Variability in thirteen-month-old infants’ touching patterns in the sequential-touching task

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Abstract

Variability in infants’ touching patterns in a sequential-touching task was evaluated to examine the hypothesis that at periods of developmental transition, apparently random responding in this task actually reflects infants’ use of multiple strategies for responding to the categorical contrast. Typically, categorization in this task is inferred only if infants successively touch items within the same category. We assessed 30 infants’ touching patterns during a 10-min sequential-touching task. Half of the infants first received a familiarization task with the individual objects. There was a great deal of variation in touching patterns, as a result of infants both alternating touching items from the two categories and successively touching items within one category. Successive touching became more prominent as infants became familiar with the toys and task. Therefore, variability in touching patterns appears to reflect different strategies used in this task. The distribution of strategies also changed as infants became familiar with the toys and the task.

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1. Introduction

In recent years, the sequential-touching task has been widely used to assess categorization in infants between the ages of 12 and 30 months of age (e.g., Mandler, Bauer, & McDonough, 1991; Oakes, Plumert, Lansink, & Merryman, 1996; Rakison & Butterworth, 1998). In this task, infants are presented with a collection of objects from two categories (e.g., four animals and four vehicles) and their pattern of touching is observed. The assumption for using this
task is that if infants recognize the categorical distinction, they should touch in succession objects from within a category more than would be expected by chance. Investigations using this procedure have demonstrated that infants in the second year of life do indeed successively touch items when faced with contrasts as diverse as animals vs. vehicles, horses vs. dogs, and cars vs. motorcycles (Mandler & Bauer, 1988; Mandler et al., 1991).

This task has become increasingly popular because it is well suited to assessing categorization in the second year of life. This is a critically important time in terms of the development of language, symbolic understanding, and other cognitive skills, and yet much less is known about the development of basic abilities such as categorization during the second year than is known about the development of such abilities during the first year. The sequential-touching task has historical roots in the work of Starkey (1981) and Sugarman (1981, 1982) and has been used successfully by many different investigators to assess categorization in the second year of life (e.g., Gopnik & Meltzoff, 1986, 1992; Mandler & Bauer, 1988; Mandler et al., 1991; Namy, Smith, & Gershkoff-Stowe, 1997; Rakison & Butterworth, 1998).

In most previous studies of categorization using the sequential-touching task, the focus has been on the kinds of categories infants possess (e.g., Mandler & Bauer, 1988; Mandler et al., 1991). Infants are presented with contrasts such as animals vs. vehicles or dogs vs. horses for a relatively brief period of time (e.g., 2 min). Researchers conclude that infants of a given age possess the categorical contrast if they exhibit more successive touching during that brief period than would be expected by chance. For example, Mandler and Bauer (1988) observed that 20-month-old children attended to the superordinate distinction between animals and vehicles but they did not attend to the basic-level distinction between dogs and horses. Based on these findings, Mandler and Bauer concluded that by 20 months, children have formed global level categories, but they have not yet formed basic-level ones. The assumption is that if infants have already formed the relevant categorical contrast they will immediately begin to spontaneously successively touch the objects.

Although this kind of evidence is important for documenting developmental changes in the kinds of categories to which infants immediately respond in this task, Oakes and Madole (2000) have recently argued for a shift in emphasis to the study of the process of categorization. That is, rather than identifying the categories to which infants do and do not respond, Oakes and Madole suggested that we should begin to evaluate how infants are forming or discovering those categories in experimental tasks. There is some evidence that when a contrast is presented in the sequential-touching task, young infants who do not initially successively touch items within the category will respond to that categorical contrast by successively touching the within-category items as the objects (and task) become familiar. Oakes et al. (1996) observed that 13-month-old infants presented with the contrast between animals and people did not engage in successive touching in the initial 2 min of the task, but they did engage in successive touching in a second 2-min segment. At 13 months, therefore, infants appeared to discover this categorical distinction as they explored the toys. In the present investigation, we extended these previous results by observing how infants’ touching patterns changed over the course of a 10-min sequential-touching session. Others have argued that the general approach of observing changes in behavior over time is useful for understanding developmental change in cognitive abilities. In particular, Thelen and Smith (1994) have argued that real-time and developmental time are continuous, and we therefore gain insight into the development of a
behavior by evaluating how it changes over relatively short periods of time. Thus, the results from the present study add to our understanding of the development of children’s approach to the sequential-touching task and how developmental changes in children’s behavior in this task should be interpreted.

Our general approach to studying infants’ systematic touching in the sequential-touching task is similar to that taken by Chen and Siegler (2000) to study toddlers’ tool use. In their microgenetic study, Chen and Siegler presented toddlers with several different tool use problems and observed changes in the strategies toddlers used to solve those problems. Thus, the goal was not to establish the one way that children at a given age solve these problems, but rather to evaluate how their approach to solving these problems changed over time. In the present investigation, we evaluated infants’ touching when presented with the same toys in the same task for a relatively long period of time (10 min). In this way, we could evaluate how infants touched the toys when the task was relatively novel as well as how they touched the toys when the task was more familiar. This small-scale microgenetic approach allowed us to determine how infants’ behavior in this task changed over time.

