×	
8.5		×

show the infants events from different event categories in the familiarization and test trials (no-container and occluder conditions); we suggested that this change in event category was noted by the infants in their initial analyses of the test events, leading to correct categorization and responding. The other way was to show the infants a familiarization event that required them to perform a more careful comparison of the widths of the ball and container (reduced-opening condition); we speculated that this experience made the width-comparison process more salient for the infants and as a result induced them to include information about the widths of the ball and container in their initial analysis of each test event.

Would the same manipulations also be effective in preventing perseverative responding in 7.5-month-old infants? To find out, we tested two additional groups of infants, one with the no-container and one with the reduced-opening procedure (see Table III). The results of the no-container condition were similar to those we had obtained with the 6.5-month-old infants: the infants looked reliably longer at the small- than at the large-container test event, suggesting that they detected the violation in the small-container test event. The results of the reduced-opening condition, however, were different from those we had obtained with the 6.5-month-old infants. Like the 7.5-month-old infants in the container condition, those in the reduced-opening condition tended to look equally at the small- and large-container test events.

Why was the reduced-opening manipulation not effective in preventing perseveration in the 7.5-month-old infants? We suspect that because these infants were somewhat more experienced than the 6.5-month-old infants at reasoning about width in containment tasks, they were easily able to determine that the ball would fit into the container, even when its opening was reduced. Hence, the manipulation did not succeed in making the width comparison process more salient for the infants and thus inducing them to include width information in their initial analyses of the test events.

F. QUANTITATIVE-BALL TASK

Our second containment task (Aguiar & Baillargeon, 1999a, 1999c) was similar to the container condition of the ball task with one exception: during the test events, the ball and container were shown successively, rather than simultaneously, so that their widths could not be visually compared (during the familiarization event, the widths of the ball and wide container could be visually compared at the end of each event cycle when the screen was removed to reveal the ball resting inside the wide container; see Figures 9 and 10). Thus, as in the ball task, infants had to compare the width of the ball to that of each test container to detect the violation in the small-container test event. The present task differed from the ball task, however, in that infants had to encode and remember the width of the ball in order to compare it to that of each test container.

Our label for the present task—the quantitative-ball task—is derived from the distinction drawn in computational models of everyday physical reasoning between quantitative and qualitative reasoning strategies (e.g., Forbus, 1984). A strategy is said to be *quantitative* if it requires subjects to encode and use information about absolute quantities (e.g., object A is "this" wide, where "this" stands for some absolute measure of A's width). In contrast, a strategy is said to be *qualitative* if it requires subjects to encode and use information about only relative quantities (e.g., object A is wider than object B). The ball task could be solved by means of a qualitative strategy: infants could visually compare the widths of the ball and container at the start of each test event when the ball was held above the container. The present task, however, could be solved only by means of a quantitative strategy: infants had to encode and remember the width of the ball to determine whether it could fit into each test container.

1. Procedure

Participants were 6.5- and 7.5-month-old infants. The procedure was similar to that of the container condition of the ball task, except that the familiarization and

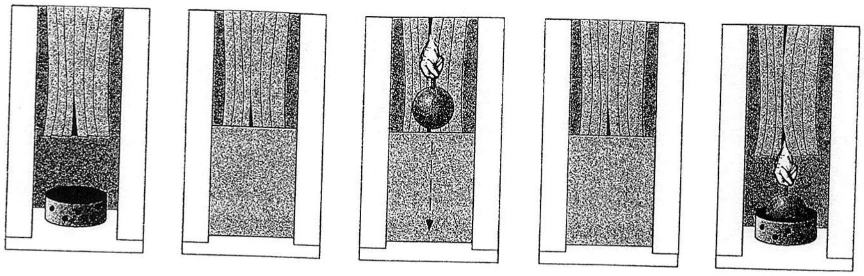

Fig. 9. Schematic drawing of the familiarization event in the quantitative-ball task.

test events were modified so that the ball was no longer held above the container. At the start of each trial, only the container was present, resting on the apparatus floor. After a few seconds, the container was hidden by the screen, and the ball was introduced into the apparatus, above the screen. Next, the ball was lowered behind the screen into the container. As in the ball task, the screen was then removed to reveal either the ball resting inside the wide container (familiarization event), or the ball's rod protruding above the small or large container (test events).

