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Infants' Reasoning About Others' Preferences

Author
Duh, Shinchieh

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INFANTS' REASONING ABOUT OTHERS' PREFERENCES

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The Dissertation of Shinchieh Duh
is approved:

Professor Maureen Callanan, Chair

Professor Nameera Akhtar

Professor Su-hua Wang

Tyrus Miller
Vice Provost and Dean of Graduate Studies

Table of Contents

Infants' Reasoning About Others' Preferences

Shinchieh Duh

Abstract

Detecting others' preferences for a relational category of objects (e.g., taller objects) may be difficult, because doing so requires comparing within and between object pairs to extract the common relation. Extending from Duh and Wang (2014), the present research examined the conditions under which infants detect such preferences. In Experiment 1, an experimenter chose the taller of two objects in three examples and the shorter object in one example; the order of this last example was manipulated. In test, the experimenter chose either the taller or the shorter of two novel objects. Fourteen-month-olds detected the experimenter's overall preference for taller objects only when the inconsistent example occurred after three consecutive consistent examples. In Experiment 2, 11-month-olds detected the preference with three consistent examples, but only if they had made a choice prior to the experiment. Together, the results highlight the role of mixed data and action experience in infants' preference reasoning.

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Infants' Reasoning About Others' Preferences

Social understanding does not stem from merely detecting a common feature shared by the events children observe (Gopnik & Wellman, 2012; Meltzoff, 2007). In real-world situations, social events rarely repeat themselves precisely. Children must learn to extract the pattern of behavior exhibited by their social partners across various scenarios, even in the presence of noise, or inconsistency, in the observed examples. Detecting others' preferences is a unique task for examining children's learning about the social world. Not only does preference-guided behavior appear different across situations, people may also act in contradiction to their preferences. For example, a person who typically prefers sweets may occasionally choose savory crackers over cookies. To detect others' preferences, one must learn to deal with noise, or contradictory evidence, in the observed examples.

The present research examines the conditions under which 11- and 14-month-old infants detect another person's preference for a certain kind of object. While the terms *preference* and *choice* may imply mental state attributions, they are used in the present research as shorthand for one's interaction with one object over another. The issue of mentalistic (vs. behavioral) interpretations is addressed in the Discussion section.

Young infants readily notice others' consistent choice of one particular object over another (e.g., Sommerville, Woodward, & Needham, 2005; Luo & Baillargeon, 2007; Luo & Johnson, 2009; Woodward, 1998). For example, Woodward (1998) habituated 6-month-old infants to an experimenter's consistent choice of one particular object from two objects (e.g., a ball on the infant's left). In test, the locations of these objects were switched, and the infants dishabituated when the experimenter chose the other object with the same trajectory of her arm movement, but not when the experimenter chose the same object as before with a different trajectory. Thus, the infants seemed to have focused on the chosen object rather than her arm movements.

Further research showed that the infants did not simply encode the association between the person and object (Luo & Baillargeon, 2007; Luo & Johnson, 2009). When the experimenter repeatedly grasped one of two objects to which she had equal visual access, the 6-month-olds detected her preference for the chosen object and prolonged looking when she made a new choice in test. In contrast, when she repeatedly grasped one object while the other was hidden from her view (e.g., by an opaque screen), the infants looked about equally at her new and old choices in test (Luo & Johnson, 2009). These findings imply that the infants have some awareness of preference-guided behavior: namely, one's tendency to select a particular object over the alternative (Luo & Johnson, 2009, p. 142). With age, infants' understanding about preferences undergoes further development: By 18 months, they recognize that a preference for a particular object does not generalize from one person to another (e.g., Buresh & Woodward, 2007; Henderson & Woodward, 2012; Repacholi & Gopnik, 1997).

Detecting others' preference for a *kind* of object is less studied, though evidence so far suggests that infants become capable of it by the end of the first year.

For example, 12-month-old infants were habituated to an experimenter choosing a doll over a truck; subsequently, they became dishabituated when the experimenter chose a new truck but not when she chose a new doll, suggesting that infants had been habituated to the experimenter's choice of the category of *dolls* over *trucks* (Spaepen & Spelke, 2007). At 16 months, after seeing an experimenter point to a red toy pepper as opposed to a black cup, and a red cardboard pyramid as opposed to a yellow toy house, 16-month-olds detected the commonality among these examples—her choice to point to *red objects.* As a result, they expected the experimenter to point to a red, as opposed to a green, screen and looked longer when she did the opposite (Luo & Beck, 2010). These results suggest that infants at this age were capable of detecting a person's preference for a feature-based category of objects such as *dolls* or *red objects*.

The present research examines infants' sensitivity to others' preference for a *relational* category, as opposed to a *feature-based* category, of objects. Whereas a feature-based category is defined by the common feature shared by the chosen objects (e.g., the color red), a relational category is defined by the common relation that can be extracted across various choices. For example, the preference for darker-colored clothing can only be detected when one compares the choice of navy over sky blue *with* the choice of burgundy over pink and extracts the common relation across these choices, as opposed to focusing on a particular feature (e.g., navy blue). Recognizing preferences based on a relational category can be difficult because it requires comparing within and across different sets of options and identifying the relevant relation (see e.g., Gentner, 2005 for a discussion on relational knowledge acquisition).

The present research focuses on two factors that are relevant to infants' everyday experience. In Experiment 1, the role of mixed data—data that include contradictory or inconsistent examples—was explored. Infants' observation of others' actions is rarely arranged in a neat, consecutive manner, and understanding others' preferences therefore requires the ability to deal with mixed data. Experiment 1 explored infants' ability to detect others' preferences when presented with mixed data. In Experiment 2, the role of action experience was explored. Starting at a young age children are likely to have opportunities to make choices in their everyday experience. Having a similar experience with choices may be related to infants' understanding of others' preferences. Experiment 2 explored this possibility.

Previous results from our laboratory showed that 14-month-old infants detected another person's preference for taller objects—a relational category of objects, but only when the events were presented with positive emotional information (Duh & Wang, 2014). The infants received three familiarization trials in which an experimenter picked up and swayed the taller of two objects. Within each pair, the objects differed only in height; across pairs, the objects differed in shape, size, color, pattern, and height. Thus, in each trial the infants observed the experimenter choose the taller object; across trials, the infants observed three examples involving three distinct object pairs. In each familiarization trial, the experimenter began with a neutral facial expression; after she made the choice, she maintained the same neutral expression (neutral-face condition), or changed the expression to a smile (happy-face condition), or to a frown (unhappy-face condition).

After the familiarization trials, the infants received one test trial in which they saw the experimenter pick up the taller (old-choice event) or the shorter (new-choice event) object from a novel object pair. If the infants noticed the experimenter's preference from the familiarization trials, they should expect the experimenter to choose the taller object in test and look longer at the new- than the old-choice event. Results showed that only the infants in the happy-face condition detected the preference. Possibly, positive emotional expression helped scaffold the process of infants' preference reasoning, because in everyday observation people tend to display a positive emotion when preferences are met and/or because the repeated expression provides a cue for infants to extract the commonality across the examples they observe (Gentner, 2005).

The findings of Duh and Wang (2014) suggest that detecting others' preference for a relational category of objects is a challenging task for 14-month-old infants. They detected the experimenter's preference for taller objects after seeing three consecutive, consistent examples, but only when the choice actions were paired with a positive emotional expression. However, in everyday life, we seldom observe examples arranged in a neat, consecutive manner. As discussed before, understanding others' preferences requires the ability to deal with mixed data—examples that are not consistent with other examples. To bring the research one step closer to infants' everyday experience, it is important to investigate the effect of observing contradictory examples in infants' ability to detect others' preference. Experiment 1 examined whether the infants could still detect the preference if they witnessed a fourth example that contradicted the three other consistent examples.

No known research has examined infants' ability to detect others' behavioral regularity from mixed data, but there is suggestive evidence from the language-learning domain (e.g., Saffran, Aslin, & Newport, 1996; Vouloumanos & Werker, 2009). For example, after being exposed to the target word-object pairing 8 times and the alternative pairing 2 times, 18-month-old infants still learned the target word-referent pairing (Vouloumanos & Werker, 2009). In fact, infants as young as 8 months of age distinguished between different frequencies (100% vs. 33%) of syllable pairings after 2 minutes of exposure to an artificial language (Saffran et al., 1996; see also e.g., Mareschal, Quinn, & French, 2002 for 3- and 4-month-old infants' ability to categorize animals using statistical information). These findings have been taken to suggest that infants readily track various regularities in their environment, and this sensitivity to statistical information underlies early learning in general (Mareschal & French, 2000; Mareschal et al., 2002; Ruffman, Taumoepeau, & Perkins, 2011; Saffran et al., 1996; Vouloumanos & Werker, 2009). If so, the infants in Experiment 1 may be able to detect the experimenter's preference for taller objects despite contradictory evidence.