One of our goals was to evaluate differences in infants’ behavior in the sequential-touching task. That is, rather than simply assessing one theoretically interesting pattern of systematic touching (i.e., successive touching) as in previous studies, we identified three different patterns of responding in this task—successive touching, alternating touching, and apparently random touching. Based on Siegler’s (1996) overlapping waves theory of cognitive development, we assumed that during periods of transition variability in infants’ touching in the sequential-touching task reflects their use of different strategies in the task. According to the overlapping waves theory, children have multiple ways of thinking about a problem or phenomena, and those different ways of thinking compete with one another. Development involves not only the introduction of new ways of thinking, but also changes in the frequency of these different ways of thinking. Thus, according to this perspective to cognitive development, the set of strategies, and not the single strategy, that children use in a given task is important (Chen & Siegler, 2000). It is, therefore, important not only to evaluate the particular strategies children use to solve a task, but also to evaluate the distribution of those strategies. Children’s responding to a task improves as they rely more on new, more sophisticated strategies than on old, less sophisticated strategies. This perspective has clear implications for understanding variability in children’s responding. Traditionally, when a group of children as a whole fail to exhibit the one pattern of behavior identified by the researcher as most informative (e.g., successive touching in a sequential-touching task), investigators assume that their responding is random and uninformative. In contrast, from an overlapping waves perspective, when children are at a point of transition and new strategies are being introduced (and old strategies have not yet been inhibited), we should see high levels of variability in children’s responding. This variability is not the result of random responding, however, but the result of children using multiple strategies in a task. Chen and Siegler’s (2000) study, for example, documented the multiple ways in which toddlers approached the tool use task and how the distribution of those approaches changed over time.

In the present investigation, we adopted this general perspective and assessed three different patterns of touching exhibited by infants in sequential-touching and how the distribution of those patterns of touches varied with familiarity with the objects and task. Traditionally, in
studies using the sequential-touching task to study infants’ categorization of diverse objects, the emphasis has been on a single pattern of touching—runs of successive touches to items from within one of the categories. Little attention has been given to other patterns of touching that infants exhibit in this task. One exception is the study by Oakes et al. (1996) in which 10- to 16-month-old infants’ successive touching of items within a category and their alternating touching of items from the two categories (e.g., person 1, dog, person 2, cow, person 1, zebra, person 3) were both evaluated. Evaluating both types of touching patterns revealed interesting developmental changes in how infants behaved in this task. Only the 16-month-old infants immediately successively touched items within a category, supporting previous conclusions that attention to such categorical contrasts develops in the second year of life (Mandler & Bauer, 1988; Mandler et al., 1991). However, Oakes et al. (1996) observed that younger infants exhibited more mixed patterns of touching. Although overall in the first 2-min 13-month-old infants did not exhibit more successive touching of the items within the categories than would be expected by chance, infants at this age did systematically touch the items. Under closer examination, it was determined that infants exhibited a mixture of successive touching and alternating between the two categories. By the second 2-min segment, they engaged in successive touching.

Adopting an overlapping waves perspective, we can consider these two touching patterns (successive touching and alternating touching) as two strategies that infants used to “solve” the task. Clearly, the analogy is not perfect—unlike Chen and Siegler’s task, infants were not presented with a problem to solve. Rather, in the Oakes et al. (1996) study, infants’ spontaneous responding to a categorical contrast was observed. However, considering these two touching patterns as strategies that infants used to respond to the categorical contrast, we can draw two conclusions from this study. First, over developmental time, infants’ initial approach to this task changed—older infants primarily used one strategy (successive touching), and younger infants used two strategies (successive touching and alternating touching). Second, younger infants’ approach to this task changed in real-time. There was no dominant strategy in 13-month-old infants’ initial approach to the task, but as the task and toys became familiar, the successive touching strategy (which may be more sophisticated as evidenced by its dominance at older ages) became more prevalent.

Importantly, these results clearly show that there are at least two meaningful strategies to touching the items in a sequential-touching task. The successive touching strategy, which emphasizes within-category similarities, and the alternating touching strategy, which emphasizes between-category differences. When engaged in successive touching, infants touch in succession items that are similar in some way. When engaged in alternating touching, infants touch in succession items that are quite different from one another. Comparing items both within and between categories is an important part of the process of forming categories (e.g., Gentner & Medina, 1998; Markman & Gentner, 2001). Presumably, comparing items highlights the similarities between items within categories as well as the differences between items from different categories. For young infants, who only discover the categorical contrast as they explore the objects, the within-category similarities may not be the most salient type of contrast. Rather, as infants explore the individual items both similarities between items from the same category and differences between items from different categories may be equally salient. As a result, younger infants may not have a single dominant strategy, but rather they may have two strategies
(alternating and successive touching). Thus, variability in infants’ touching may reflect changes in the distribution of alternating and successive touching patterns in the sequential-touching task. As the data from this procedure have been traditionally evaluated, however, such a mixture of touching patterns would be considered random responding with respect to the category.

Factors other than developmental change may influence the distribution of the strategies used. Chen and Siegler (2000), for example, manipulated environmental cues that helped children learn to rely on the most effective strategy and inhibit using less sophisticated strategies. Another goal of the present investigation was to determine whether 13-month-old infants’ use of the successive touching strategy is influenced by factors such as prior experience with the items. We suspected that infants’ initial experience with the items may influence their reliance on a successive touching strategy. Indeed, Namy et al. (1997) observed that 18-month-old infants whose initial experience with objects highlighted the within-group similarities (they were given a shape sorter that only one type of object could fit in) responded in a more sophisticated way in a sequential-touching task than did 18-month-old infants whose initial experience did not highlight the within-group similarities. In the present investigation, we sought to determine whether 13-month-old infants’ use of successive touching was influenced by familiarization with the items by comparing the strategies used by a group of infants who were first familiarized with the items in an object-examining task with a group of infants who did not receive familiarization with the items.