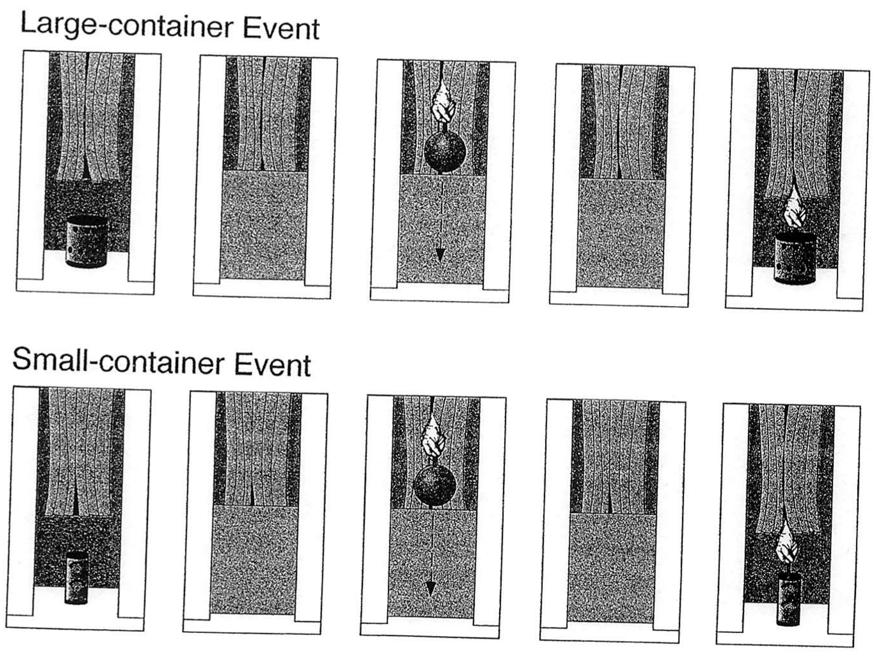

Fig. 10. Schematic drawing of the test events in the quantitative-ball task.

2. Results and Interpretations

As shown in Table III, the 6.5-month-old infants looked reliably longer at the small- than at the large-container test event, whereas the 7.5-month-old infants tended to look equally at the two events. The results of the quantitative-ball task thus mirrored those obtained with the 6.5- and 7.5-month-old infants in the reduced-opening condition of the ball task. We believe that this similarity is not accidental but instead reflects the fact that similar factors were at work in the two tasks.

Let us first consider the 6.5-month-old infants. We argued earlier that reducing the opening of the wide container in the familiarization event forced the infants to attend more closely to the widths of the ball and container; this experience made the width comparison process more salient for the infants and induced them to include information about the widths of the ball and container in their initial analyses of the test events. We suspect that, in the quantitative-ball task, having to remember the ball's width in the familiarization event again had the effect of making more salient for the infants the width comparison process; as a result, the infants were more likely to attend to the widths of the ball and container in their initial analyses of the test events.

Let us now turn to the 7.5-month-old infants. We suspect that these infants perseverated in both the reduced-opening condition of the ball task and the quantitative-ball task for the same reason: they were somewhat more experienced than the 6.5-month-old infants at comparing the widths of objects and containers. For these more experienced infants, reducing the opening of the wide container or showing the ball and wide container successively did not make the process of comparing the widths of the ball and container noticeably more effortful or salient. Consequently, the infants were not induced by these manipulations to attend to the widths of the ball and container in their initial analyses of the test events. In future experiments, we plan to explore whether more challenging manipulations (e.g., combining the manipulations used here in a reduced-opening quantitative-ball task) might prove effective in taxing the limits of 7.5-month-old infants' reasoning and thus in preventing them from responding perseveratively.

In another experiment (Aguiar & Baillargeon, 1998), we tested 8.5-month-old infants in the quantitative-ball task. The infants looked reliably longer at the small- than at the large-container test event, suggesting that they detected the violation in the small-container test event (see Table III). Presumably, these older infants were sufficiently experienced at reasoning about width in (either qualitative or quantitative) containment tasks that they automatically encoded information about the widths of the ball and container in their initial analyses of the test events.