In Experiment 1, the timing of the contradictory example in infants' observation was manipulated. To my knowledge, little research has directly tested the order effect of inconsistent information in infants' detection of behavioral regularity.

But research on rational learning or hypothesis formation in infants and young children implies that whether inconsistent examples occur early or late in observation may influence infants' detection of others' preference (see e.g., Gopnik & Wellman, 2012). Specifically, it has been suggested that young children may engage in a process of hypothesis testing when making inferences about their world (Gopnik & Wellman, 2012). According to this account, infants and young children have the ability to formulate multiple hypotheses to explain the events they have observed, and subsequent "evidence leads children to gradually revise their initial hypotheses and slowly replace them with more probable hypotheses" (Gopnik & Wellman, 2012, p. 1086). Thus, a likely hypothesis may be preserved despite subsequent contradictory information, until such information amounts to make an alternative hypothesis more probable (Gopnik & Wellman, 2012, p. 1088). Applied to the present research, when the experimenter's initial choices are consistent, infants may be likely to formulate and strengthen a hypothesis about her preference for taller objects. In contrast, when her initial choices are inconsistent, infants may have difficulty forming a hypothesis about her preference.

Experiment 2 examined another potentially relevant factor for infants' preference detection—action experience. In everyday settings, infants actively engage in their surroundings, and converging evidence shows that action experience is linked to their understanding of others' behavior (e.g., in referential gesture, Hamlin, Hallinan, & Woodward, 2008; Sodian & Thoermer, 2004; visual attention, Meltzoff & Brooks, 2008; and tool use, Sommerville et al., 2005; Sommerville, Hildebrand, &

Crane, 2008; Sommerville & Woodward, 2005). For example, 10-month-olds who successfully retrieved a toy by pulling the cloth underneath detected the experimenter's object goal when she used the same method to retrieve a toy, whereas the infants who failed to use the same method were less likely to detect her goal (Sommerville & Woodward, 2005). Moreover, 12-month-old infants who had experienced blindfolds as visual barriers no longer followed a blindfolded person's gaze towards distant objects (Meltzoff & Brooks, 2008). At 3 months of age, the infants who had been given the opportunity to practice a novel goal-directed action (e.g., using a mitten's Velcro to grasp objects, Sommerville et al., 2005) subsequently recognized the goal of another person who performed these actions; the infants who did not practice the goal-directed action were less likely to recognize her goal.

In explaining the relationship between action experience and social understanding, Meltzoff (2007) proposed a "like me" model for social cognition. More specifically, he argued that when infants recognize the similarity in action between the self and others, they are in the position to perceive and reason about the goals and intentions underlying others' actions. Following this proposal, one may expect infants to benefit from their own experience with choosing, and therefore their sensitivity to preference-guided behavior may increase after the experience. It was hypothesized that the infants in Experiment 2 who had experience with choosing should be more likely to detect the experimenter's preference, compared to those who lack the experience.

Experiment 1

In Experiment 1, 14-month-old infants observed mixed data about one's preference. The choice of this age was based on the previous finding that infants of this age detected the experimenter's preference for taller objects after watching three consistent examples (Duh & Wang, 2014). The infants in Experiment 1 received *four* familiarization trials in which the experimenter chose the taller of two objects in three trials, and the shorter object in one trial. The contradictory example was presented either in the first (inconsistent-first condition), second (inconsistent-second condition), third (inconsistent-third condition), or the last (inconsistent-last condition) familiarization trial. Next, all infants received one test trial in which a novel pair of objects were used, and the experimenter chose either the taller (*old-choice* event) or the shorter (*new-choice* event) object. If the infants detected the experimenter's overall preference for taller objects in familiarization, they should expect her to choose the taller object again in test. The infants who saw the new-choice event should look significantly longer than did those who saw the old-choice event.

Drawing from the hypothesis-testing account of early learning (e.g., Gopnik & Wellman, 2012), it was predicted that infants would be more likely to detect the experimenter's preference when the initial observations are consistent, than when they are inconsistent, to support a hypothesis about her choices. In contrast, infants might have difficulty detecting the preference when the initial observations do not converge to support a hypothesis about her choices. For example, formulating a hypothesis about the experimenter's preference could be challenging when the experimenter's first few choices immediately contradicted one another. Following this reasoning, there is reason to expect that the infants in the inconsistent-last condition would be more likely than the infants in the other conditions to notice the preference and look longer at the new-choice event.

Method

Participants. Fifty-two full-term healthy infants (27 female, 25 male; *M* = 13 months, 15 days; range = 12 months 24 days to 14 months 10 days) were recruited from predominantly Caucasian, upper-middle class neighborhoods, using birth announcements and local baby group lists. Parents were offered travel reimbursement but were not otherwise compensated for their participation. The infants were randomly assigned to either the inconsistent-first (*n* = 14), inconsistent-second (*n* = 12), inconsistent-third (*n* = 12), or the inconsistent-last (*n* = 14) condition. Seven additional infants were excluded from the analyses due to inattentiveness (*n* = 5), observers' difficulty following the infant's eye gaze (*n* = 1), or the infant's exhausting the maximum looking time in all trials (*n* = 1).

Design and materials. The present research utilized a between-subjects design. Infants were randomly assigned to one of the four conditions that differed in the sequencing of the inconsistent example in familiarization (i.e., inconsistent-first, -second, -third, and -last conditions). Within each condition, half of the infants received the old-choice test event (i.e., picking taller object) and the other half the new-choice test event (i.e., picking shorter object). Thus, each infant received four familiarization trials and one test trial (see Figure 2).

A wooden display box (182 cm high × 104 cm wide × 63 cm deep) was mounted 77.5 cm above the room floor. The infant faced an opening (55 cm high × 97 cm wide) in the front of the box; between trials, a muslin-covered wooden frame was lowered in front of this opening. The experimenter sat behind a window (27.5 cm high × 35 cm wide) centered on the lower edge of the back wall. Two muslin-covered wooden frames (each 182 cm high × 63 cm wide with a peephole approximately 1 cm in diameter) were hinged to either side of the display box to isolate the infant from the rest of the room, while the observers monitored the infant's gaze through the peepholes. A metronome beat softly once per second to guide the experimenter in performing the prescribed script for each event.

Four pairs of objects were used in the familiarization trials, one pair per trial. The order in which the objects were presented was the same for all infants.[1] A fifth pair was used in the test trial. Within each pair, the objects were identical except for their heights; across pairs, the objects varied in shape, size, color, pattern, and height (see Figure 1). To present a category of *relatively taller* objects, the objects in the present research were designed so that any given "taller" object was taller within—but not across—the object pairs (e.g., the taller object from the third pair was shorter than both objects from the first pair). This helped address a potential limitation of Duh and Wang (2014) that the preference category might not be truly relational

[1]The presentation order was not counterbalanced due to the large sample size it would require: With four pairs of object there are 24 orders (4 × 3 × 2 = 24) to consider, resulting in a sample size requirement of 48 (24 orders × 2 test events) for each condition and 192 (48 infants × 4 conditions) for Experiment 1. The sample requirement doubles when gender is also considered.

because the taller objects were of similar heights and that infants could have responded to the objects' absolute rather than relative heights. Thus, to extract the preference, the infants in the present research could not rely on information about absolute height, and instead had to detect the relational commonality in the experimenter's choices across the different object pairs. At the beginning of each trial, the objects were placed 15.5 cm apart from one another and 33 cm from the front opening of the display box.

During the familiarization trials, the taller of the two objects was always placed on the infant's right. During the test trial, the locations of the objects were switched so that the experimenter either chose the shorter object with the same trajectory of her arm movement, or chose the taller object with a different trajectory. This design addressed the potential concern that infants' prolonged looking at the new-choice test event could be due to the novelty of the experimenter's arm movements (e.g., Woodward, 1998). If infants detected the experimenter's overall preference for taller objects from the familiarization trials, they should expect the experimenter to choose the taller object again and prolong their looking time when she chose the shorter object in test.

Procedure. Each infant received four familiarization trials and one test trial (see Figure 2). As in Duh and Wang (2014), all trials consisted of an initial phase, a reaching phase, and a final phase. The initial phase began when the muslin-covered wooden frame was raised to reveal a display of the objects and the experimenter's hands resting on the stage floor. After the infant had looked at this static display for 2 cumulative seconds, the reaching phase began: The experimenter reached with her right hand and grasped one of the two objects (1 s), moved it toward herself (1 s), and placed her left hand with her fingers closed on the other side of the object (1 s). In the final phase, the experimenter tilted the object 45 degrees to the right and then to the left (1 s each side) continuously until the computer signaled the end of the trial.

