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Infants Detect Patterns of Choices Despite Counter Evidence, but Timing of Inconsistency Matters

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ABSTRACT

Understanding others' preference for a relational category of objects (e.g., prefer darker colored shirts) can be challenging for young children, as it involves comparison of choice options within and across exemplars. Adding to the challenge is occasional inconsistency in choices made by others. Here the authors examined whether 14-month-olds could detect an experimenter's preference for taller objects when they observed choices that were somewhat inconsistent. Infants watched four familiarization events involving different object pairs: The experimenter chose the taller of two objects thrice and the shorter object once—the inconsistent choice was presented at different time points of familiarization. The infants detected the experimenter's preference for taller objects only when they had observed three consistent choices consecutively from the beginning. This finding is in line with relational learning, specifically the significant role of initial data in the extraction of relational commonality. It also connects to the hierarchical Bayesian models of rational learning: Inconsistency can be discounted when the initial data allow learners to distinguish a highly probable hypothesis.

Preference understanding, a key aspect of social-cognitive development, facilitates the prediction of others' behavior (Lucas et al., 2014; Ma & Xu, 2011). In everyday language, preferences denote one's liking attitudes toward certain items when given alternatives. Preferences are often expressed verbally, and children readily attend to these linguistic markers. For example, statements of likes and dislikes enable preschoolers' preference attribution and prediction of others' behavior (Kalish, 2002, 2012; Kalish & Shiverick, 2004).

Preference can also be expressed nonverbally through stable patterns of choices that are rooted in subjective states such as affect, intention, and volition (e.g., Costanzo, Grumet, & Brehm, 1974). Thus, nonverbal preference understanding may begin with detecting patterns in the goal-directed behaviors that young children observe. The present experiment examines this ability in 14-month-old infants. Throughout this article, we use the term *preferences* as a shorthand for *an enduring tendency to choose one alternative over another* (i.e., beyond a single example) without assuming attribution of liking attitudes. Whether noticing enduring patterns of choices reflects an understanding of preferences as affect laden raises an interesting question but is beyond the scope of the present research.

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All behaviors shown in the present experiment were goal-directed actions. However, we use the term *preferences*, rather than *goals*, to highlight the stability of the pattern detected across multiple exemplars.

Noticing patterns should not pose great difficulty for infants who are capable of extracting probabilistic patterns (Aslin & Newport, 2012) and inferring physical and psychological causes from probabilistic information (e.g., Gopnik & Wellman, 2012; Xu & Kushnir, 2013). For example, infants attend to sampling cues to infer intentionality underlying others' choices (Kushnir, Xu, & Wellman, 2010). Indeed, infants are sensitive to patterns of choices made by others, suggesting an early emergence of preference understanding. By age 6 months, infants notice others' preference for a particular object over another as their goal of action (Woodward, 1998); by 9 months, they appreciate that preferences do not generalize from one agent to another (Buresh & Woodward, 2007; Henderson & Woodward, 2012; Repacholi & Gopnik, 1997). Furthermore, infants attribute to an agent a preference for one set of identical objects over a different set if the choices signal nonrandom sampling from a mixed population (Wellman, Kushnir, Xu, & Brink, 2016). Detecting preferences for an object category is less studied. Evidence so far suggests that infants attribute preferences for taxonomic categories by age 12 months (e.g., various trucks; Spaepen & Spelke, 2007) and feature-based categories by 16 months (e.g., various red objects; Luo & Beck, 2010).

All of the above preferences can be detected by matching surface features of chosen objects. However, not all patterns of choices can be detected this way. In the case of detecting relational patterns of choices (e.g., prefers darker colors or taller objects), one must go beyond first-order data (e.g., Sam's choice of a black shirt over a blue shirt, and purple over turquoise) and attend to second-order data (e.g., Sam's choice of darker- over lighter-colored shirts). In this case, matching surface features of chosen items across examples (the black and purple colors) will not lead infants to the relational pattern underlying the choices. Instead, detecting preferences for a relational category of objects (e.g., taller objects) requires at least two steps. Infants must 1) notice the relation between the alternatives in each example (e.g., one is taller than the other) and 2) extract relational commonality across examples (e.g., the chosen one is always taller than the unchosen). These requirements resemble those of relational reasoning.