We evaluated variability in 13-month-old infants’ touching of animals and people in the sequential-touching task by assessing infants’ touching of the same set of toys over a relatively long period of time (10 min). Thus, we were able to evaluate how infants’ touching changed as the task and the objects became familiar. In particular, we were not interested in the single approach children took to this task, but rather how children’s responding changed over the course of the session. We had three specific goals. First, we sought to determine how familiarization with the toys and task influenced infants’ touching. We expected that familiarization that highlights within-category similarity would cause infants to exhibit more successive touching than would an equivalent amount of familiarization that did not highlight within-category similarity. Second, we sought to determine how infants’ successive touching changed over time. Specifically, we expected that as the toys and task became familiar, infants’ reliance on successive touching would increase, as was found by Oakes et al. (1996). Finally, we sought to understand variability in infants’ responding to sequential-touching by evaluating the touching strategies they used in this task and how the distribution of those strategies changed over time. We tested 13-month-old infants because infants at this age in the Oakes et al. (1996) study showed a mixture of touching patterns when presented with this categorical contrast. Thus, we expected infants to engage in both alternating and successive touching. We familiarized half of the infants with the items one at a time, organized according to category membership (e.g., all of the animals first then all of the people). We expected that infants who first received this familiarization would show more successive touching than would infants who did not receive this familiarization. Moreover, we expected that infants who did not receive this familiarization would initially show a mixture of alternating and successive touching. As the task and toys became familiar, however, all infants were expected to show higher levels of successive touching.
2. Method

2.1. Participants

The final sample consisted of 30 13-month-old infants, average age 57.28 weeks (SD = 1.39 weeks). There were 15 boys and 15 girls. Twenty-five additional infants were tested but were not included in the final sample due to fussiness \((n = 11)\), maternal or sibling interference \((n = 3)\), experimenter error \((n = 7)\), or failure to exhibit at least 20 touches in 10 min of sequential-touching \((n = 4)\). Infant names were obtained from the county birth records, and phone numbers were obtained in the local phone directory. Parents were sent a letter about the experiment when their infant approached 13 months, and they were contacted by phone a few days later. Infants were given a T-shirt for their participation.

2.2. Apparatus

Infants were recorded via a Panasonic camcorder, positioned on a tripod facing the infant at a distance of approximately 100 cm, focused to capture the infant’s torso, head, and the table top on screen. A Panasonic character generator was used to write the time elapsed directly onto the videotape of each infant’s session.

2.3. Stimuli

Plastic replicas of exemplars from the animal and people category were used as stimuli for this study. For the sequential-touching portion of the session, four 4-legged land animals (black and white cow, zebra, brown horse, and brown dog) and six people (Caucasian man in pink shirt, Caucasian woman in purple skirt, Caucasian man in blue shirt, African-American woman in a green skirt, African-American woman in a pink skirt, and Caucasian woman in yellow dress) were used. (Each infant received only four of the six people. All infants received the first two people and two of the four remaining people. These last four people were very similar—they had similar body shapes and level of detail.) For the familiarization portion of the session, an additional person (a Caucasian woman in a pink dress) and an additional animal (a lion) were used. All objects were made of hard plastic and were approximately the same size. The animals all were in standing positions, 8–15 cm in length. The people could stand or sit, and ranged from 8–15 cm tall when standing.

The distinction between animals and people was chosen because there is evidence that infants of this age can attend to this distinction in familiarization-test procedures (Oakes et al., 1996; Paun, 2000; Ross, 1980). Thirteen-month-old infants did not, however, spontaneously successively touch items from the distinction in sequential-touching task in at least one previous experiment (Oakes et al., 1996). It is worth noting that our goal is not to establish whether infants have this distinction; rather, our goal is to evaluate how infants’ touching unfolds over time. Thus, it is critically important that we use a categorical distinction that we know infants can learn in some contexts, and yet they do not immediately respond to in sequential-touching by successively touching items from within one or the other category.
2.4. Procedure

Each infant was seated on his or her parent’s lap, at a table facing the experimenter. Infants were randomly assigned to one of two conditions. For infants in the no-familiarization condition, the experimenter placed all eight toys randomly on a tray, and pushed the tray within the infant’s reach. Infants were encouraged to manipulate the toys throughout a 10-min session. If the infant failed to touch any toys or remained attentive to only one toy for at least 30 s, the experimenter would encourage the infant to look at the other toys by passing his or her hand over the tray and saying “Can you play with all of these?” If a toy was dropped off the table, it was quickly replaced by the experimenter or the parent who then touched all of the toys. The procedure continued until 10 min had elapsed. The experimenter used a hand-held stopwatch to time the session.

For infants in the familiarization-first condition, the experimenter introduced the toys using an object-examining procedure (Oakes, Madole, & Cohen, 1991) before the sequential-touching portion of the session. The experimenter presented each item, one at a time, on a series of 30-s trials. Each trial began with the experimenter presenting a single object in front of the infant and saying “Look at this! Can you play with this toy?” Infants were then allowed to manipulate the object in any way he or she chose for 30 s. If the object was dropped off the table, the experimenter or the parent immediately replaced it. Infants were first presented with the four objects from one of the two categories (e.g., animals), on eight consecutive trials (each object was presented once in the first four trials, and again in the second four trials). They then received two “test” trials with the novel items (pink woman and lion). The sequence then was repeated with the other category (e.g., people): the four items from within the category were presented on eight consecutive trials followed by two test trials. Thus, infants received 8 min of familiarization with the eight objects to be presented during sequential-touching and 2 min of “test” trials. Immediately after this familiarization phase, the sequential-touching phase (as described before) was administered.

2.5. Coding

Infants’ behavior during the sequential-touching phase was coded for all intentional touches of the toys. Coders wrote down any time the infant touched an object with his or her hand or with another object while he or she was looking at the object being touched. Thus, touches to toys while the infant was looking at the experimenter, mother, or other toys were not counted. So, if an infant was holding the cow in his or her hand and touched the horse with the cow, a touch to the horse would be counted if the infant was looking at the horse. If the infant was looking at the cow, no touch would be recorded. If two toys were touched simultaneously (e.g., the infant touched the horse with his or her left hand and the cow with his or her right hand, while looking at both toys), the order of touches was determined by a flip of a coin. Coders wrote down all intentional touches, recording the item touched and the time the item was touched, for the entire 10-min session. Two coders independently recorded the touching behavior of 12 randomly chosen infants. Average agreement between these coders regarding the particular items touched, and the order in which those items were touched, was 89%.
For infants in the familiarization-first condition, the duration of visual attention on each of the trials during the familiarization phase also was coded. On each trial, the duration of focused attention (clearly focused, concentrated looking at the object) was recorded. Coders use a variety of cues, such as gaze direction, facial cues, and manipulation, to determine whether or not an infant was examining the object. In general, focused attention is the portion of infants’ looking at the toy when they appear to be concentrating and learning about the objects (see Oakes & Tellinghuisen, 1994; Ruff & Saltarelli, 1993 for discussions of examining). Coders observed the videotape of each infant’s session and recorded the duration of focused attention on each trial. For each trial, coders recorded the duration of focused attention by pressing a key on a Macintosh computer and holding it as long as the infant continued to examine the object. Reliability between two coders for eight infants was good, average $r = .86$ with an average difference between the two coders for 30-s trials of 1.79 s.