In the familiarization trials, the experimenter held a neutral facial expression during the initial and reaching phases but changed to a positive facial expression (i.e., smile) during the final phase. She chose the taller of the two objects in three of the four familiarization trials, and chose the shorter object in one familiarization trial either at the beginning or the end of familiarization phase. Each familiarization trial ended when the infant looked at the final phase for 60 cumulative seconds, or when the infant looked away for 1 consecutive second after having looked at the final phase for 8 cumulative seconds. During the test trial, the experimenter's face was out of the infant's view by sitting on a very high chair; only her torso and hands were visible to infants (as in Duh & Wang, 2014). The experimenter chose either the taller (old-choice event) or the shorter (new-choice event) object. The test trial ended when the infant looked at the final phase for 30 cumulative seconds, or when the infant looked away for 1 consecutive second after having looked at the final phase for 8 cumulative seconds.

The infant sat on the parent's lap about 60 cm from the front of the display box. The parent was asked not to interact with the infant and to remain silent and neutral throughout the experiment. The experimenter wore a white sweatshirt and greeted the infant with both of her hands prior to the experiment. This minimized the possibility that the infant would focus more on the experimenter's hands than on the actions being presented during the experiment. Two online observers, blind to the experimental hypotheses, observed the infant's gaze through the peepholes in the door on each side. They measured the infant's looking time by pressing a button linked to a computer whenever the infant was watching the event. The primary (and typically more experienced) observer's input was used to terminate each trial.

To assess inter-observer agreement, infants' looking times during the final phase of the test trial were divided into 100-ms intervals. Percent agreement was calculated by dividing the number of intervals in which the observers agreed whether the infant was looking at the event or not by the total number of intervals during this portion of the trial. Agreement was calculated for all but 5 infants (only one observer was present for these 5 infants) and averaged 95.5% and 96.2% (*SD*s = 4.7% & 5.5%) in Experiments 1 and 2, respectively.

Results and Discussion

Preliminary data analyses indicated no significant effect involving sex and test event; thus, the data were collapsed across sex in subsequent analyses. Infants' looking times during the final phase of each familiarization trial were averaged across familiarization trials. A one-way Analysis of Variance (ANOVA) with condition (inconsistent-first, -second, -third, -last) as the between-subjects factor revealed no effect of condition, $F(3, 48) < 1$, $p = .74$. Regardless of condition, the infants looked about equally during the familiarization trials (inconsistent-first: $M = 21.97$ s, $SD =$

6.35 s; inconsistent-second: $M = 24.45$ s, $SD = 12.67$ s; inconsistent-third: $M = 23.25$ s, $SD = 8.26$ s; inconsistent-last: $M = 25.78$ s, $SD = 9.29$ s). This result precluded the possibility that infants had responded differently in test due to different overall attention in familiarization.

The infants' looking times during the final phase of the test trial (Figure 3) were analyzed by a 4 × 2 ANOVA with condition (inconsistent-first, -second, -third, -last) and event (old-choice, new-choice) as between-subjects factors. The analysis yielded a marginal Condition × Event interaction, $F(3, 44) = 2.58$, $p = .07$, $\eta^2 = .13$. Planned comparisons showed that only the infants in the inconsistent-last condition looked significantly longer at the new-choice ($M = 19.53$ s, $SD = 6.60$ s) than the old-choice ($M = 10.79$ s, $SD = 2.59$) event, $F(1, 44) = 6.15$, $p = .02$, $d = 1.74$, whereas those in the other conditions looked about equally at the two events (for new-choice and old-choice events, respectively; inconsistent-first: *M*s = 16.17 s & 19.76 s, *SD*s = 7.42 s & 5.97 s; inconsistent-second: *M*s = 19.03 s & 21.43 s, *SD*s = 8.84 s & 7.21 s; inconsistent-third: *M*s = 13.47 s & 15.20 s, *SD*s = 4.57 s & 7.90 s), *F*s < 1.1, *p*s > .31, *d*s < 0.54. Nonparametric Wilcoxon Rank-Sum tests confirmed these results (inconsistent-last: $W = 32$, $p = .007$; inconsistent-first: $W = 43$, $p = .26$; inconsistent-second: $W = 36$, $p = .70$; inconsistent-third: $W = 38$, $p = .94$). These results suggest that only the infants in the inconsistent-last condition had noticed the experimenter's preference for taller objects and expected her to repeat that choice.

The infants in the inconsistent-last condition detected the experimenter's preference for taller objects despite inconsistent evidence. This finding lends support to Ruffman and colleagues' (2009) conjecture that infants' sensitivity to statistical regularities may underlie learning about language as well as about human behavior. That is, statistical learning as a domain-general mechanism enables infants to extract various patterns in their environment, pertaining to speech (Saffran et al., 1996), word-object mappings (Vouloumanos & Werker, 2009), animal categories (Mareschal & French, 2000; Mareschal et al., 2009), and human actions (Ruffman et al., 2011). Thus, infants seem adept at noticing how people typically behave even though human behavior in everyday observation tends to vary from one situation to the next, and may be inconsistent at times.

An interesting finding of Experiment 1 was that the infants detected the preference only if the contradictory example was shown *after* the infants had observed three consecutive, consistent examples. When the early evidence was mixed (i.e., the inconsistent-first, -second, and -third conditions), the infants did not detect the preference even though the likelihood of the experimenter selecting the taller object was always the same (three times out of four). Insofar as no known research with infants has examined the effect of order vis-à-vis inconsistent data, this finding requires further consideration.

Because the presentation order of the object pairs was fixed, one could interpret the positive finding in the inconsistent-last condition as an item effect rather than an order effect. That is, some idiosyncratic feature(s) of the fourth object pair (or the chosen object from this pair) could be responsible for the infants' success in detecting the preference. For example, the shorter object from this pair was so short (at 4.5 cm) that the infants may have failed to encode or remember which of the two objects was picked up, therefore missing the event entirely and responding as those who had seen only three consistent examples in Duh and Wang's study (2014). However, given this argument the infants in the inconsistent-third condition should have also missed the inconsistency and detected the preference: Those infants saw the experimenter picked up the smallest object of all (same height of 4.5 cm, but smallest in total volume; see Figure 1 for dimensions). Yet, this was not the case. Alternatively, there could be an interaction between order and item effects, and future research will be needed to replicate the order effect (e.g., by switching or counterbalancing the object pairs). In any case, there appears to be an effect related to order, and this finding offers insight into how infants deal with mixed data in their learning.

It has been proposed that infants' learning arises from their ability to extract regularities from the information received over time (e.g., Mareschal & French, 2000; Mareschal et al., 2002; Ruffman et al., 2011; Saffran et al., 1996; Vouloumanos & Werker, 2009), but how learning may be affected by the timing of inconsistent data is less clear. The order effect shown in Experiment 1 implies that the infants did not simply track the overall frequencies of the experimenter's choices, and thus statistical information alone cannot explain the infants' success or failure in preference detection.

Instead of aggregating information over the entire observation, the infants in Experiment 1 responded to the inconsistent evidence differently depending on when it occurred in their observation. While no detailed discussions of order effects have been given, the proposition that infants engage in hypothesis testing may be relevant here (see e.g., Gopnik & Wellman, 2012). This account suggests that infants learn by forming and updating multiple working hypotheses about the world. If so, early consistency may be especially important in allowing the infants detect the regularity in the experimenter's choices because they have the opportunity to form and then strengthen the hypothesis about her preference for taller objects (after watching three consistent examples consecutively). Subsequently, this hypothesis may be weakened in light of inconsistent evidence but not immediately abandoned; the infants may still use this hypothesis to predict her future behavior.

In contrast with those in the inconsistent-last condition, the infants in the inconsistent-first, -second, and -third conditions may be less likely to have focused on a hypothesis about the experimenter's preference on which to predict her future behavior. Specifically, a contradictory example that occurs first or second in the event series offers equally uninformative evidence about the experimenter's preference for either type of objects. Although it is possible to form a hypothesis about others' preference after observing only two consistent examples, the hypothesis may be too fragile to withstand an immediate contradictory example. Alternatively, early inconsistency may lead the infants to hypothesize that the experimenter chooses randomly and thus to respond similarly to her choice of either object in test.