Put together, the results obtained with the 6.5-, 7.5-, and 8.5-month-old infants in the quantitative-ball task form a rather unusual developmental pattern (see Table III): the 6.5- and 8.5-month-old infants succeeded at the task, but the 7.5-month-old infants did not. As should be clear from the preceding discussion, however, we believe that the 6.5- and 8.5-month-old infants were successful for somewhat different reasons. The older infants were at the stage where they routinely encoded information about the widths of objects and containers in their initial analyses of containment events. In contrast, the young infants were merely induced to encode width information in their initial analyses of the small- and large-container test events, because the challenge of having to remember the ball's width made the width-comparison process more salient for them. The 7.5-month-old infants were not so induced, presumably because having to remember the ball's width to compare it to that of the container posed little difficulty for them.

G. SUMMARY OF FINDINGS IN CONTAINMENT TASKS

The results of our containment tasks can be summarized as follows. First, both 6.5- and 7.5-month-old infants responded perseveratively to the ball task test events in some conditions, carrying forth—inappropriately in the context of the small-container test event—the expectation they had formed about the familiarization event. Second, infants responded perseveratively to the ball task test events if they saw containment events during both the familiarization and test trials, but not if they saw events from another event category during the familiarization trials. The 6.5-month-old infants failed to detect the violation in the small-container test event (a) when the ball was lowered into the wide container or basket during familiarization, but not (b) when the ball was lowered to the apparatus floor or behind the occluder. Similarly, the 7.5-month-old infants tended to look equally at the small- and large-container test events (a) when the ball was lowered into the wide container during familiarization, but not (b) when the ball was lowered to the apparatus floor. Third, the 6.5-month-old infants did not perseverate, even when shown containment events in both familiarization and test, if the familiarization event was modified so that comparing the widths of the ball and container required greater attention or effort from the infants. Two modifications proved effective in this respect: one was reducing the opening of the wide container, and the other was showing the container and ball successively. Fourth, the 7.5-month-old infants did not benefit from either of these modifications, presumably because they were not sufficiently taxing to require significantly more attention or effort from these older and somewhat more experienced infants.

The results of our containment tasks are consistent with those of our support tasks (described in section V). Together, these two sets of results point to four main conclusions. First, infants aged 6.5 to 11 months produce perseverative errors in nonmemory-and-motor tasks. Second, with experience, infants include more and more crucial information in their initial analyses of problems, and as a result are less likely to perseverate at tasks that depend on more detailed encodings (e.g., 7-month-old infants perseverated in the toy-attached task, but 9-month-old infants did not, and 7.5-month-old infants perseverated in the quantitative-ball task but

8.5-month-old infants did not). Third, novice infants can be induced to include in their initial analyses of problems crucial features they do not yet routinely encode, by being given in the familiarization or A trials more taxing problems that require greater attention or effort in the processing of these features (e.g., 6.5-month-old infants perseverated in the container but not the reduced-opening condition of the ball task). Finally, novice infants are also less likely to perseverate if some of the changes introduced in the test or B trials involve features infants do spontaneously attend to in their initial analyses of the trials (e.g., 9-month-old infants perseverated in the toy-unattached but not the two-experimenters-toy-unattached task, and 6.5-month-old infants perseverated in the container and basket but not the no-container and occluder conditions of the ball task).

These results provide strong support for our model of infant perseveration. In the future, we plan to expand our model in several directions. First, we will seek to confirm our results using new object-manipulation and violation-of-expectation tasks. Second, we will continue our attempts to specify what information infants do and do not include in their initial analyses of problems and events, and how this information is affected by changes in task context and experience. Finally, we plan to explore how our model can be elaborated to account for the perseverative errors that have been observed in memory-and-motor tasks. This last issue is discussed in more detail in the next section.

VII. Revisiting Infant Perseveration in Memory-and-Motor Tasks

As we discussed in section II, most of the research on infant perseveration has tended to be focused on memory-and-motor tasks—tasks such as Piaget's (1954) two-location search task that require infants (a) to update and remember information about objects and (b) to use this information to select one of two alternative motor responses. We also mentioned that, in keeping with the particular requirements of memory-and-motor tasks, accounts of perseveration in these tasks typically refer to limitations in (a) infants' ability to update and maintain information in working memory across trials and/or (b) infants' ability to use this information to select a novel motor response over a previously successful but no longer appropriate response.

Such accounts could not easily explain the findings of the support and containment tasks reported in this chapter. In the support tasks, infants perseverated even though they were not required to update and remember information about objects: the toys and cloths all lay visible before them. In the containment tasks, infants again perseverated even though these tasks differed maximally from memory-and-motor tasks. First, infants were not required to produce one of two alternative motor responses—they simply looked at the event before them. Second, infants were not required to update and remember information about objects. What changed in the test trials was the width of the containers, which were always plainly visible; although the ball was not visible after it was lowered into the test containers, it remained the same throughout the experiment. Thus, infants had no need to update and remember information to respond appropriately to the test events.