3. Results

3.1. Familiarization phase

Initial analyses were conducted on infants’ attention during the familiarization phase in the familiarization-first condition. As expected, infants’ attention to each category decreased across the eight familiarization trials [$F(7, 91) = 3.42, p < .01$]. Tukey’s honestly significant difference (HSD) test revealed that infants exhibited more focused attention on the first trial with a category than the seventh or eighth trial ($p < .05$). Importantly, the order of categories presented was counterbalanced across infants and there was no difference in attention to the people and animal category [$F(1, 13) = 1.62, p = .23$]. In addition, infants’ exhibited more attention to the novel item from the “other” category (e.g., the lion after the eight people trials and the woman after the eight animal trials) than to the novel item from the “familiar” category during both tests [$F(1, 13) = 14.12, p < .01$]. Infants also exhibited more focused attention overall during the first set of test trials than during the second set [$F(1, 13) = 20.61, p < .001$]. Thus, infants appeared to learn the categories during familiarization.

3.2. Sequential-touching phase

The more important analyses for the present purposes were those evaluating infants’ touching patterns during the sequential-touching phase of the experiment. We identified at least three different touching strategies infants might have in this task. First, infants might adopt a successive touching strategy. In this strategy, infants touch items from within the same category in succession, apparently ignoring the items from the other category. Infants may also adopt an alternating touching strategy. In this strategy, infants touch items from the two categories in alternation (e.g., a person, an animal, a person, an animal). A third “strategy” is no apparent systematic responding to the category. For convenience we will call this a random touching strategy, but it is important to point out that it is only random with respect to the categorical distinction—infants may have been responding systematically to some other stimulus feature or some other relation among the items. However, when infants engage in neither successive
nor alternating touching, it is not clear that their touching is systematic with respect to category membership. We expected that infants who were not first familiarized with items one at a time would initially show a mixed pattern of responding—some infants would engage in successive touching, other infants would engage in alternating touching, and the remaining infants would exhibit no clear systematic touching with respect to the categories. After some time with the task, however, we expected that the distribution of the strategies would change, with the use of successive touching becoming more dominant. No change in touching patterns was expected for infants in the familiarization-first condition.

3.2.1. Evaluation of mean run-lengths

We first addressed these hypotheses by evaluating infants’ responding using mean run-length (Mandler, Fivush, & Reznick, 1987). Mean run-length is a measure of the level of successive touching by a group of infants as a whole. It is a measure of the average length of “runs” of successive touches to items within a category. A run can range from 1 (if infants touch only one item from one category before touching an item from the other category) to the total number of touches (if infants touch only items from one category). The mean run-length is calculated by dividing the total number of touches in a given segment by the number of runs of successive touches exhibited in that segment. By chance, we expect a mean run-length of 1.75 (Mandler et al., 1987).

We evaluated infants’ mean run-lengths in the first and second half of their touches. Because infants exhibited very different numbers of touches during the 10 min of sequential-touching, and those touches were not evenly distributed across the 10 min, we needed to divide the touching in a different way to look at changes in touching over the entire session. We evaluated each infant’s touching in the first half of their total touches and their touching in the second half of their total touches. Because our goal was to establish how infants’ touching changed over time, it was important to compare their touching early in the session and later in the session. There are many strategies we could have taken for how to divide infants’ touching. For example, we could have compared infants’ touching in each 2-min segment, or in the first 5 min compared to the second 5 min. However, inspection of infants’ pattern of touches over the 10 min suggested that such divisions would be problematic. This approach would not take into account the variability in infants’ rate of touching (e.g., some infants had many more touches in the first 5 min and other infants had many more touches in the second 5 min) and many infants had periods of time in which they touched few objects. As a result, we concluded that infants’ experience with the toys was better equated by comparing the first half and second half of their touches. In this way, we could compare how infants touched during their first touches with how they touched during their later touches. In addition, this strategy for dividing infants’ touches is relative to each individual infant’s touching behavior, rather than relative to an absolute (and arbitrary) metric.

To establish whether the amount of successive touching changed over time and whether the changes were different in the two conditions, the mean run-lengths were entered into a mixed-model ANOVA with half as the within-subjects factor and condition as the between-subjects factor. This analysis revealed a marginally significant main effect of condition \[ F(1, 28) = 3.96, \ p = .06 \], due to infants in the familiarization first condition exhibiting longer mean run-lengths overall \( M = 2.19, SD = 0.67 \) than infants in the no-familiarization
condition \((M = 1.86, \ SD = 0.55)\). Importantly, the predicted condition by half interaction was significant \([F(1, 28) = 4.96, p < .05]\), suggesting that the rate of successive touching changed in different ways for the two groups.

Recall that we expected that (1) infants in the familiarization-first condition would initially exhibit more successive touching than would infants in the no-familiarization condition because they had previous experience with the toys highlighting the within-category similarity, and (2) that infants in the no-familiarization condition would increase their successive touching over time as they became familiar with the toys and the task. We tested these predictions with a series of \(t\)-tests. These comparisons revealed that in the first half of their touches, infants in the familiarization-first condition exhibited marginally greater mean run-lengths than did infants in the no-familiarization condition \([t(28) = 1.85, p = .07]\). The two groups had similar mean run-lengths in the second half of their touches \([t(28) = 1.21, p = .23]\) (see Table 1). Moreover, infants in the no-familiarization condition significantly increased their mean run-length as the session progressed \([t(28) = 2.30, p < .05]\), but infants in the familiarization-first condition exhibited similar mean run-lengths in the first and second half of their touches \([t(28) = 1.10, p = .29]\). Thus, it appears that infants in the no-familiarization condition changed their strategy as the task progressed, whereas infants in the familiarization-first condition used the same strategy throughout the task.