Relational reasoning involves comparing across examples to highlight relational structure, which is more taxing than finding a featural match among items (Gentner, 2005). Research on relational reasoning has yielded fruitful insights into the mechanisms underlying cognitive development (e.g., Gentner, Anggoro, & Klibanoff, 2011; Oakes, Kovack-Lesh, & Horst, 2009; Waxman & Klibanoff, 2000) but tends to focus on preschoolers and older children (for rare exceptions, e.g., Ferry, Hespos, & Gentner, 2015; Walker, Bridgers, & Gopnik, 2016; Walker & Gopnik, 2014, 2017). Further, most research with infants examined their reasoning of same-versus-different objects, often in the context of learning physical causes. We see preference understanding, specifically infants' detection of others' choices, as offering opportunities to connect relational reasoning in early years with social cognition (e.g., Gerson & Woodward, 2012).

The present research focused on one particular challenge in preference understanding—inconsistency in observed behavior. In everyday life, preferences transcend behavioral consistency: People sometimes act against their preferences, while their preferences remain stable. For example, Sam prefers sweets but chooses savory crackers occasionally; Sam's enduring tendency to choose sweet over savory food does not prescribe all choices to conform to that tendency. To detect others' preferences, we must learn to deal with noise, or counter evidence, in the observation. By age 4 years, children can attribute behavioral traits from mixed evidence (Hu, Lucas, Griffiths, & Xu, 2015; Seiver, Gopnik, & Goodman, 2013). Insofar as infants readily extract linguistic rules from mixed evidence in language acquisition (e.g., Saffran, Aslin, & Newport, 1996; Vouloumanos & Werker, 2009), we examined infants' ability to extract preferences from inconsistent actions. Moreover, we varied the timing of the contradictory action to explore potential order effects.

Preference detection may be especially relevant to rational learning, wherein learners evaluate hypotheses based on prior beliefs and observed data (e.g., Gopnik & Wellman, 2012; Lucas et al., 2014; Xu & Kushnir, 2013). Specifically, the process of detecting others' preference from mixed evidence could be connected to hierarchical Bayesian models (Schulz, Goodman, Tenenbaum, & Jenkins, 2008): Learners favor higher-order hypotheses (e.g., Sam prefers darker- over lighter-colored shirts) over lower-order hypotheses (e.g., Sam prefers black over blue shirts) for the sake of parsimony and flexibility. Consequently, inferences may occur quickly with a few observations and be somewhat resistant to change (Schulz et al., 2008). From the traditional rational perspective, the specific placement of counter evidence should have little impact on learners' inference as long as the degree of consistency in the evidence remains the same. However, if learners favor higher-order hypotheses, we would expect an order effect: A hypothesis about a specific preference that has been sufficiently strengthened by the data so far could withstand subsequent counter evidence (e.g., by spontaneous auxiliary hypotheses to preserve the favored hypothesis; Schulz et al., 2008). In other words, consistency in the initial choices should facilitate preference detection. It follows that preference detection should be easier when the contradictory example occurred late than early.

The present experiment examined infants' detection of a person's preference for taller objects. Fourteen-month-olds were tested because infants at ages 12 to 16 months detect nonrelational categorical preferences (Luo & Beck, 2010; Spaepen & Spelke, 2007). In addition, our pilot results indicated that 14-month-olds detected a preference for taller objects after watching three consistent examples (Duh & Wang, 2012). The key question was whether infants would detect this preference when an inconsistent example was added to various points of their observation. In the familiarization phase, an experimenter chose the taller of two objects in three trials and the shorter object in one trial. Possible placements of the inconsistent trial led to four experimental conditions: The experimenter chose the shorter object in the first, the second, the third, or the last familiarization trial (the inconsistent-first, inconsistent-second, inconsistent-third, and inconsistent-fourth conditions, respectively).

Two important steps were taken to raise the requirement for infants to engage in extracting relational commonality, beyond encoding and matching object features—a strong propensity when they encounter novel objects (e.g., Wang, 2011; Wilcox, Smith, & Woods, 2010). First, the objects differed, across pairs, in shape, color, and pattern. Second and crucially, the objects ranged greatly in height: Some of the chosen objects were very short, shorter than the unchosen object in another pair. Thus, the height range of chosen objects would not be informative for detecting the pattern of choices.

After familiarization, all infants saw one test event in which the experimenter chose the taller (old-choice event) or shorter (new-choice event) object from a new object pair. If infants detected the experimenter's preference instantiated by the familiarization events, they should look longer at the new-choice than the old-choice test event. We predicted that infants in the inconsistent-fourth condition, whose observation of the first three events should strengthen the hypothesis that the experimenter prefers taller objects, should be best at detecting the preference, compared to infants in the other conditions. Anticipating the above results, we tested an additional group of infants as in the inconsistent-fourth condition (the replication condition).

