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Infants' Understanding of Preferences When Agents Make Inconsistent Choices

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This study showed that 8.5-month-old infants seemed to consider the consistency of an agent's choices in attributing preferences to her. When the agent consistently chose one object over another, three or four times consecutively, infants acted as if they had interpreted her actions as evidence for her preference. In contrast, when the agent inconsistently chose between the two objects, at the ratio of 1:3, infants did not seem to interpret her actions as suggesting her preference. Converging evidence was obtained from infants' responses across a looking-time task and an action task. The results are discussed in terms of how infants might use frequencies of agents' actions directed toward different objects to understand agents' preferences.

As adults, we constantly gauge what is on each other's minds to interpret and predict people's behavior. Such theory-of-mind understanding emerges even in infancy (for reviews, see Baillargeon et al., 2015; Luo & Baillargeon, 2010). Infants attribute to agents (i.e., entities that can detect their environment and exert control over their actions, human or non-human) mental states such as goals, dispositions (e.g., preferences), perceptions, and beliefs, to make sense of their behavior (e.g., Gergely, Nádasdy, Csibra, & Bíró, 1995; Kovacs, Teglas, & Endress, 2010; Leslie, 1995; Luo & Choi, 2013; Luo & Johnson, 2009;

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Onishi & Baillargeon, 2005; Song, Baillargeon, & Fisher, 2005; Southgate & Vernette, 2014). In the present research, we focus on infant' understanding of agents' preferences.

A preference is a dispositional state that helps explain why an agent chooses a particular goal-object in the presence of another option. Findings from looking-time studies show that by 3 months of age, infants who watch an agent repeatedly act toward object-A, but not object-B, behave as though they attribute to the agent a preference for object-A over object-B (Luo, 2011b; Luo & Baillargeon, 2005; Woodward, 1998). In contrast, when the agent is faced with object-A only, either because object-B is absent or hidden from the agent (but not from the infant), infants act as though the agent's same actions toward object-A do not suggest a preference (e.g., Luo, 2011a,b; Luo & Baillargeon, 2007; Luo & Johnson, 2009). Therefore, an agent's consistent actions directed toward one of two objects might reveal her underlying preference.

Recently, researchers have varied the proportions of the two kinds of objects involved in studies of infants' understanding of agents' preferences. In one study (Kushnir, Xu, & Wellman, 2010), an agent consistently picked out five toy frogs from a box with 31 toy ducks and seven toy frogs (minority condition; 18% versus 82%) or a box with 31 frogs and seven ducks (majority condition; 82% versus 18%). Twenty-month-olds were more likely to judge that the agent had a preference for frogs over ducks and offered them to her more frequently in the minority condition than in the majority condition. Similar but weaker results were found in younger, 16-month-old infants when the agent sampled six preferred toys with different minority proportions (7:53 or 12%, and 9:60 or 13%) and the minority toys were less attractive than the majority ones (Ma & Xu, 2011). These results suggest that young children can use statistical information, that is, proportions of the two kinds of objects, to make inferences about agents' preferences (Xu & Kushnir, 2013).

In the studies described above, the agent always chose one object or one kind of object. Whether or not her actions showed her preference depended on the presence or absence of another option or on the varied proportions of the two kinds of objects. In real life, however, people do not consistently act toward a single object or one kind of object. Rather, they change their minds to act on different objects all the time. In fact, this led to the suggestion that "preference should be defined in a probabilistic fashion" as "when faced with repeated choices between x and y, people often choose x in some instances and y in others" (Tversky, 1969, p. 31).

The present research was the first to examine how infants might take into account others' inconsistent choices in their preference attributions. In our tasks, an agent acted inconsistently, choosing object-A or object-B, as opposed to consistently choosing one of the two objects. Adults can automatically encode frequency information (Hasher, Zacks, Rose, & Sanft, 1987) and may decide that an agent who chooses A more often than B still prefers A. Infants are also sensitive to frequencies (e.g., Kochukhova & Gredeback, 2007; Saffran, Aslin, & Newport, 1996). Might they use different frequencies of the agent's actions directed toward the two objects in their preference attributions? How would this help to define preferences in probabilistic terms? We will return to this issue in the General Discussion.