It seems that infants have the tendency to make rapid inferences about others' preferences, but only after receiving a certain amount of consistent data. This echoes prior research showing that a minimum amount of data is required for infants to detect another's person's behavioral regularity. For example, 9.5-month-old infants detected a person's preference to slide objects after observing six distinct examples; they failed to notice the regularity with only three examples (Song & Baillargeon, 2007). The finding that the 14-month-old infants in Experiment 1 detected the preference only in the inconsistent-last condition suggests that the infants of this age needed at least three initial consistent examples to make this particular inference. Contradictory evidence that occurs before this minimum threshold is met is likely to disrupt infants' ability to detect the regularity in the person's behavior.

Experiment 2

Experiment 2 tested whether younger, 11-month-old infants' ability to reason about others' choices may be related to their own short-term experience with choosing. The choice of this age was based on the previous findings that infants between 10 and 12 months old could benefit from active experience when reasoning about others' behavior (e.g., Meltzoff & Brooks, 2008; Sommerville & Woodward, 2005). The procedure was similar to that of Experiment 1 with a number of modifications. First, a subset of infants participated in a choosing task prior to watching the staged events. Because height was the dimension along which the experimenter made her choices, a different dimension was used for the choosing task to address the potential concern that the infants' preference reasoning might be biased by whether the experimenter subsequently showed the same preference. It was expected that infants' responses to the choosing task would vary and only some infants would exhibit a clear preference by choosing one of the two options. Thus, to examine the relationship between infants' short-term action experience and preference reasoning, Experiment 2 contrasted those who picked up one of the two objects (choice-present group) with those who picked up neither or both objects (choice-absent group).

Following the choosing task were two staged trials to help the infants transition from one choosing dimension to another: The *display* trial was a static display of three objects varying only in height; the *survey* trial consisted of the tallest and the shortest object from the display trial at which the experimenter looked back and forth. The display trial was included to highlight the differences in object heights. The survey trial was included to help the infants further assimilate their own experience of choosing to the experimenter's, as choosing often involves a visual comparison of available options. Finally, the infants received three familiarization trials and one test trial, using the same procedure as in Experiment 1, except that the experimenter always chose the taller of two objects in familiarization.

To ensure that the addition of the display and survey trials did not contribute to infants' ability to detect the preference, Experiment 2 included a third group of infants who received only the staged trials (no-experience group). Thus, the no-experience group was tested the same way as the other two groups, except for the removal of the choosing task. It was hypothesized that those who exhibited a choosing behavior (choice-present group) would be better at detecting the experimenter's preference than those who did not make clear choices (choice-absent group) or those who did not have an opportunity to make any choices (no-experience group).

Method

Participants. Thirty-six full-term healthy infants (22 females, 14 males; *M* = 11 months 1 day; range = 10 months 17 days to 11 months 16 days) were tested. Twelve infants were randomly assigned to the no-experience group, who received only the staged trials and did not participate in the choosing task (*M* = 11 months, 4 days, 7 females, 5 males). Among those who participated in the choosing task, group assignments were based on whether the infants clearly displayed a preference during the choosing task (choice-present group: *n* =12, *M* = 10 months 29 days, 7 females, 5 males; choice-absent group: *n* = 12; *M* = 11 months 0 days, 8 females, 4 males). Three additional infants were excluded due to fussiness (*n* = 1), inattentiveness (*n* = 1), or observers' difficulty following the infant's eye gaze (*n* = 1).

Design and materials. Experiment 2 included three groups of infants. The opportunity to participate in the choosing task was randomized between the infants. The choice-present and choice-absent groups were formed on the basis of the infants' response during the choosing task and therefore not randomly assigned. Within each of the three groups (no-experience, choice-present, choice-absent), infants were randomly assigned to watch either the old- or the new-choice event during the test trial. The procedure was identical for the infants in the choice-present and choice absent groups: Each infant received a choosing task, a display trial, a survey trial, three familiarization trials, and a test trial. For the no-experience group, the procedure was identical except for the removal of the choosing task.

The choosing task was carried out by a separate experimenter (termed the "assistant" hereafter, to be distinguished from the "experimenter" who carried out the staged trials); the assistant did not participate in any other trials. This ensured that all three groups of infants had about the same familiarity with the experimenter. For the choosing task (see Figure 5), a plastic tray (41 cm wide x 30 cm deep) covered with black felt and two beanbags (one red and one blue, both 7.50 cm in diameter) were used. The sides of the beanbags were randomly determined for each infant, resulting in about half of the infants seeing the blue beanbag on their left and half on their right. The assistant played a warm-up activity with the infant prior to the choosing task by inviting the infant to take a toy from her hand twice. After the infant and the parent were seated in their usual testing position, the choosing task began.

For the display and survey trials (see Figure 6), a black felt cloth (30.5 cm wide x 15.5 cm tall) was attached to the bottom of the window opening to block the experimenter's hands from accessing the objects on the stage during the survey trial. The display trial showed three cylinders identical except in height covered in wood-patterned contact paper; the tallest and shortest of these cylinders were used in the survey trial.

Three pairs of objects were used in the familiarization trials, one pair in each trial. A fourth pair was used in the test trial. Within each pair, the objects were identical except for their heights; across pairs, the objects varied in shape, size, color, pattern, and height (see Figure 4). As in Experiment 1, at the beginning of each trial, the objects were placed 33 cm from the front opening of the display box and 15.5 cm apart from each other; the taller object was always on the infant's right in familiarization and on the left in test.

Procedure. Infants in the choice-present and choice-absent groups received a choosing task, a display trial, a survey trial, three familiarization trials, and one test trial. Those in the no-experience group received all but the choosing task.

For the choosing task (Figure 5), the assistant played a warm-up activity with the infant prior to the choosing task by inviting the infant to take a yellow toy pan from her hand twice. After the infant and the parent were seated, the choosing task began. The assistant brought over a tray with two beanbags placed 30 cm apart (11 cm away from the edge of the tray nearest to the infant), smiled at the infant, and asked, "Here you go, which one do you like?" If the infant did not make contact with any of the beanbags within 10 s, the assistant gave the second prompt, "Which one do you like?" If another 10 s passed without the infant making any contact with the beanbags, the assistant gave the third and final prompt, "Which one do you like? You can play with it!" If 10 s had passed after the final prompt and the infant still made no contact with the beanbags, the assistant said, "Ok! See you later!" and left with the tray and the beanbags.

The three prompts together allowed the infant a total of 30 s to make a choice during the choosing task. The assistant always smiled and looked at the infant when giving a prompt; however, at the end of each prompt, the assistant looked down at the ground while maintaining a positive facial display to avoid biasing the infant's response. If at any time the infant picked up any of the beanbags, the assistant would leave with the remaining stimuli; the infant was given 10 s before the assistant returned to retrieve the chosen beanbag(s).

The display trial showed three objects that were identical except in height and ended when the infant had looked at the objects for 12 consecutive seconds, or when the infant looked away for 2 consecutive seconds after having looked at the objects for 6 cumulative seconds. The bottom half of the window opening was blocked by the black felt cloth, as in the subsequent survey trial. The tallest and shortest of the three objects were 15.5 cm apart from one another, the medium object was placed halfway between the tallest and shortest objects; the objects were placed 33 cm from the front opening of the display box.

The survey trial began with the experimenter sitting behind the window opening with her face visible to the infant. The bottom half of the window opening was blocked by the black felt cloth, allowing only enough room for her face to fit; thus, the experimenter had only visual access and not manual access to the objects on the stage. Only the tallest and shortest objects from the height trial were used. The two objects were placed 15.5 cm apart from one another and 33 cm from the front opening of the apparatus, with the taller object to the infants' right (as in all familiarization trials). The experimenter began with a neutral face while looking down at the bottom of the window opening. When the computer signaled that the infant had looked at the display for two cumulative seconds, the experimenter slowly moved her gaze forward, following along a straight tape marking on the stage floor that led her gaze to the midpoint between the objects; the experimenter vocalized "ooh" with a pleasant tone as she moved her gaze (2 s). The experimenter then shifted her gaze to look at the short object (2 s), tall object (2 s), short object again (2 s), and tall object again (2 s), before moving her gaze along the tape marking on the stage floor back to the bottom of the window opening. After the experimenter's gaze moved back to the bottom of the window opening, the trial ended when the infant had looked at the final scene for 60 cumulative seconds, or when the infant looked away for 2 consecutive seconds after having looked at the final phase for 3 cumulative seconds. The experimenter maintained a neutral face throughout the survey trial.

Following the choosing task, the display trial, and the survey trial, the infants in the choice-present and choice-absent groups received three familiarization trials and a test trial, using the same procedure as in Experiment 1, except that the experimenter always chose the taller of the two objects. The no-experience group did not take part in the choosing task but received all other trials.