A. COULD OUR MODEL BE EXTENDED TO MEMORY-AND-MOTOR TASKS?

If current accounts of perseveration in memory-and-motor tasks cannot readily be extended to explain perseveration in nonmemory-and-motor tasks, could the reverse be true? Could our account of perseveration in nonmemory-and-motor tasks be elaborated to explain infants' perseverative errors in memory-and-motor tasks?

The memory-and-motor task literature (reviewed in section II) indicates that *novice* infants who have just begun to search for hidden objects typically perseverate with delays of 0 to 1 s, whereas more *expert* infants who have been able to search for longer periods of time err only with longer delays. For ease of description, we will refer to tasks with delays of 0 to 1 s as immediate-search tasks, and to tasks with longer delays as delayed-search tasks.

1. Immediate-Search Tasks

Our model can readily account for the perseverative errors of novice infants in immediate-search tasks. Specifically, we would argue that (a) infants' initial analysis of the problem on B trials is too shallow to enable them to register the change in the hiding location of the toy; (b) infants consequently miscategorize the problem as similar to that on the preceding A trials; and hence (c) infants retrieve their prior solution, leading to perseverative errors. On this account, novices' perseverative errors in immediate-search tasks are thus analogous to the perseverative errors we found in our support and containment tasks.

2. Delayed-Search Tasks

However, our model cannot as easily explain the perseverative errors of infants who are more expert at searching for hidden objects in delayed-search tasks. The fact that these infants perseverate only with a delay suggests that they do initially encode the change introduced in the B trials, but lose access to this information over time. In addition, the fact that longer delays are necessary with age to elicit errors suggests that older or more expert infants can retain information about the hiding location of an object for longer intervals. How could our model be elaborated to explain these effects?

Findings from the literature on the development of self-produced locomotion and its impact on spatial cognition (e.g., Acredolo, 1985, 1990; Acredolo, Adams, & Goodwyn, 1984; Bai & Bertenthal, 1992; Bertenthal, Campos, & Barrett, 1984;

Bremner, 1985; Horobin & Acredolo, 1986; Kermoian & Campos, 1988) suggest the following hypothesis. As infants learn to move independently about their environment, they develop more effective ways of encoding information about the locations of desired objects. This improved encoding not only helps infants remember the locations that objects occupy, but also helps them remember these locations for longer intervals. Such memory developments would be highly beneficial. For example, a standing infant, who sees a forbidden yet highly attractive remote-control device across a room on one end of a couch, might drop down to the floor (thus losing sight of the device) and crawl around an armchair and coffee table to reach the device. Being able to remember the precise location of the device long enough to reach it would present obvious advantages for the infant.

3. Changes in Infants' Encoding of Location Information

What changes in infants' encoding of location information might result in their improved memory performance in search tasks? Several possibilities exist, all of which might hold true. For example, one possibility is that when infants form the goal of retrieving an object, they learn to link or bind more tightly in memory the description of the goal object to information about its current location (for a discussion of binding processes in memory, see Cohen & Eichenbaum, 1993). Under these conditions, calling the goal object to mind would thus simultaneously remind infants of its location (e.g., as infants, after being momentarily distracted, set course once again for the remote-control device).

Results from the adult problem-solving literature provide some support for this possibility (e.g., Chase & Simon, 1973): when faced with a problem, chess and physics experts typically interconnect crucial features to form a large cohesive cluster in memory, whereas novices tend to keep crucial features in small separate units. One would expect that the links experts establish among the crucial features of a problem make them more accessible in memory and allow experts to recall more of the features, even after a delay, when computing the problem's solution.

Another possible change in infants' encoding of location information is that the encoding becomes more elaborate with increasing locomotor experience. A more detailed encoding of an object's location would result in a stronger memory trace, allowing the information to remain accessible in memory for a longer period of time (see, e.g., Stein, Littlefield, Bransford, & Persampieri, 1984, for a discussion on the effects of elaboration on memory).