In a previous study (Luo & Johnson, 2009), 6-month-old infants saw an agent reach for and grasp object-A, but not object-B, across *four* familiarization trials before test trials. Infants responded with heightened interest when she grasped object-B during test, suggesting that infants interpreted her actions as evidence of a preference for object-A. In the present research, we also used four familiarization trials and designed three conditions: consistent, inconsistent, or two-agent condition. The consistent

condition was similar to Luo and Johnson (2009). In the inconsistent condition, to maximize the weight of consistent actions, the agent chose object-A in three consecutive familiarization trials, and B in one trial (order counterbalanced). In the two-agent condition, the inconsistency in actions occurred across two agents: Agent1 chose object-A in three consecutive familiarization trials and Agent2 chose object-B in one familiarization trial (order counterbalanced). Hence, each agent's choice was still consistent. We measured infants' looking-time (Experiment 1) and action (Experiment 2) responses. Because we sought converging evidence from two behavioral measures, we tested 8.5-month-old infants, an age older than those in Luo and Johnson (2009). This is one of the few preference-attribution studies (Hamlin, Hallinan, & Woodward, 2008; Thoermer, Woodward, Sodian, Perst, & Kristen, 2013; Woodward, 1998) that attempted to obtain corroborative measures.

EXPERIMENT 1

In Experiment 1, 8.5-month-old infants were randomly assigned to one of three conditions: consistent, inconsistent, or two-agent condition (see Figure 1). In the consistent condition, during four familiarization trials, an agent, Agent1, sat equidistant between two stuffed animals, a puppy and a bird, and reached for and grasped the bird. Next, the positions of the two toys were reversed and infants received two test trials. Agent1 chose the bird again (old-goal event) in one test trial and the puppy (new-goal event) in the other test trial. The inconsistent and the two-agent conditions were similar to the consistent condition except that in the first or the fourth familiarization trial, the puppy was the target of the action. In the inconsistent condition, because Agent1 reached for and grasped the puppy once and the bird three times, her choices between the two toys were inconsistent across the four familiarization trials. In the two-agent condition, it was a different agent, Agent2, who reached for and grasped the puppy. Therefore, Agent1's choice was still consistent: she chose the bird but not the puppy three times. Note that in both conditions, each toy was attended to the same number of times during familiarization.

If consistency in choice signaled the agent's preference between the two toys, infants should attribute a preference to Agent1 in both the consistent and the two-agent conditions but not in the inconsistent condition. If this is the case, at test we expect infants in the former two conditions to look longer when the agent chose the new-goal option over the option she had previously chosen, but in the latter condition to not show any difference in looking behavior to either of the agents' choices.

Method

Participants

Participants were 60 healthy, full-term infants, 30 male and 30 female (7 months, 12 days to 9 months, 20 days, M = 8 months, 13 days). Twenty infants were randomly assigned to the consistent (10 male, M = 8 months, 13 days), inconsistent (9 male, M = 8 months, 16 days), and two-agent condition (11 male, M = 8 months, 10 days). Thirteen infants were excluded for differences in test looking times more than 2 SDs from the mean of their condition (4), fussiness (3), observer errors (2), being distracted (2), the agent's coughing fit (1), or taking a long break (about 7 min) (1).