We also compared each mean run-length to chance to determine in which segments infants’ responding was significantly different from that expected by chance. These results confirmed the conclusions from the analyses described before. In the first half of their touches, infants in the familiarization-first condition exhibited a mean run-length that was marginally greater than chance \([t(14) = 1.66, p = .06, \text{ one-tailed}]\). Infants in the no-familiarization condition did not exhibit mean run-lengths greater than chance in the first half of their touches \([t(14) = -0.81, p = .78]\), one-tailed. In the second half of their touches, however, both groups of infants exhibited mean run-lengths that were significantly greater than chance \([t(14) = 3.32, p < .01]\) for infants in the familiarization-first condition, and \([t(14) = 1.81, p < .05]\) for infants in the no-familiarization condition. Thus, when looking at the performance of the group as a whole, the conclusion is that only 13-month-old infants who were first familiarized with items one at a time generally attended to the category in the first half of their touches, and both groups of infants eventually attended to the categorical contrast.

3.2.2. Evaluation of changes in individual mean run-lengths over time

To evaluate variability in infants’ responding, we looked at changes in the level of successive touching, as indicated by mean run-lengths, over time. We calculated the mean run-length for

<table>
<thead>
<tr>
<th>Condition</th>
<th>First half of touches</th>
<th>Second half of touches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiarization-first</td>
<td>2.06 (0.73)*</td>
<td>2.32 (0.61)**</td>
</tr>
<tr>
<td>No-familiarization</td>
<td>1.67 (0.39)</td>
<td>2.04 (0.63)*</td>
</tr>
</tbody>
</table>

* Indicates marginally different from chance, \(p = .06\) (one-tailed).

** Indicates significantly different from chance, \(p < .01\) (one-tailed).

\(t\)-tests were conducted using a one-tailed test due to the directionality of the predictions.
each bin of 10 touches. This allowed us to look at whether infants’ touching strategy was fairly consistent across the session, or whether they adopted different strategies at different points in the 10-min session. In Fig. 1, we have plotted mean run-length for each bin of 10 touches for each infant (note that because infants exhibited different numbers of overall touches, infants had different numbers of bins). The infants tested in the familiarization first condition (infants number 1–15) are represented by dark lines and filled symbols and infants tested in the no familiarization condition (infants number 16–30) are represented by lighter lines and open symbols. For reference, 1.75 is the mean run-length expected by chance (a dark solid line indicates the 1.75 level in each graph). In general, mean run-lengths greater than 1.75 suggest higher levels of successive touching, and mean run-lengths that approach 1.0 suggest higher levels of alternating touching. Mean run-lengths near the 1.75 level indicate that infants were engaged in neither successive or alternating touching—perhaps they were responding randomly, or perhaps they were exhibiting some other strategy that we were unable to identify.

We identified four patterns of responding that infants exhibited in this task, and each pattern is presented in a different part of Fig. 1. Fig. 1A shows the group of infants whose mean run-lengths never were greater than 1.75 during the entire session. These infants appeared to exhibit mostly alternating touching intermixed with some apparently random (with respect to the category) touching patterns. Fig. 1B shows the group of infants whose mean run-length was initially lower than 1.75 and then had some bins of 10 touches with mean run-lengths greater than 1.75 and other bins with mean run-lengths less than 1.75. These infants seemed to fluctuate between the three touching strategies we have identified. Fig. 1C shows the group of infants whose mean run-lengths were initially lower than 1.75, but showed a steady increase in mean run-length, eventually exhibiting mean run-lengths that were greater than 1.75. These infants appeared to start out alternating or exhibiting apparently random touching, but their touching became more successive with experience with the task. Finally, Fig. 1D shows the group of infants whose mean run-lengths were initially greater than 1.75. Although these infants were quite variable in the amount of successive touching they exhibited, it is notable that they generally exhibited high levels of successive touching (i.e., few points were lower than 1.75) and when these infants did engage in successive touching their runs were much longer than the successive touching runs exhibited by the other three groups.

This figure clearly demonstrates that infants’ touching is highly variable. As can be seen in Fig. 1, nearly all the infants had at least one bin in which their mean run-length was greater than 1.75, suggesting some level of successive touching. In addition, nearly all infants had at least one 10-touch bin in which the mean run-length approached 1, suggesting that most infants did engage in some level of alternating touching. However, infants clearly showed different overall patterns across the 10-min session (i.e., there were different patterns of how infants used successive and alternating touching strategies across the task), and the particular pattern infants exhibited was related to their initial experience with the items. Specifically, most of the infants who initially exhibited mean run-lengths below 1.75 were in the no-familiarization condition (14 of 19 infants). Most of the infants who initially exhibited mean run-lengths above 1.75 were in the familiarization-first condition (8 of 11). In addition, although we identified four different patterns of touching across time, two were clearly most frequent and those two were highly associated with infants’ familiarity with the toys. Infants in the no-familiarization condition were very likely to exhibit the fluctuating pattern—initially
Fig. 1. Individual patterns of mean run-lengths for each bin of 10 touches. The mean run-length expected by chance is 1.75 (indicated by a solid line). Mean run-lengths greater than 1.75 represent more successive touching, mean run-lengths that approach 1 represent more alternating touching, and mean run-lengths near 1.75 represent apparently random touching. Dark lines and solid symbols represent infants in the familiarization-first condition. Light lines and open symbols represent infants in the no-familiarization condition. Four different patterns of responding were identified. The infants represented in (A) never had mean run-lengths greater than 1.75; (B) initially had low mean run-lengths and then their mean run-lengths fluctuated above and below the 1.75 level; (C) initially had low mean run-lengths and then their mean run-lengths steadily increased to above the 1.75 level; and (D) initially had high mean run-lengths and their mean run-lengths generally remained high (note: Infant 4 had a mean run-length of 10 on the first bin of 10 touches).
Fig. 1. (Continued).
exhibiting a low mean run-length, and then exhibiting mean run-lengths that were both above and below 1.75. Infants in the familiarization-first condition, in contrast, were likely to initially have mean run-lengths that were greater than 1.75. It is also interesting to note that when infants in the familiarization-first condition had mean run-lengths greater than 1.75, those mean run-lengths tended to be relatively high, regardless of which of the general patterns they exhibited. Infants in the no-familiarization condition, in contrast, rarely exhibited high mean run-lengths and even when their mean run-lengths were greater than 1.75.