The spatial orientation literature provides evidence that is consistent with this possibility. Bertenthal et al. (1984) conducted an experiment in which 8-month-old infants with or without locomotor experience sat at a table in a small room with a window on either side; one of the windows was unremarkable in appearance ("plain window"), but the other was surrounded by bright stripes and flashing lights that served as a salient landmark for the window ("landmark window"). To longer include information about the new hiding location of the object, infants conclude—based on the remaining contents of their initial analysis—that they are again faced with the same problem as in the preceding A trials; infants thus retrieve their previous solution, leading to a perseverative response.

Another assumption of our model of perseveration in nonmemory-and-motor tasks is that infants' initial analysis of a problem tends to be shallow when they are novices at the task. As they become expert, infants come to automatically encode more and more of the crucial features of the problem in their initial analysis; as a result, they are more likely to detect changes in these features and to respond to them appropriately. Our discussion of infants' perseveration in delayed-search tasks suggests that, here again, expertise plays a crucial role. We proposed that, as infants become skilled at self-produced locomotion, they learn to encode location information in more and more effective ways. As a result, infants are able to retain information about the hiding location of the object in their initial analysis of the problem on B trials for longer and longer delays.

Our analysis of memory-and-motor tasks does not even begin to deal with the vast literature on these tasks, nor does it make clear how the many variations that have been shown to increase or decrease perseverative responding in these tasks have their effects. Such an extensive analysis is clearly beyond the scope of this chapter. All we meant to accomplish here was to show one way our model of perseveration in nonmemory-and-motor tasks could be extended to account for perseveration in memory-and-motor tasks. Experiments are planned to test this new account and to ascertain how well it compares to existing accounts.

VIII. Concluding Remarks

We have presented a model of infant perseveration in nonmemory-and-motor tasks, reviewed evidence from support and containment tasks that supports this model, and finally examined how our model could be extended to account for infant perseveration in more traditional memory-and-motor tasks, such as delayed-search tasks. Although obviously preliminary and in need of greater elaboration and refinement, we believe that the approach proposed here nevertheless holds great promise. First, it helps place infant perseveration in the broader context of human problem solving, and brings to light striking continuities in infants' and adults' responses to repeated events and problems. Second, it makes clear that a full account of infants' responses to events and problems will require detailed analyses of (a) the contents of infants' representations in specific task situations and (b) the changes that take place in these representations as infants acquire expertise at the tasks.

start, the infants were trained to orient to the landmark window at the sound of a buzzer; after a short delay, an experimenter appeared at the window and talked to the infants. Following training, the infants were wheeled to the opposite side of the table. The question of interest was whether, at the sound of the buzzer, the infants would turn in the same direction as before (to what was now the plain window), or would turn in the opposite direction toward the landmark window. The results indicated that the infants with locomotor experience turned toward the landmark window on the majority of the trials, whereas the prelocomotor infants were about equally likely to turn toward the landmark or the plain window. The authors concluded that the development of self-produced locomotion leads to more consistent use of landmark information. Such a conclusion supports the notion proposed above that with self-produced locomotion comes a more detailed and extensive encoding of location information.

Infants' encoding of location information might improve in yet other ways. Horobin and Acredolo (1986) tested infants aged 8 to 10 months in a delayed-search task and found that the infants with more experience at self-locomotion were more likely to maintain visual fixation on the hiding place of the object during the delay and hence were more likely to succeed at finding the object (see also Acredolo et al., 1984; Bai & Bertenthal, 1992). To be sure, most researchers who use memory-and-motor tasks today do not allow infants to use this simple strategy to keep track of the hiding place of the object (see section II). Nevertheless, the results of Horobin and Acredolo, like those of Bertenthal et al. (1984), support the point that with the development of self-produced locomotion, infants develop new and more effective ways of keeping track of the locations of objects. Maintaining visual fixation and referring to landmarks are two such ways; no doubt others remain to be discovered.

B. ELABORATING OUR MODEL

According to our model of perseveration in nonmemory-and-motor tasks such as our support and containment tasks, infants perseverate on B trials because their initial analysis of the problem is too shallow to enable them to detect the crucial change introduced; as a result, infants miscategorize the problem as being similar to that on the preceding A trials and retrieve their previous solution, leading to a perseverative error. Our discussion of infant's perseverative errors in memory-and-motor tasks such as delayed-search tasks suggests another, slightly different path to perseveration. Specifically, infants in these tasks notice in their initial analysis of the problem on B trials that the object has been hidden in a new location, but this location information decays rapidly during the delay imposed before infants are allowed to search. At the end of the delay, infants return to the contents of their initial analysis. However, because these contents are degraded and no

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