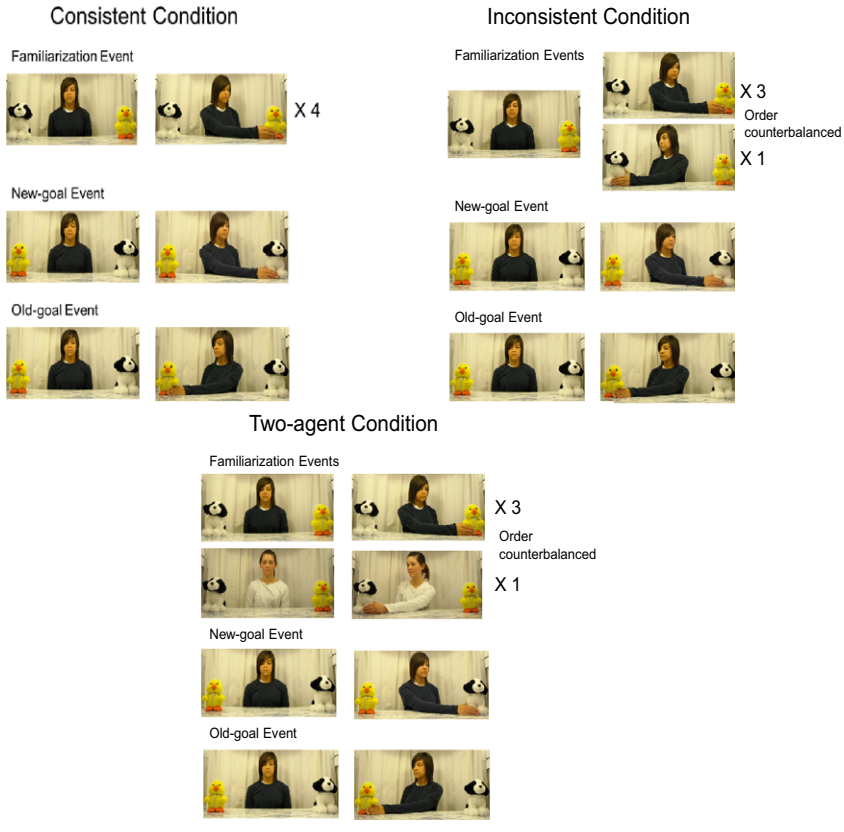

Figure 1 Photographs of the familiarization and test events shown in the three conditions of Experiment 1.

Apparatus

Two stuffed animals, a bird and a puppy, were used. The yellow bird with orange beak and feet and a purple bonnet was 20 cm high, 17 cm wide, and 13 cm deep. The black and white puppy was 22 cm high, 17 cm wide, and 21 cm deep.

The apparatus resembled a puppet stage. It was 117 cm high, 104 cm wide, and 82 cm deep. The front opening was 56 cm high by 102 wide. Between trials, a curtain was lowered in front of the opening. The side walls were painted white, and the floor was covered with blue granite patterned contact paper. The back of the apparatus was covered with a white cloth curtain. During the experiment, Agent1 wore a blue shirt and Agent2 wore a white shirt (for six infants in the inconsistent condition, Agent1 mistakenly wore the white shirt. As each infant still saw the agent with the same outfit throughout the experiment, the infants' data were retained). When an agent sat in front of the back curtain, she was approximately 50 cm from the bird and puppy. The apparatus is also equipped with two video cameras. One records the events being shown on the apparatus, whereas the other captures the infant. The input from the two cameras is combined to create a video file, which can be monitored online and checked offline to ensure proper testing.

Procedure

Each infant sat on a parent's lap, facing the apparatus. Parents were instructed to close their eyes during the test trials and not interact. After being seated in front of the apparatus, the infant was greeted by Agent1 in the consistent and inconsistent conditions and by Agent1 and Agent2 sequentially in the two-agent condition. Two naïve observers monitored the infant's looking behavior by viewing infants through peepholes in large cloth-covered frames on either side of the apparatus. Looking times recorded by the primary observer were used. For 7 of the 60 infants, only the primary observer was present. Interobserver agreement for the remaining 53 infants averaged 94.5% per trial per infant.

Infants first received four *familiarization* trials. Each trial consisted of a 2-sec pre-trial and a main-trial. In the consistent condition, after infants watched the scene with Agent1 and the two toys for two cumulative seconds, the pre-trial began in which Agent1 reached for and grasped the bird with her right hand (2 sec). She then paused, with her eyes fixated on the bird. In the main-trial, infants watched the paused scene until the trial ended when they (1) looked away for two consecutive seconds after having looked for at least five cumulative seconds, or (2) looked for 60 cumulative seconds. In the other two conditions, Agent1 (inconsistent condition) or Agent2 (two-agent condition) chose the puppy in one familiarization trial. Half of the infants received this inconsistent trial on the first and the other half on the fourth trial.

Infants in all three conditions then received two *test* trials in which the positions of the two toys were reversed and Agent1 reached for and grasped the puppy (new-goal event) or the bird (old-goal event) in the 2-sec pre-trial. Half of the infants saw the new-goal event first and the other half saw the old-goal event. The criteria to end the main-trial were identical to those of the familiarization trials.