Method

Participants

Seventy full-term healthy infants (M = 13 months 16 days; range = 12 months 24 days to 14 months 10 days; 35 females and 35 males) were assigned to one of the five conditions: inconsistent-first, inconsistent-second, inconsistent-third, inconsistent-fourth, and replication. The number of infants was identical across conditions (n = 14). Within each condition, one half of the infants watched the old-choice test event, and one half the new-choice test event. Six additional infants were excluded from the analyses due to fussiness (n = 2), inattentiveness (n = 3), or observers' difficulty following the infant's gaze (n = 1). Participants, primarily Whites from middle-class backgrounds, were recruited from birth announcements, local hospitals, and public libraries. Parents were offered a small gift or travel reimbursement but not otherwise compensated.

Materials

A wooden display box (182 cm high × 104 cm wide × 63 cm deep) was mounted 77.5 cm above the floor. The infant faced an opening (55 × 97) in the front of the box; between trials, a muslin-covered wooden frame was lowered in front of the opening. The experimenter sat behind a window (27.5 × 35) centered on the lower edge of the back wall. Two muslin-covered wooden frames (each 182 × 63) on either side of the display box isolated the infant from the rest of the room. A metronome beat softly once per second, allowing the experimenter to perform the prescribed script for each event.

Different object pairs were used across trials (Figure 1). Within each pair, objects differed only in height; across pairs, they varied in shape, size, color, and pattern.

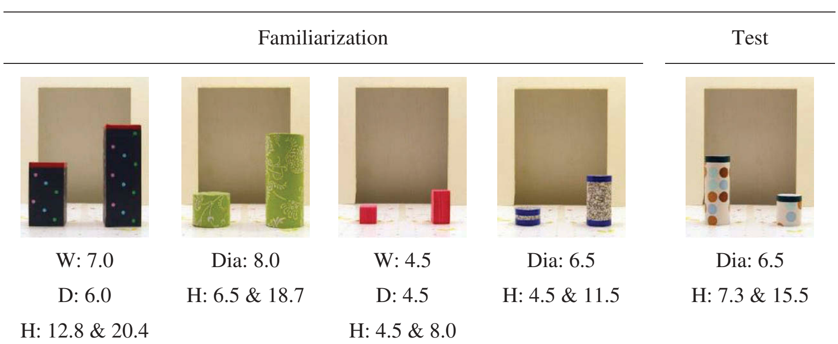

Figure 1. Objects Used in the Familiarization and Test Trials.

Across the two conditions, the order of object pairs varied systematically to control for potential item effects. At the beginning of each trial, objects were placed 15.5 cm apart from each other and 33 cm from the front opening. The taller object was on the infant's right in familiarization and on the left in test.

Procedure

The infant sat on the parent's lap about 60 cm from the display box. The parent was asked to remain neutral and not interact with the infant throughout the experiment. After the infant was seated, the experimenter (E) in a white sweatshirt greeted and showed both hands to the infant. During all trials, E never looked at or interacted with the infant.

Each infant received four familiarization trials and one test trial (Figure 2). Depending on the condition assigned, the infants saw E pick up the shorter object in the first, second, third, or fourth familiarization trial, and the taller object in all other trials. In familiarization, E always started with a neutral facial expression and changed to a smile after making the choice. In test, E sat on a very high chair and grasped either the taller or shorter object, with the face out of infant's view to highlight the objects and the choice.

Two independent observers, who were unable to see the events and unaware of the condition assigned, watched the infant through peepholes in the muslin-covered frames. Whenever the infant looked at the event, the observers pressed a button on a controller linked to a computer that ran a Windows-based software. Each trial ended when infants looked away from the event for 1 consecutive second after having looked at the final phase of the trial for at least 8 cumulative seconds, or when they had looked at it for 30 cumulative seconds. The 8-s minimum look ensured that infants had a chance to see the choice for at least four cycles of E's playing with the object. The final phase of the test trial was divided into 100-ms intervals for calculating interobserver agreement: the number of observers-in-agreement intervals divided by the total number of intervals. Agreement was measured for all but four infants (only one observer was present during these infants' testing) and averaging 96% (SD = 5%). Reported looking times were based on inputs from the primary and typically more experienced observer. Preliminary data analyses indicated no significant effect involving sex; the data were therefore collapsed across sex in subsequent analyses.