Results and Discussion

Infants' mean looking times (see Figure 7) during the final phase of the test trial were analyzed using a 3 (groups) × 2 (events) ANOVA with group (choice-present, choice-absent, no-experience) and test event (old-choice, new-choice) as between-subjects factors. The analysis indicated a marginal Group × Event interaction, $F(2, 30) = 3.26$, $p = .05$, $\eta^2 = .16$. The infants in the choice-present group looked significantly longer at the new- than the old-choice event (new-choice: M = 23.82 s, SD = 5.29 s; old-choice: M = 12.15 s, SD = 2.79 s), $F(1, 30) = 7.18$, $p = .01$, *d* = 2.76, whereas those in the choice-absent group looked about equally at the two events (new-choice: *M* = 13.82 s, *SD* = 7.83 s; old-choice: *M* = 18.36 s, *SD* = 8.44 s), *F*(1, 30) < 1, *p* = .33, *d* = 0.55, as did those in the no-experience group (new-choice: *M* = 21.6 s, *SD* = 10.88 s; old-choice: *M* = 17.52 s, *SD* = 7.13 s), *F*(1, 30) < 1, *p* = .36, *d* = 0.44. Wilcoxon Rank-Sum tests confirmed these results (choice-present: *W* = 21, *p* = .002; choice-absent: *W* = 21, *p* = .46; no-experience: *W* = 37, *p* = .82). A one-way ANOVA with group as the between-subjects factor showed that the infants had looked about equally at the familiarization events (choice-present: *M* = 23.61 s, *SD* = 10.52 s; choice-absent: *M* = 25.29 s, *SD* = 9.07 s; no-experience: *M* = 28.66, *SD* = 7.22), *F*(1,33) < 1, *p* = .39, η^2 = .06. These results indicated that only the choice-present group detected the experimenter's preference for taller objects.

The results from Experiment 2 showed that 11-month-old infants detected the experimenter's preference for taller objects when they had made a clear choice of one object over another immediately before their observation of the experimenter's choices. The infants did not differentiate their looking times between the two test events when they did not clearly exhibit a preference during the choosing task, or when they only got to observe the experimenter's preference.

It should be noted that the infants who detected the preference had chosen objects based on *color* and not on relative heights. Thus, the infants' success in detecting the experimenter's preference for taller objects could not result from simply aligning their own preference with the experimenter's. In other words, it is the *act of choosing*, or experience with preference, that was linked to the infants' reasoning about preference behavior in others. This finding supports the notion that infants bring to bear their own experiences to interpret others' behavior (e.g., Hamlin et al., 2008; Meltzoff, 2007; Meltzoff & Brooks, 2008; Sodian & Thoermer, 2004; Sommerville et al., 2005, 2008; Sommerville & Woodward, 2005).

Further research is required to conclude *how* the choosing task was linked to infants' subsequent success in detecting the experimenter's preference. The infants' differential responses could have stemmed from a number of potential differences between the groups (e.g., personality, level of choice-making in everyday life, language comprehension, attentiveness), thus making it difficult to identify the main driving force behind infants' preference reasoning. At minimum, the two groups differed in their experience with choosing immediately before observing the experimenter's choosing behavior. One group of infants engaged in the action of choosing one object over another, whereas the other group did not. Thus, having an immediately prior experience with choosing predicted the infants' detection of the experimenter's preference.

If the infants in the two groups had come with similar prior experience with choosing, the choosing task may have served as a prime to encourage the infants to think in terms of preferences. When given the choices between two different-colored beanbags, infants may respond differently because some infants might clearly prefer one color to another, whereas others might have no preference for either color, dislike beanbags in general, or feel too apprehensive to take objects from the experimenter. The infants may also have differed in other attention, language, or social skills that contributed to their differential responses to the choosing task. Whichever the reason might be, the infants in the choice-present group carried out an action similar to the experimenter's behavior in the subsequent trials, and this experiential alignment might have served to help infants' reasoning about the experimenter's preference.

However, it is also possible that the choosing task served to separate the infants who had relatively more experience with choosing in everyday life from those who had less, prior to participating in the present research. If so, the infants who were more experienced with choosing may be more likely to make a choice during the choosing task, and also more likely to have the relevant experience to draw on when representing the experimenter's actions as related to preferences. Future research can test this possibility by having the choosing task at the end of the experiment, or by having the parents complete a survey regarding the infants' choosing experiences outside of the laboratory.

The finding that the 11-month-olds detected the preference under selective conditions suggests that their ability to reason about others' preferences is still developing and therefore they only succeed under optimal conditions. In the present research, the 11-month-olds who detected the preference were given the choosing task and two additional trials (the display and the survey trial) prior to seeing the experimenter make her choices. It is unlikely that the additional trials could have accounted for the younger infants' success in the task. If this were the case, those in the no-experience group should have succeeded as well; however, they did not. The infants' ability to detect the preference was indeed associated with their experience with the choosing task. Nonetheless, as discussed above, it is unclear whether the choice-present and choice-absent groupings reflected pre-existing individual differences in readiness to reason about preference. If the infants in the choice-present group are already inclined to reason about others' behavior in terms of preference, they may have succeeded with the original procedure alone or the original procedure in addition to any combination of the additional task and trials. These possibilities await further research.

General Discussion

The present experiments examined two factors that contribute to infants' ability to detect others' preference for a relational category of objects: (a) the order in which inconsistent evidence is presented, and (b) infants' experience with choosing one object over another. In Experiment 1, 14-month-old infants detected the experimenter's preference for taller objects with mixed evidence when the inconsistent example was shown after they had observed three consistent examples, but not if the inconsistent example occurred anywhere else in their observation. Thus, when initial examples suffice for infants to detect the preference, a contradictory example does not disrupt preference detection. In Experiment 2, 11-month-old infants detected the experimenter's preference when they had previously engaged in choosing objects and made a choice themselves, but not when they failed to make a choice prior to the experiment. Thus, infants seem to draw upon their own experience to make sense of others' behavior.

The finding that the infants' preference detection relies on initial evidence lends support to the proposition that infant learning involves rapid formation and updating of multiple hypotheses, as opposed to gradual aggregation of information (e.g., Gopnik & Wellman, 2012). It appears that infants' inferences about people's behavior exhibit a bias for generalization based on initial information. Specifically, infants readily used the initial examples of the actor's preference to predict her future behavior despite a subsequent contradictory example. An interesting extension is to test how robustly this initial hypothesis holds up in light of additional contradictory examples. For example, can the infants discount more than one contradictory example? If indeed infants are simultaneously tracking multiple hypotheses, their expectation for the experimenter's choices should change if sufficient contradictory evidence is presented to them.

Past research has primarily focused on infants' ability to detect a behavioral regularity given repeated or consistent examples (e.g., Duh & Wang, 2014; Henderson & Woodward, 2012; Luo & Beck, 2010; Luo & Baillargeon, 2007; Song & Baillargeon, 2007; Song et al., 2005; Woodward, 1998). The present research adds to this research by showing that infants can detect a preference, a type of behavioral regularity, despite the presence of a contradictory example. However, it remains an open question whether infants could tolerate contradictory examples when reasoning about other types of behavioral regularity, such as the tendency to perform a certain type of action (Song & Baillargeon, 2007; Song et al., 2005), or to be helpful (see e.g., Hamlin & Wynn, 2011; Hamlin, Wynn, & Bloom, 2007; Kuhlmeier, Wynn, &

Bloom, 2003). It is possible that certain types of behavioral regularities may be deemed more rigid than others, and infants' ability to reason about such tendencies may be easily disrupted by a single contradictory example—no matter how late it occurs in observation.

It is remarkable that infants younger than 12 months could successfully detect the experimenter's preference after seeing only three examples, if they had exhibited a similar choosing behavior. This finding extends the research that shows that infants at 14 months and older can recognize categorical preferences in others (e.g., for taller objects, Duh & Wang, 2014; for boring vs. interesting toys, Fawcett & Markson, 2005; for red objects, Luo & Beck, 2010; for dolls vs. trucks, Spaepen & Spelke, 2007) and marks the youngest age at which infants show such a capacity. Moreover, this finding supports the view that infants' own experience with intentional behavior is closely related to their ability to reason about others' intentional behavior possibly by the process of assimilation (Meltzoff, 2007; see also Hamlin et al., 2008; Sodian & Thoermer, 2004; Meltzoff & Brooks, 2008; Sommerville et al., 2005, 2008; Sommerville & Woodward, 2005).