Infants were attentive during the 2-sec pre-trials of familiarization (M = 2.0 sec) and test (M = 2.0 sec) trials in all three conditions. Infants' mean looking times during the main-trial of familiarization did not differ among the three conditions, $F(2, 57) = .14$, $p > .250$. In addition, in the inconsistent and the two-agent conditions, infants' mean looking times in the two familiarization blocks when the agent reached for and grasped one of the two toys did not differ across condition and familiarization order (inconsistent trial on the first or the fourth familiarization trial), $F(1, 36) = 1.76$, $p = .193$. To further compare attention allocation during familiarization in these two conditions, two naïve observers were able to code from the videos 32 of the 40 infants' looking behavior (attending to the side of the agent's reach or the other side), with an average interobserver agreement of 92.6%. Again, infants' mean looking times in the two familiarization blocks did not differ across condition and familiarization order (looking toward target side: $F(1, 28) = .03$, $p > .250$; looking toward non-target side: $F(1, 28) = .89$, $p > .250$). Therefore, although two different agents chose the puppy (Agent1 in the inconsistent condition but Agent2 in the two-agent condition) in one of the four trials, infants' looking behavior was similar across the two conditions during the familiarization phase.

Results and discussion

Two sets of preliminary analyses of *test* main-trial data were conducted. First, in the inconsistent and the two-agent conditions, familiarization order did not affect the

interaction between condition and event, $F(1, 36) = .00$, $p > .250$; data were therefore collapsed across this factor. Second, across the three conditions, there were no significant interactions between condition and event involving sex and/or test order, all Fs$(2, 48) < 2.19$, ps $> .122$; data were therefore collapsed across sex and test order in subsequent analyses.

Infants' looking times during the main-trial of test (see Figure 2) were analyzed using a 3 × 2 analysis of variance (ANOVA) with condition (consistent, inconsistent, or two-agent) as a between-subjects factor and event (new- or old-goal) as a within-subject factor. The analysis yielded a significant effect of event, $F(1, 57) = 6.29$, $p = .015$, and a significant condition × event interaction, $F(2, 57) = 3.61$, $p = .033$. No other effect was significant. Planned comparisons suggest that infants looked reliably longer at the new-goal than at the old-goal event in both the consistent (new-goal event: $M = 22.78$ sec, $SD = 12.78$; old-goal event: $M = 16.64$ sec, $SD = 7.89$, $F(1, 57) = 4.48$, $p = .039$, Cohen's $d = .561$) and the two-agent (new-goal event: $M = 21.72$ sec, $SD = 18.74$; old-goal event: $M = 13.23$ sec, $SD = 6.29$, $F(1, 57) = 8.54$, $p = .005$, $d = .494$) conditions, whereas those in the inconsistent condition looked about equally at the two events (new-goal event: $M = 15.82$ sec, $SD = 12.45$; old-goal event: $M = 17.84$ sec, $SD = 16.22$, $F(1, 57) = 0.48$, $p > .250$, $d = -.251$). Examination of individual infants' looking times confirmed these results. Fifteen of the 20 infants in the consistent condition (Wilcoxon signed-ranks $z = 2.17$, $p = .015$, one-tailed) and 13 of the 20 infants in the two-agent condition ($z = 1.65$, $p = .050$, one-tailed) looked longer at the new- than at the old-goal event, whereas only seven infants in the inconsistent condition did so, $z = -1.09$, $p = .138$, one-tailed.

Therefore, when the agent, Agent1, consistently chose the bird over the puppy across three or four consecutive familiarization trials, infants seemed to understand that her actions reflected her preference. During test, infants acted as if they expected the agent to again choose the bird and hence responded with prolonged looking when she chose the puppy instead. However, if the agent's choice was inconsistent, even

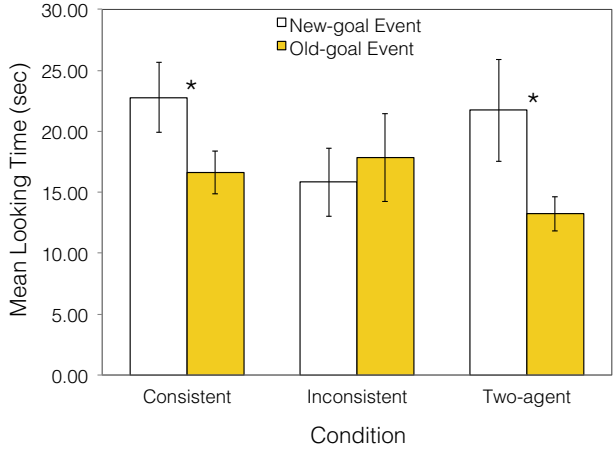

Figure 2 Mean looking times of the infants in Experiment 1 during the test trials. Error bars represent standard errors. An asterisk (*) indicates a statistically significant difference ($p < .05$) between infants' mean looking times at the two test events.