In summary, evaluating the data in this way allows us to explore variability in infants’ responding to this task. We can see that overall infants tended to fluctuate between the three strategies we have identified (successive touching, alternating touching, and apparently random touching). However, we can also see several different ways in which infants approached this task. These different patterns of responding reflect differences in the distribution of touching strategies infants used and are related to the infants’ initial experience with the toys.

3.2.3. Evaluation of individual patterns of touching

We also evaluated each individual infant’s touching pattern in the first and second half of their touches for their use of successive touching, alternating touching, and apparently random touching strategies. Each run of successive touches that involved at least three unique items (e.g., a run of eight touches involving three different animals) was evaluated using probabilities generated by a Monte-Carlo program developed by Mandler et al. (1987). In the context of 15 touches, a run of 8 touches involving three objects from one of the categories (e.g., dog, zebra, cow, dog, zebra, cow, dog, zebra) has a probability of $p = 0.008$. Infants are classified as single categorizers if they exhibit runs of successive touches to items from only one category (e.g., runs to animals, but no runs to people) and as dual categorizers if they exhibit runs of successive touches to items from both categories. This second approach is assumed to be more sophisticated because infants attend to both categories (Mandler et al., 1991).

Each run of alternating touches involving at least three unique items was evaluated using probabilities generated from a Monte-Carlo program developed by Oakes et al. (1996). Given 15 touches overall, a run of 8 touches alternating between the two categories, involving at least three different objects (e.g., dog, woman in purple, dog, woman in green, cow, man in pink, zebra, woman in purple) has a probability of $p = 0.039$. Note that alternating runs are more likely than successive runs. Thus, infants who were classified as alternators necessarily exhibited longer alternating runs than the successive runs exhibited by infants who were classified as successive touchers. As in previous experiments (Mandler & Bauer, 1988; Mandler et al., 1991; Oakes et al., 1996; Rakison & Butterworth, 1998), we adopted a $p = .10$ cut-off for classifying infants as “successive touchers” or “alternators.” That is, if an infant’s runs of successive touches were associated with a probability of $p < .10$, he or she was classified as having adopted a successive touching strategy. Similarly, if an infant’s alternating runs were associated with a probability of $p < .10$, he or she was classified as having adopted an alternating touching strategy. If an infant did not exhibit any significant successive or alternating runs of touches, he or she was classified as having adopted a random touching strategy with respect to category membership.

We assessed infants’ touching to determine which of these strategies they used in each half of their touching. The summary of these analyses is found in Table 2. Inspection of the proportion
Table 2
Percentage of infants in each condition who exhibited systematic patterns of touching

<table>
<thead>
<tr>
<th>Condition</th>
<th>First half of touches (%)</th>
<th>Second half of touches (%)</th>
<th>Overall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiarization-first</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Successive touching: Total</td>
<td>53.33</td>
<td>73.33</td>
<td>73.33</td>
</tr>
<tr>
<td>Successive touching: Single</td>
<td>33.33</td>
<td>33.33</td>
<td>20.00</td>
</tr>
<tr>
<td>Successive touching: Dual</td>
<td>20.00</td>
<td>40.00</td>
<td>53.33</td>
</tr>
<tr>
<td>Alternating touching</td>
<td>26.67</td>
<td>6.67</td>
<td>33.33</td>
</tr>
<tr>
<td>Apparently random touching</td>
<td>20.00</td>
<td>20.00</td>
<td>6.67</td>
</tr>
<tr>
<td>No-familiarization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Successive touching: Total</td>
<td>20.00</td>
<td>40.00</td>
<td>40.00</td>
</tr>
<tr>
<td>Successive touching: Single</td>
<td>13.33</td>
<td>20.00</td>
<td>13.33</td>
</tr>
<tr>
<td>Successive touching: Dual</td>
<td>6.67</td>
<td>20.00</td>
<td>26.67</td>
</tr>
<tr>
<td>Alternating touching</td>
<td>40.00</td>
<td>26.67</td>
<td>53.33</td>
</tr>
<tr>
<td>Apparently random touching</td>
<td>40.00</td>
<td>40.00</td>
<td>20.00</td>
</tr>
</tbody>
</table>

The number of infants using the three touching strategies may not add up to the total because a few infants engaged in both successive and alternating touching.

of infants exhibiting each type of touching pattern in the two conditions during the first and second half of their touching reveals that indeed a large proportion of infants in both conditions were responding systematically with regard to the category, but they used different strategies in each condition. Specifically, 12 of 15 infants in the familiarization-first condition (80%) exhibited some type of systematic touching in the first half of their touches and only 20% exhibited apparently random touching. In the no-familiarization condition, 9 of 15 infants (60%) exhibited some systematic touching and 40% exhibited apparently random touching. Importantly, the distribution of the touching strategies differed in the two groups. In the familiarization-first condition, the most common strategy was successive touching. Eight infants in this condition (53.33%) exhibited successive runs to one or both of the categories (five infants exhibited runs to only one category and three infants exhibited runs to both categories). Only four infants in this condition (26.67%) alternated between the two categories. In the no-familiarization condition, in contrast, the pattern was reversed. Six infants in this condition (40%) exhibited alternating runs in the first half of their touches, and only three infants (20%) exhibited successive runs (two touched items from only one category and one touched items from both categories). Thus, consistent with the mean run-length analysis, infants in the familiarization-first condition exhibited relatively high levels of successive touching to one or more categories. Most of the infants in the no-familiarization only condition also responded systematically to the two categories, but more infants alternated between the two categories than engaged in successive touching. Thus, the lack of a significant mean run-length in the no-familiarization condition should not be taken as evidence that these infants were not attending to the category.