Whereas Duh and Wang (2014) showed that emotional information bootstraps 14-month-old infants' reasoning about the experimenter's preference for taller objects, the present data suggest that action experience may also play a critical role in infants' preference reasoning. An interesting extension would be to compare the facilitating roles of action experience with those of emotional information. The question is whether having experiences with choosing would suffice to allow the infants to detect the experimenter's choosing behavior in the absence of emotional information.

In the present research, the choice-present and choice-absent groups were not randomly assigned, but instead were determined by infants' response to the choosing task. Future research that randomly assigns infants to one of the groups can offer a stringent test for the effect of the choosing experience. For example, the groups can be randomly assigned by asking half of the parents to lead the infants' hand to pick up an object in one condition (choice-absent) and asking half of the parents to follow the infants' hand in the other condition (choice-present). In both conditions, the parent and the infant jointly pick up an object, but the infants in the choice-present condition are more likely to experience the process of making a choice. A design as such can help clarify the mechanism underlying the present results.

Another area worth exploring relates to how infants' recognition of a person's preferences may influence their interaction with the person. Knowledge about others' behavioral tendencies can allow infants to predict others' future behavior in novel situations (e.g., present study; Duh & Wang, 2014; Luo & Beck, 2010; Song & Baillargeon, 2007; Song et al. 2005). It can also serve to guide infants' social interaction: For example, infants may be more likely to avoid a hindering individual than a neutral or helpful individual (see Hamlin et al., 2007; Hamlin & Wynn, 2011). Fawcett and Markson (2005) also found that 23-month-olds chose to take a bag of concealed toys or books from an experimenter who had shared the child's preferences in toys, as opposed to another experimenter who preferred the child's disliked toys.

Whether there was a shared preference between the infants and the experimenter, and how it might affect their interaction with the experimenter, are beyond the scope of the present research. However, inquiries in this area are interesting and worth exploring to advance our understanding of how infants perceive and interact with others.

The familiarization and test events in the present experiments were similar in many aspects: The actor performed a sequence of similar hand movements in the same apparatus with the objects placed in a similar spatial arrangement. Even though the infants extracted the common relation across choices involving different pairs of objects, further investigation is needed to determine whether infants are still able to do so when observed examples are less similar. As our everyday observation of preference-guided behavior is often scattered and seldom arranged as consecutive events, future research can also examine the limits of infants' preference detection by inserting delays between examples.

Although the present research provides evidence for preference detection in infancy, further research is needed to determine whether detecting others' preferences reflects infants' insights into others' mental states or behavioral tendencies (see Ruffman et al., 2011 for further discussion on infants' mentalistic vs. behavioral understanding). On the one hand, the results of the present experiments can be taken to indicate a detection of behavioral regularity without attributing any mental state: The person tends to pick up taller over shorter objects. On the other hand, the positive relationship between action experience and preference detection implies that the infants may have benefited from comparing their own experience with choosing to others'. This points to the possibility that they might have the opportunity to attribute the mental state of desiring one thing over the other to the choosing behavior demonstrated by others. In addition, the previous finding (Duh & Wang, 2014) that facial expressions affect infants' preference detection could also be taken to support the mentalistic interpretation, as facial expressions often indicate different mental states in people. Whether the underlying process is mentalistic or not, the present findings show that by 14 months of age, infants are sensitive to others' behavioral regularities—specifically, choosing one object over the other based on a relational feature (the taller object)—despite the presence of contradictory evidence, and that by 11 months, infants seem to benefit from their action experience when detecting this type of behavioral regularities.

References

Buresh, J. & Woodward, A. L. (2007). Infants track action goals within and across agents. *Cognition, 104,* 287-314. doi:10.1016/j.cognition.2006.07.001

Duh, S., & Wang, S. (2014). Emotion bootstraps 14-month-old infants' detection of others' preferences. Manuscript under review.

Fawcett, C. A., & Markson, L. (2010). Children reason about shared preferences. *Developmental Psychology, 46,* 299-309.

Gentner, D. (2005). The development of relational category knowledge. In L. Gershkoff-Stowe & D. H. Rakison (Eds.), *Building object categories in developmental time* (pp. 245-275). Mahwah: Lawrence Erlbaum Associates.

Gopnik, A., & Wellman, H. M. (2012). Reconstructing constructivism: Causal models, Bayesian learning mechanisms, and the theory theory. *Psychological Bulletin*, 138, 1085-1108.

Hamlin, J. K., Hallinan, E. V. & Woodward, A. L. (2008). Do as I do: 7-month-old infants selectively reproduce others' goals. *Developmental Science, 11,* 487-494. doi:10.1111 /j.1467-7687.2008.00694.x

Hamlin, K., & Wynn, K. (2011). Young infants prefer prosocial to antisocial others. *Cognitive Development, 26,* 30-39. doi: 10.1016/j.cogdev.2010.09.001

Hamlin, K., Wynn, K. & Bloom, P. (2007). Social evaluation in preverbal infants. *Nature, 450,* 557-559. doi:10.1038/nature06288

Henderson, A. M.E., & Woodward, A. L. (2012). Nine-month-old infants generalize object labels, but not object preferences across individuals. *Developmental Science, 15,* 641-652.

Kuhlmeier, V., Wynn, K., & Bloom, P. (2003). Attribution of dispositional states by 12-month-olds. *Psychological Science, 14,* 402-408.

Luo, Y., & Baillargeon, R. (2007). Do 12.5-month-old infants consider what objects others can see when interpreting their actions? *Cognition*, *105,* 489–512.

Luo, Y., & Beck, W. (2010). Do you see what I see? Infants' reasoning about others' incomplete perceptions. *Developmental Science, 13*(1), 134-142. doi: 10.1111/j.1467-7687.2009.00863.x

Luo, Y., & Johnson, S. C. (2009). Recognizing the role of perception in action at 6 months. *Developmental Science, 12*(1), 142-149. doi: 10.1111/j.1467-7687.2008.00741.x

Mareschal, D., & French, R. (2000). Mechanisms of categorization in infancy. *Infancy, 1*, 59-76.

Mareschal, D., Quinn, P. C., & French, R. M. (2002). Asymmetric interference in 3- to 4-month olds' sequential category learning. *Cognitive Science, 26*, 377-389.

Meltzoff, A. N. (2007). 'Like me': A foundation for social cognition. *Developmental Science, 10*(1), 126-134. doi:10.1111/j.1467-7687.2007.00574.x

Meltzoff, A. N., & Brooks, R. (2008). Self-experience as a mechanism for learning about others: A training study in social cognition. *Developmental Psychology, 44*, 1257-1265. doi:10.1037/a0012888

Repacholi, B. M., & Gopnik, A. (1997). Early reasoning about desires: Evidence from 14- and 18-month-olds. *Developmental Psychology, 33,* 12-21.

Ruffman, T., Taumoepeau, M., & Perkins, C. (2011). Statistical learning as a basis for social understanding in children. *British Journal of Developmental Psychology, 30*, 87-104. doi: 10.1111/j.2044-835X.2011.02045.x

Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science, 274,* 1926-1928.

Sodian, B., & Thoermer, C. (2004). Infants' understanding of looking, pointing, and reaching as cues to goal-directed action. *Journal of Cognition and Development, 5*(3), 289-316. doi: 10.1207/s15327647jcd0503_1

Sommerville, J. A., Hildebrand, E. A., & Crane, C. C. (2008). Experience matters: The impact of doing versus watching on infants' subsequent perception of tool-use events. *Developmental Psychology, 44,* 1249-1256.

Sommerville, J. A., & Woodward, A. L. (2005). Pulling out the intentional structure of action: The relation between action processing and action production in infancy. *Cognition, 95,* 1-30. doi: 10.1016/j.cognition.2003.12.004

Sommerville, J. A., Woodward, A. L., & Needham, A. (2005). Action experience alters 3-month-old infants' perception of others' actions. *Cognition, 96,* B1–B11.