when she chose the bird three times consecutively but the puppy only once during familiarization, infants did not appear to interpret her actions as evidence for her preference. These results suggest that an agent's consistent choice between two toys signals to 8.5-month-old infants her preference.

In the present experiment, the two options were both stuffed animals. Infants readily attributed to the agent a preference for the bird over the puppy when the agent's choice was consistent. It has been shown that at about 12 months of age, infants seem to attribute to an agent a preference when the two options are from different categories, for example, a toy truck versus a doll, but *not* when they are of the same category, for example, two toy trucks or two dolls (Spaepen & Spelke, 2007). Comparisons between these results and Experiment 1 results highlight the category level infants might attend to in preference attributions: an agent may prefer a toy bird over a toy puppy but not a specific toy bird over other toy birds. Interestingly, Spaepen and Spelke (2007) also found that infants generalized the agent's preference, for example, for the truck over the doll, to new examples and expected the agent to prefer a new truck over a new doll during test. Therefore, infants in the present experiment might also succeed if a different puppy and a different bird were used during the test trials when the agent made consistent choices during the familiarization trials.

In Experiment 2, we sought converging evidence from infants' responses in an action task. The basic question and design of Experiment 2 mirrored that of Experiment 1, however, due to the different measures there were minor procedural differences.

EXPERIMENT 2

In Experiment 2, a new group of 8.5-month-old infants were randomly assigned to the consistent, inconsistent, or two-agent condition. Each infant received two blocks of trials consisting of four familiarization trials appropriate for their condition and one test trial. Two pairs of toys were used in the two blocks. During test, Agent1 asked the infant to choose between two toys by saying "Can you give it to me? Can you give me the toy?" Based on the data from Experiment 1, we expected infants to choose the agent's preferred toy more often in the consistent and the two-agent conditions than in the inconsistent condition.

Method

Participants

Participants were 60 healthy, full-term infants, 35 male and 25 female (7 months, 18 days to 10 months, 1 day, M = 8 months, 25 days). Twenty infants were randomly assigned to either the consistent (12 male, M = 8 months, 27 days), inconsistent (9 male, M = 8 months, 26 days), or two-agent condition (14 male, M = 8 months, 23 days). Fourteen infants were excluded for not reaching for either toy on either one or both test trials (10), experimenter error that consisted of the target object falling over (2), or parental interference (2).

Apparatus

Two pairs of toys—a duck stuffed animal and book, and a dog stuffed animal and toy boat—were used. The duck was yellow and orange, 15 cm high, 14 cm wide, and 9 cm deep. The dog was brown and white, 16 cm high, 13 cm wide, and 16 cm deep. The toy boat was yellow and blue, 9 cm high, 9 cm wide, and 15 cm deep. The book was green and white, 15 cm high, 11 cm wide, and 1.5 cm deep.

The apparatus resembled a puppet stage with two sides, a roof, and a curtain across the front. It was 91 cm high by 86 cm wide by 64 cm deep and was placed on a desk that was 72 cm high, 83 cm wide, and 57 cm deep. The table was covered with a white sheet. The apparatus was constructed from white foam core; the front and back were completely open. A white curtain could be raised and lowered to cover the front of the stage. An additional board was placed on the bottom of the apparatus to serve as the floor during familiarization. This board was replaced with a longer board during test to create a "tray" that could be pushed forward to position the toys closer to the infant. Agent1 wore a black shirt and Agent2 wore a yellow one.

Procedure

Each infant sat on a parent's lap facing the apparatus, and an experimenter, who controlled the curtain, stood behind and to the right of the infant, out of view of the infant. In the *consistent* condition, to begin, the curtain was raised and the infant was greeted by Agent1. Then, the curtain was lowered in preparation for the familiarization trials. Two cameras, one behind the infant and one behind the agent, recorded the session. After the test trial, the experimenter also recorded which object the infant touched first.