We also examined how infants’ strategies changed over time. A large proportion of infants exhibited some type of systematic touching in the second half of their touches (see Table 2). Overall, the proportion of infants in each condition who exhibited one of the two systematic touching strategies was the same as in the first half of their touches. Again, 80% of the infants in the familiarization-first condition exhibited one of the two systematic touching strategies...
and 20% of the infants in this condition exhibited the apparently random touching strategy. In the no-familiarization condition, 60% of the infants exhibited one of the two systematic touching strategies and 40% exhibited the apparently random touching strategy.

The distribution of the systematic strategies varied across conditions, however. In the familiarization-first condition, the distribution of successive and alternating touching strategies in the second half of touches looked similar to that in the first half of touches. Eleven infants (73.33%) exhibited successive touching (five with runs to only one category and six with runs to both categories) and only one infant (6.67%) used the alternating strategy. Thus, these infants continued their relatively high level of successive touching as they continued to touch and manipulate the objects, and there was an increase in the number of infants who engaged in runs of successive touches to both categories.

In the no-familiarization condition, in contrast, the distribution of successive and alternating touching strategies was the reverse of that in the first half of touches. In the second half of their touches, six infants (40%) exhibited successive touching (three with runs to only one category and three with runs to both categories), and only three infants (20%) exhibited alternating runs. Thus, infants’ responding in this condition continued to be more mixed than in the familiarization-first condition, but the distribution of strategies changed over time. As the toys and the task became more familiar, the successive touching strategy increased in frequency and the alternating strategy decreased. In other words, infants’ initial reliance on the alternating strategy gave way to an emphasis on successive touching.

Finally, we considered infants’ runs across all of their touches. Overall, a large proportion of infants in both conditions exhibited some type of systematic touching, and only a small proportion of infants in each condition adopted the apparently random touching strategy throughout the 10-min session. Consistent with the data described before, the distribution of approaches differed in the two conditions (see Table 2). In general, the successive touching pattern dominated in the familiarization-first condition. In this condition, many more infants exhibited runs of successive touches (11 of 15) than exhibited runs of alternating touches (5 of 15). The picture is quite different for infants in the no-familiarization condition. In this condition, the frequency of two approaches was more equivalent. Six of 15 infants exhibited runs of successive touches and 8 exhibited runs of alternating touches. Thus, although a high proportion of infants in the two conditions adopted one of the systematic touching strategies, the types of systematic touching differed in the two conditions. Infants in the familiarization-first condition tended to engage only in runs of successive touches and infants in the no-familiarization condition tended to engage in both successive touching and alternating touching. Consistent with the overlapping waves theory of cognitive development, infants used multiple touching strategies in this task, the distribution of strategies changed over time, and infants’ initial experience with the toys and tasks served to strengthen one strategy over a competing approach.

4. Discussion

The present results add to our understanding of infants’ behavior in the sequential-touching task in several ways. First, the type of initial experience infants have with the objects clearly influences their touching behavior. Infants who were first familiarized with the category by
presenting them with the items one at a time organized by category membership initially engaged in high levels of successive touching when they were tested with those objects in the sequential-touching task. Although by the end of the session infants in the no-familiarization condition also exhibited relatively high levels of successive touching, infants in the familiarization-first condition exhibited high levels of successive touching initially and sustained high levels of successive touching throughout the session. This pattern suggests that when infants’ initial experience with the objects highlights within-category similarity, they engage in more successive touching (which also emphasizes within-category similarity). These findings are consistent with other research showing that providing infants with experience that highlights within-category similarity facilitates successive touching in a sequential-touching task (e.g., Namy et al., 1997).

Second, the present results make it clear that an emphasis only on successive touching leads to an incomplete understanding of infants’ awareness of the categorical contrast in this context. Specifically, infants in the no-familiarization condition initially failed to successively touch items from within one category more than would be expected by chance. However, this failure did not mean that they were responding randomly with respect to the category. Inspection of the individual patterns of touching indicated that indeed infants were responding systematically with respect to the category membership—their initial approach simply was more variable than that of infants in the familiarization-first condition. The variability seen in this condition was not the result of random touching, but rather reflected their reliance on different patterns of systematic patterns of touching. A serious limitation of group analyses, such as comparing mean run-lengths to chance, is that they do not provide insight into individual patterns of responding and thus are not sensitive to meaningful variability within the groups.

The present results are consistent with the overlapping waves theory of cognitive development (Siegler, 1996). Clearly, infants used a mixture of touching strategies in the sequential-touching task. Variability in this task stemmed from infants engaging in both alternating and successive touching, and not from infants responding randomly with respect to the category. Previous results reported by Oakes et al. (1996) suggests that the alternating touching strategy emerges earlier in development than does the successive touching strategy. Thus, from an overlapping waves perspective, the touching of 13-month-old infants in the no-familiarization condition of the present investigation reflects the use of both the older (less sophisticated) alternating touching strategy and the newer (more sophisticated) successive touching strategy. As infants had more time and experience with the task and the toys, the distribution of these strategies changed with infants relying more on the newer strategy later in the session. As others have suggested (e.g., Siegler, 1996; Thelen & Smith, 1994), this type of variability is a hallmark of developmental transitions in thinking. In the case of sequential-touching, infants in transition exhibit a mixture of successive and alternating touching that ultimately gives way to a reliance on successive touching.