Results

To examine whether timing of inconsistency affected preference detection, infants' looking times (in seconds) during the final phase of the test trial (Figure 3) were compared by a 4 × 2 ANOVA with condition (inconsistent-first, inconsistent-second, inconsistent-third, inconsistent-fourth) and event (new- or old-choice) as between-subjects factors. The analysis yielded a significant Condition × Event interaction, $F(1, 48) = 2.96$, $p < .05$, $\eta^2 = .11$. Planned contrasts indicated that in the inconsistent-fourth condition, infants who saw the new-choice event looked significantly longer (M = 20.36, SD = 6.40) than those who saw the old-choice event (M = 11.13, SD = 2.77), $F(1, 48) = 6.84$, $p = .01$, Cohen's d = 1.87. In contrast, infants' looking times did not differ significantly between the new- and old-choice test events in the inconsistent-first (new-choice: M = 16.17, SD = 7.42; old-choice: M = 19.76, SD = 5.97),

Figure 2. A schematic drawing of the events in the familiarization and test trials. Each trial consisted of the display, choice, and final phases. The trial began with a static display of the object pair and E's bare hands resting on the apparatus floor. After the infant had looked at the display for 2 cumulative seconds, the choice phase began. E reached with the right hand and grasped one of the two objects (1 s), lifted and brought the object closer (1 s), and placed the left hand with fingers closed on the other side of the object (1 s). In the final phase, E tilted the object 45 degrees to the right (1 s) and then left (1 s) repeatedly until the end of the trial.

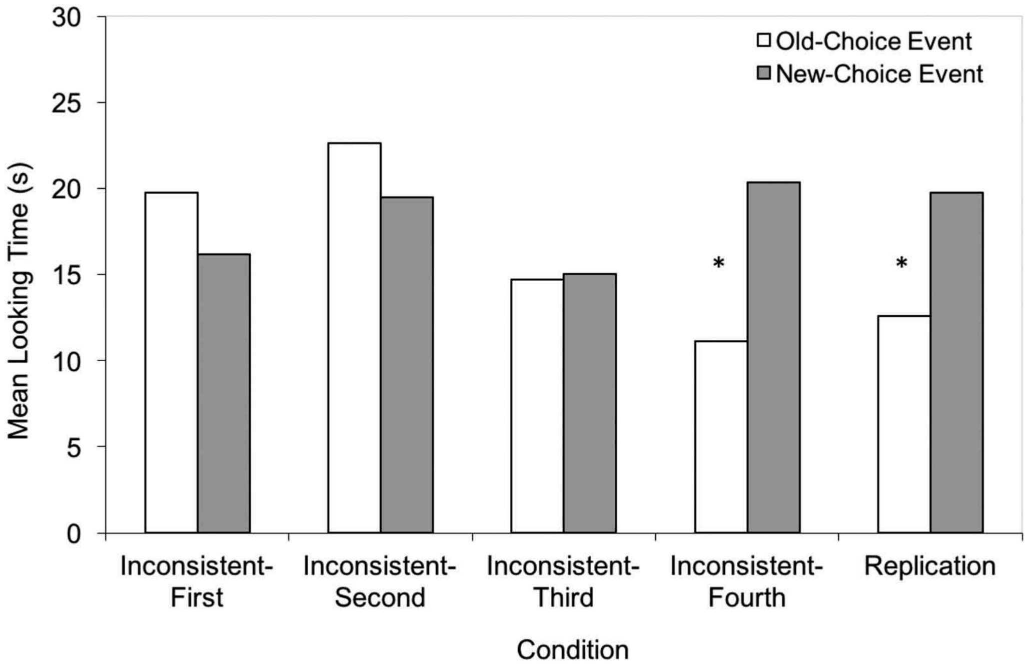

Figure 3. Infants' mean looking times at the final phase of the test event. Error bars represent Standard Errors. Asterisks above bars represent significant differences in the looking times between the old- and new-choice test events (*ps* < .05). Infants in the replication condition were tested as those in the inconsistentfourth condition.

inconsistent-second (new-choice: M = 19.47, SD = 8.15; old-choice: M = 22.66, SD = 7.34), or inconsistent-third (new-choice: M = 15.06, SD = 5.93; old-choice: M = 14.70, SD = 7.33) conditions, Fs < 1.09, ps > .32, ds < 0.53. As expected, the replication condition (new-choice: M = 19.77, SD = 7.69; old-choice: M = 12.59, SD = 2.40) yielded the same pattern as did the inconsistent-fourth condition, independent-samples $t(12) = 2.36$, $p < .05$, Glass's $\Delta = 0.93$. Wilcoxon rank-sum tests confirmed these results (inconsistent-fourth and replication: Ws < 37, ps < .05; inconsistent-first, -second, -third: Ws > 43, ps > .23). Together, the results suggested that the 14-month-olds in the inconsistent-fourth and replication conditions detected the experimenter's preference for taller objects, but those in the other conditions did not.