Song, H., & Baillargeon, R. (2007). Can 9.5-month-old infants attribute to an agent a disposition to perform a particular action on objects? *Acta Psychologica, 124,* 79–105. doi:10.1016/j .actpsy.2006.09.008

Song, H., Baillargeon, R., & Fisher, C. (2005). Can infants attribute to an agent a disposition to perform a particular action? *Cognition, 98,* 45-55. doi: 10.1016/j.cognition.2005.04.004

Spaepen, E., & Spelke, E. (2007). Will any doll do? 12-month-olds' reasoning about goal objects. *Cognitive Psychology, 54*, 133-154. doi: 10.1016/j.cogpsych .2006.06.001

Vouloumanos, A., & Werker, J. F. (2009). Infants' learning of novel words in a stochastic environment. *Developmental Psychology, 45,* 1611-1617. doi: 10.1037/a0016134

Woodward, A. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69,* 1-34. doi:10.1016/S0010-0277(98)00058-4

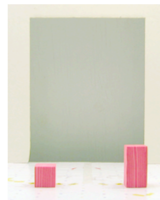
Trial	Fam. 1	Fam. 2	Fam. 3	Fam. 4	Test
Objects and dimensions (cm.)					
	W: 7.0 D: 6.0 H: 12.8 & 20.4	Dia: 8.0 H: 6.5 & 18.7	W: 4.5 D: 4.5 H: 4.5 & 8.0	Dia: 6.5 H: 4.5 & 11.5	Dia: 6.5 H: 7.3 & 15.5

Figure 1. Objects used in Experiment 1. W = width, D = depth, H = height, Dia = diameter.

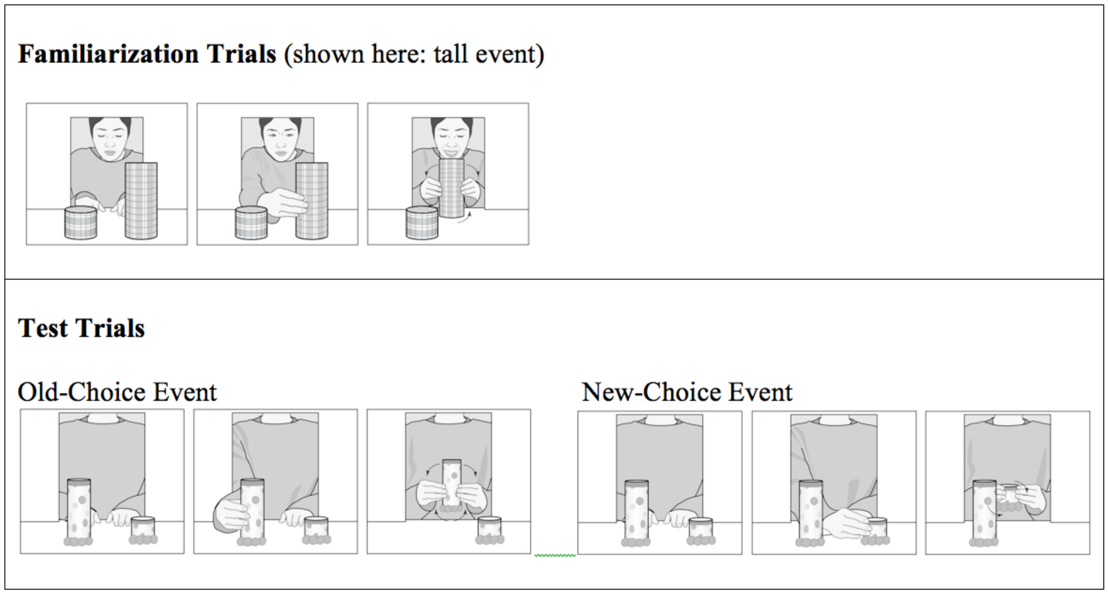


Figure 2. A schematic drawing of trial events in Experiment 1. The tall event is shown during three of the four familiarization trials; the order of the lone short event (not illustrated) varied between the conditions (i.e., first, second, third, or last).

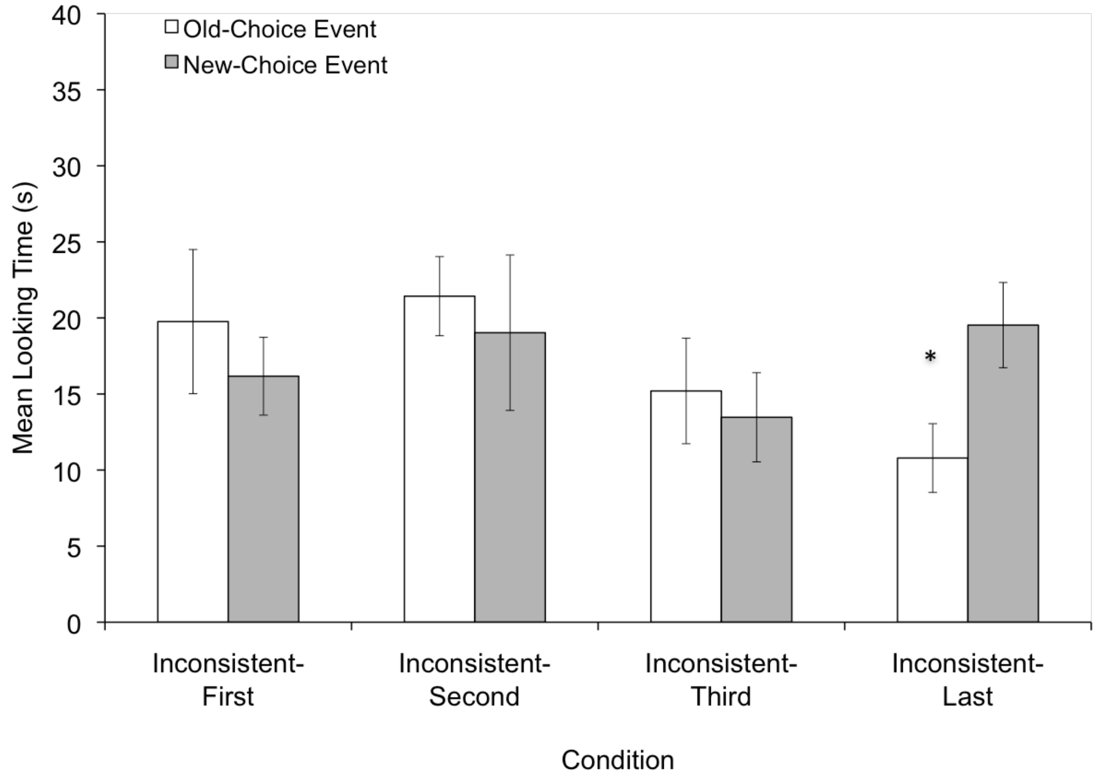


Figure 3. Infants' mean looking times in Experiment 1. Error bars represent standard errors, whereas asterisks above bars represent significant differences in the looking times between the old- and new-choice test events.

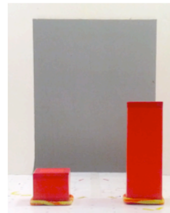
Trial	Fam. 1	Fam. 2	Fam. 3	Test
Objects and dimensions (cm.)				
	Dia: 8.1 H: 6.1 & 18.2	Dia: 5.5 H: 6.0 & 14.0	W: 5.6 D: 5.3 H: 5.0 & 16.5	Dia: 5.5 H: 5.2 & 14.8

Figure 4. Objects used in Experiment 2. W = width, D = depth, H = height, Dia = diameter.