The present results also demonstrate that infants’ initial experience with items and tasks can help increase the use of some strategies and inhibit the use of others. Over time, infants in the no-familiarization condition relied more on the successive touching strategy. Moreover, we were able to strengthen infants’ reliance on this strategy by manipulating infants’ initial experience with the items. Specifically, we increased the prevalence of the successive touching strategy by first familiarizing infants with the items one at a time, organized according to
category. In this way, we highlighted the within-category similarities and as a result the successive touching strategy increased. Thus, the present results demonstrate that the overlapping waves theory and the microgenetic approach can be used to successfully assess cognitive development even during infancy.

It is important to point out that the two patterns of systematic touching described here are not the only strategies infants use in this task. There have been a number of investigations of infants’ touching when they are presented with collections of identical, or nearly identical, objects (e.g., yellow boxes vs. blue balls) (e.g., Starkey, 1981; Sugarman, 1981, 1982). These studies have shown that at around 18 months, infants begin to exhibit exhaustive sorting, or mixed-ordered grouping, in which they do not successively touch items from within one category, but arrange the items according to categories by first grouping some of the objects from one category, then some of the objects from the other category, and then back to the first category (Gopnik & Meltzoff, 1987; Gopnik & Meltzoff, 1992; Sugarman, 1981). Future investigations may focus on the developmental trajectory of additional strategies in infants’ approach to the sequential-touching task.

Finally, the present results are generally consistent with a framework that emphasizes the process of categorization, rather than the content of children’s categories, for understanding the early development of categorization (Jones & Smith, 1993; Madole & Oakes, 1999; Oakes & Madole, in press; Smith, 2000). According to this framework, categories are discovered or formed on-line in the course of an experimental session. Infants’ responding in a particular experimental task need not solely reflect the categories they had before they came into the lab (although, infants’ immediate successive touching of items within a category likely does reflect their existing knowledge about those objects). Their responding may also reflect how their understanding of the relations among items unfolds during the course of the task. Infants who are first shown a series of items from within one category, as were the infants in the familiarization-first condition of the present experiment, may have been more explicitly taught about the relations within the category than were infants in the no-familiarization condition. That is, presenting infants with a series of items all from within the same category in succession may have pointed out to the infants similarities and differences among those items. As a result, infants then could immediately begin to successively touch the items within one or both categories. In contrast, infants who are simply presented with the eight objects randomly arranged on the tray may not immediately see the within-category relations. For them, contrasts between items from different categories may be as salient (or even more salient) than similarities among items from the same category. As a result, these infants should show different patterns of touching initially. By evaluating the changes in infants’ touching over time we learn about how their recognition and discovery of the categorical relations changes as the items become familiar. Clearly, changes in infants’ understanding of categorical relations with increasing familiarity is important for their everyday encounters with objects. Therefore, results like those presented here contribute to our understanding of how infants typically learn about categories.

In summary, the results of this investigation suggest that when infants are faced with a difficult task, there is variability in their responding. That is, we tested 13-month-old infants because we expected them to have difficulty responding to the categorical distinction between land animals and people in the sequential-touching task. Indeed, our results confirmed this prediction. However, our results also confirmed our suspicion that even though infants at this
age were not initially engaged in successive touching to the objects, their touching was not random. We looked at both successive touching and alternating touching strategies because these touching patterns reflect comparison of items across and between categories—two types of comparisons that are important for discovering categorical boundaries. What our results showed was that these young infants were exhibiting both strategies. That is, they had adopted at least two different strategies for dealing with the task. At some later point in development, infants generally exhibit only one pattern of responding (i.e., successive touching), and we were able to elicit this pattern of responding by first explicitly teaching infants the categorical contrast in a familiarization task. Thus, we conceive of variability in this context like Siegler’s (1996) overlapping waves. Because infants were using two different strategies to solve the task, traditional measures of categorical responding in this context were uninformative as to how these infants were responding to the categorical contrast. Only by looking at different types of strategies that infants might exhibit did we gain insight into how infants were approaching this task and how the use of these strategies changed over time.

Notes

1. It must be pointed out that long session certainly contributed to the relatively high attrition rate in this study. Although 11 infants did not complete the session because of fussiness, approximately the same number of infants in each condition did not complete the session due to fussiness (six infants in the no-familiarization condition and five infants in the familiarization-first condition). Thus, although the long session may have been demanding and as a result a relatively high proportion of infants did not complete the session, the attrition rates in the two conditions were similar and, therefore, it is not the case that one of the conditions was more demanding than the other.

2. The analysis of the duration of infants’ focused attention during the tests also revealed a significant 3-way interaction between contrast (first vs. second), category presented first (animal vs. people), and test trial (within-category vs. out-of-category) [\(F(1, 13) = 5.36, p < .05\)]. Inspection of the means revealed that infants looked much longer at the novel out-of-category item than at the novel within-category item for the first contrast regardless of whether they were familiarized with animals or people. For the second contrast presented, however, infants who were familiarized with animals looked equally at the novel out-of-category and within-category items, whereas infants who were familiarized with people looked longer at the out-of-category item. This pattern may reflect infants who were familiarized with people and then animals not differentiating animals and people after this second familiarization (but see the sequential-touching data). Because infants’ level of interest in the tests was so low relative to their interest in the first test pair, it seems more likely that by this point infants were simply not interested in playing with any toys in this context.

3. Three infants (two in the familiarization-first condition and one in the no-familiarization condition) exhibited more than 60 touches. We only evaluated the first 60 touches from these infants because most infants had many fewer touches than 60 total. We were concerned that the amount of experience with the toys would be so different for touches beyond 60 that the comparisons would not be legitimate. That is, by the end of the first
half of their touches, the infants who would eventually exhibit more than 60 touches would be much more familiar with the toys than would the infants who had exhibited many fewer touches. Thus, we felt that comparisons would be more meaningful if we equated the amount of touching somewhat.

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