To rule out an alternative explanation that infants' differential test responses were attributable to preexisting biases between groups assigned, we compared the mean looking times in familiarization by infants across all five conditions (the four experimental conditions and the replication condition), using a 5 × 2 ANOVA with the assigned condition and assigned test event as between-subjects factors. The analysis yielded no significant effects, Fs < 0.60, ps > .67, indicating that infants looked about equally in familiarization regardless of the condition (inconsistent-first, -second, -third, -fourth, replication: Ms = 21.97, 26.04, 23.82, 23.50, 24.58; SDs = 6.35, 12.66, 7.89, 8.27, 8.16; respectively) or the test event they were assigned to (new-choice: M = 23.70, SD = 8.90;

old-choice: M = 24.26, SD = 8.74). The results indicated that infants' detection of preference in the inconsistent-fourth and replication conditions was not driven by pre-existing biases across the groups.

Discussion

After watching three consistent choices and then an inconsistent choice, infants in the present research detected the experimenter's preference for taller objects. The results suggest that detection of relational patterns of choices emerges by age 14 months and that it withstands counter evidence to some extent. This finding echoes the evidence that infants are capable of detecting patterns of speech sounds from mixed evidence (e.g., Saffran et al., 1996; Vouloumanos & Werker, 2009) and that preschoolers attribute traits despite inconsistent evidence (Hu et al., 2015; Seiver et al., 2013). Furthermore, we showed that timing of the inconsistent example affected 14-month-olds' detection of the preference. Infants expected the experimenter to choose the taller object in test when the inconsistent choice was presented after three consistent choices but not when the inconsistent choice was presented earlier. Thus, adequate consistency in the initial data facilitated infants' detection of the relational pattern of choices. Analogous to this finding, research on children's relational reasoning has shown that extracting relational commonality across examples is best supported when initial examples are well aligned to highlight structural commonality in the data (e.g., Gentner, 2005).

In the rational model of preference understanding (Lucas et al., 2014), data presenting strong regularities will enhance infants' arrival at the most probable hypothesis. The present results further specify that such consistency in the initial data will facilitate infants' reasoning, in line with the hierarchical Bayesian models suggesting that the most probable higher-order hypothesis could be strengthened to the extent of discounting contradictory evidence (Schulz et al., 2008). When facing a sea of infinite hypotheses, rather than treating each choice as independently motivated, infants in the present research might prioritize the hypotheses for the pattern of choices. When the experimenter consistently chose taller objects in the first three trials, the probability for the hypothesis of a preference for taller objects was strengthened to an extent that it withstood counter evidence in the following trial. However, when the experimenter made inconsistent choices within the first three trials, multiple hypotheses remained probable, making it difficult for infants to detect the preference.

The present research offers initial evidence that infants can detect patterns in others' choices despite counter evidence, but the timing of inconsistency matters. This is consistent with the findings that children actively take into account new information and adjust their beliefs about physical and psychological events (see e.g., Legare, Schult, Impola, & Souza, 2016; Seiver et al., 2013). The mechanisms through which counter evidence is processed may be a fruitful area for future research. Schulz et al. (2008) found that children learned an arbitrary physical rule after only a few demonstrations and they made up justifications to uphold the newly learned rule when it seems challenged, rather than revising the rule. A similar process may exist in preference reasoning: Once an inference is made, it could be resistant to minor challenges by way of ad hoc explanations. Future work can systematically manipulate the amount and timing of inconsistency to illuminate the fine-grained aspects of the preference-reasoning process.

To conclude, the present results demonstrate that by age 14 months, infants are capable of detecting an enduring pattern of choices without relying on featural match. Instead, they extract relational commonality in the choices made by others. With just a few examples presenting a consistent pattern, infants demonstrate the ability to deal with variability and counter evidence, which is crucial for interpreting and predicting others' behaviors in everyday experience. Insights into the development of this ability have important theoretical implications for social-cognitive development as well as general learning mechanisms.

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