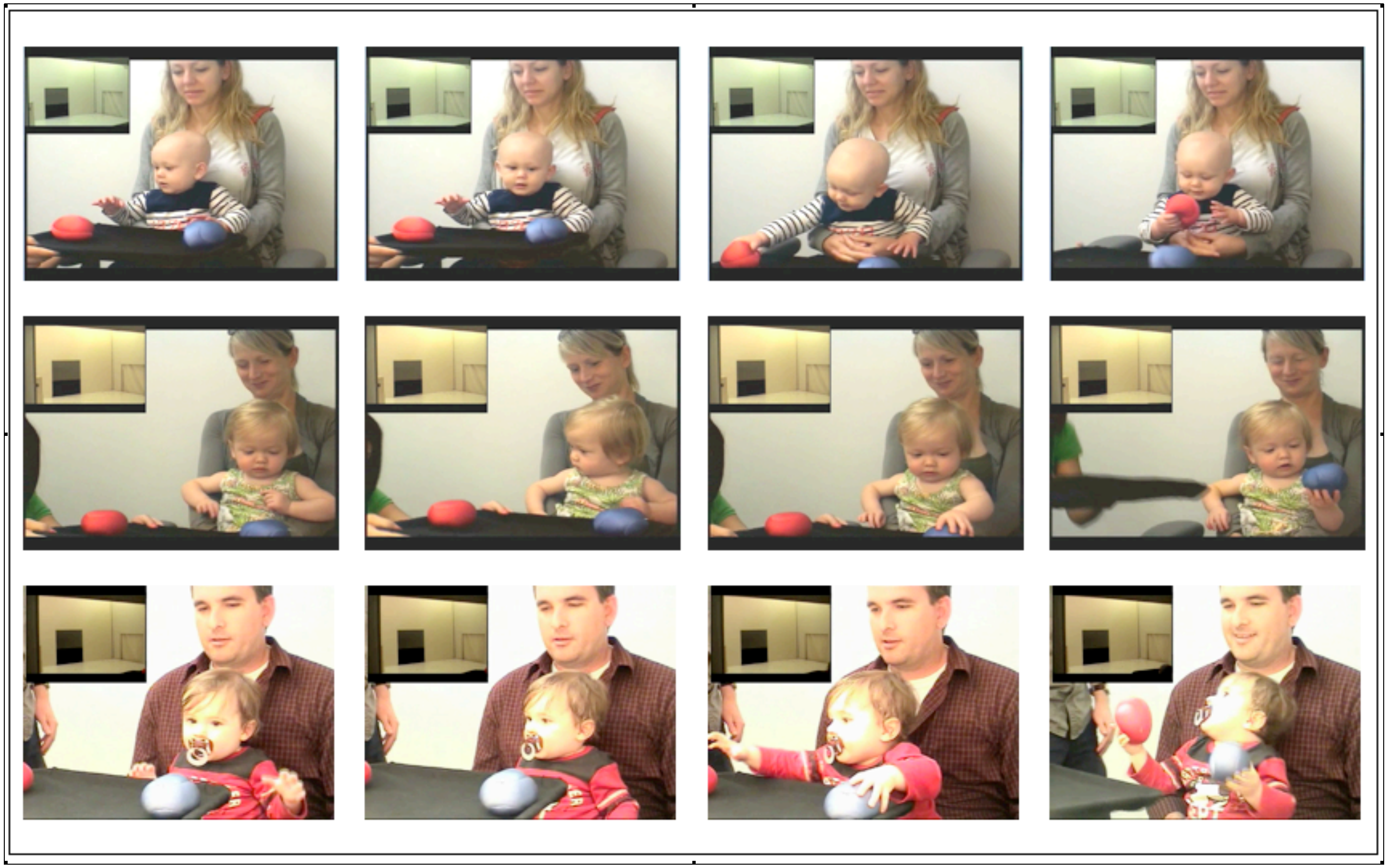


Figure 5. Select still frames from the video recordings of three infants participating in the choosing task in Experiment 2. The top two rows show infants from the choice-present group who made clear choices, whereas the bottom row shows an infant from the choice-absent group who chose both options simultaneously (i.e., no clear choice).

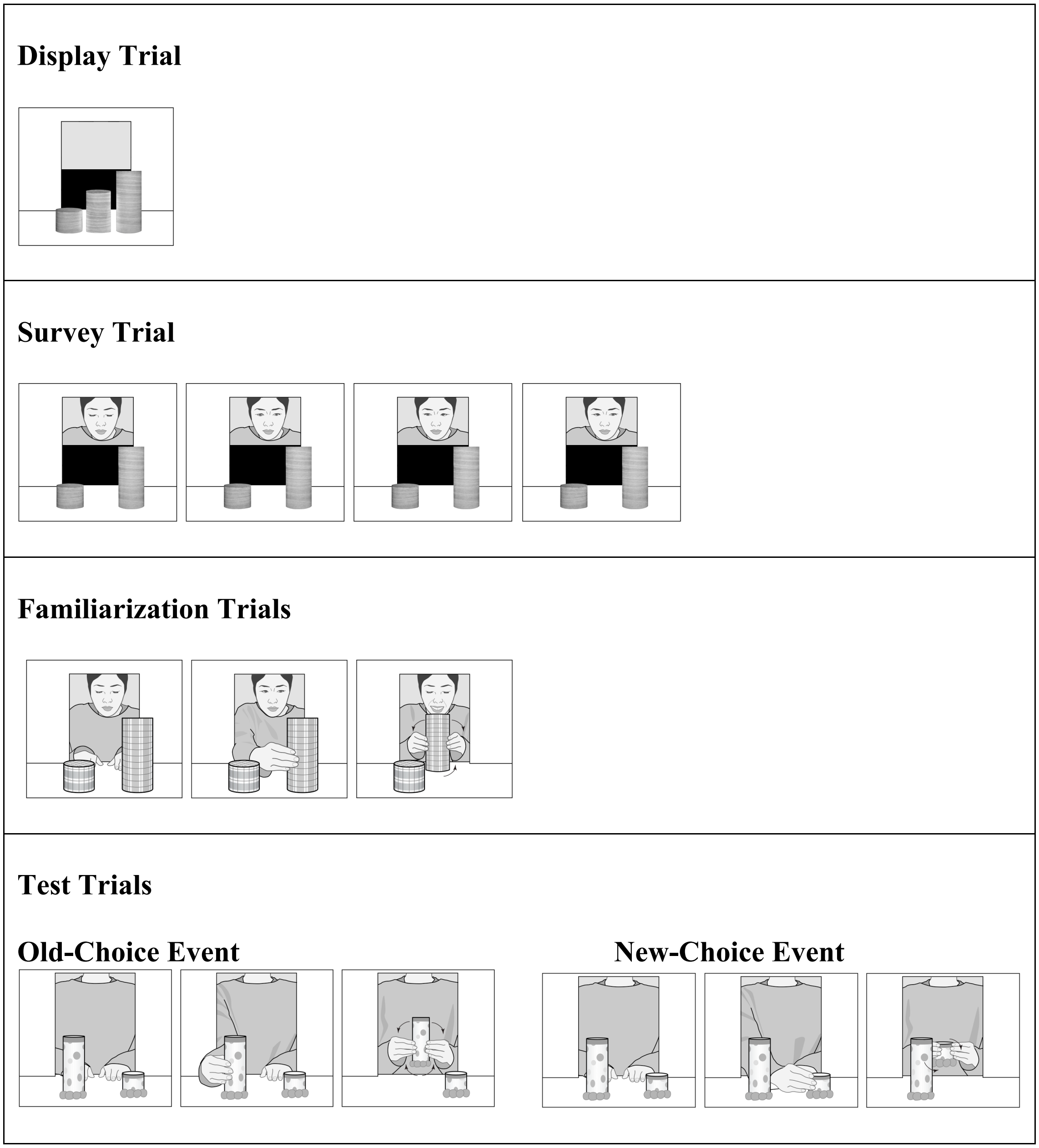


Figure 6. A schematic drawing of staged trial events in Experiment 2.

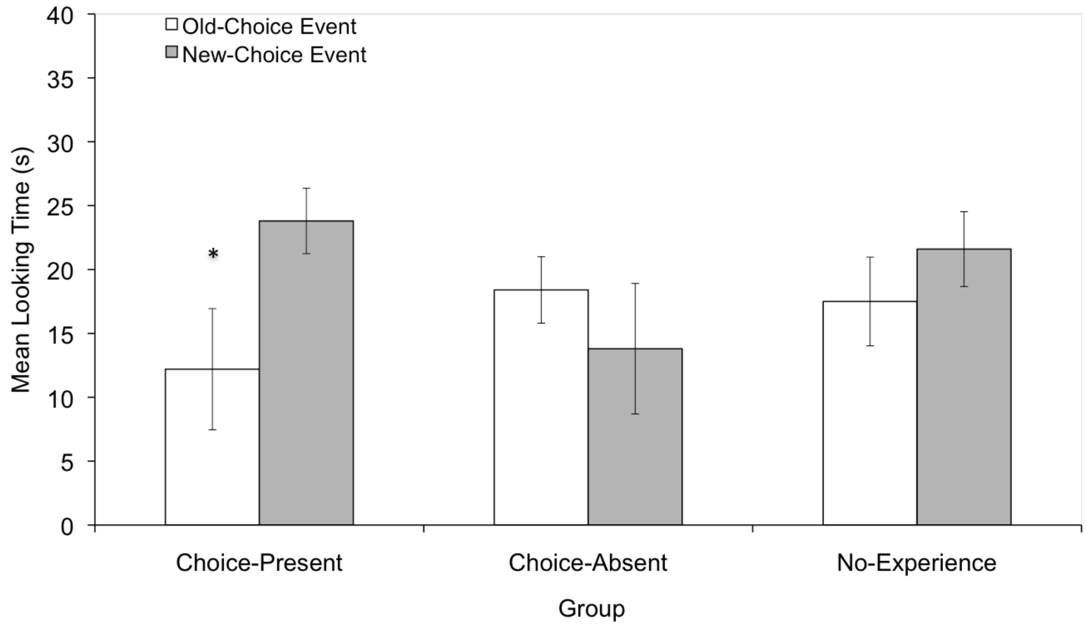


Figure 7. Infants' mean looking times in Experiment 2. Error bars represent standard errors, whereas asterisks above bars represent significant differences in the looking times between the old- and new-choice test events.