Infants received four familiarization trials. Each trial began with the curtain being raised to reveal two toys on the stage (either the duck/book or dog/boat pair, counterbalanced), 41 cm from each other and 15 cm from the front of the stage. The target object was counterbalanced in Experiment 2 to control for side biases inherent in reaching tasks as well as any intrinsic preferences that infants might have for one of the objects. The agent looked directly between the two toys for 2 sec. Then, the agent reached for and grasped one of the toys (the target) (2 sec), as in Experiment 1. She then remained still with her hand on the toy. Infants watched this paused scene for 7 sec. There was a 3-sec pause between familiarization trials.

Next, infants received one test trial. The experimenter instructed the parent to move their chair up to the stage and then close their eyes. The curtain was raised to reveal the two toys (either on their original sides or contralateral sides, counterbalanced across the two test trials—one per block). The agent pushed the board containing the toys toward the infant. She then placed her hand, palm facing up, between the toys, made eye contact with the infant, and asked, "Can you give it to me? Can you give me the toy?" The parent repeated the request directly after the agent. If the infant did not touch either toy for 15 sec, the agent repeated her request. The trial ended when the infant touched one toy or after 30 sec had elapsed. After the first block of trials, infants took a short break to play with one of the toys and then began the second block of trials. The second block was similar to the first, but used the other pair of toys.

Across the two blocks, whether or not the two toys were switched in the first test trial, the pair of toys used for each block, and which of the two toys in each pair was the target, were counterbalanced between infants.

As in Experiment 1, the procedure for the *inconsistent* and the *two-agent* conditions was similar to that of the consistent condition except that Agent1 (inconsistent condition) or Agent2 (two-agent condition) reached for and grasped the non-target toy on the first or the fourth familiarization trial (order counterbalanced). One infant in the inconsistent condition was accidentally tested with the objects pairs flipped (dog paired with book, duck paired with boat). As excluding/including this participant did not change the overall pattern of results, the data were therefore retained.

All infants included in the analyses touched at least one toy in both test trials. Infants received a score of one when their first touch was the target toy and zero for the non-target toy (range = 0–2), after having first looked at each object. Two coders, blind to the study conditions, coded from video which toy was first touched, with touch operationalized as an intentional reach toward and contact with an object that was preceded by the infant's visual fixation on the object. There was near perfect agreement between the coders, $k = .909$, $p < .001$. The few discrepancies were resolved through discussion by the coders.

Videos were available and of high enough quality to code infants attention to the familiarization event for 51 of the 60 infants. The videos were coded by an individual blind to the hypotheses of the study who determined how much time each infant spent looking at the familiarization event versus looking away from the event. A repeated-measures ANOVA revealed that, overall, infants spent slightly more time looking at the familiarization event (over the four familiarization trials) during the first test block ($M = 40.21$ sec, $SD = 5.69$) than the second test block ($M = 38.62$ sec, $SD = 5.37$), $F(1, 48) = 4.203$, $p = .046$. Importantly, infants' looking time did not differ by condition, $F(2, 48) = 1.214$, $p = .306$. In addition, as in Experiment 1, in the inconsistent and the two-agent conditions, infants' mean looking times in the two familiarization blocks (averaged across the two test blocks) when the agent reached for and grasped one of the two toys did not differ across condition and familiarization order (inconsistent trial on the first or the fourth familiarization trial), $F(1, 28) = .552$, $p = .464$. Again, to ensure that infants' attention allocation during familiarization did not differ between the two conditions, two observers were able to code from videos 26 of the 40 infants' looking toward the target side versus the non-target side, with an average agreement of 89.5%. All but one infant contributed data from two sets of familiarization trials. As in Experiment 1, condition and familiarization order did not affect infants' looking in the two familiarization blocks (target: $F(1, 47) = .749$, $p = .391$; non-target: $F(1, 47) = 1.259$, $p = .268$).

Results and discussion

Preliminary analyses of test data revealed that, for all three conditions, whether the toys were switched for test trials, and which toy was the target toy in each pair, made no difference in infants' performance. As in Experiment 1, there was no difference in performance with regard to the order of the familiarization trials (inconsistent trial on the first or the fourth familiarization trial) for either the inconsistent condition, Fisher's exact $p = .3$, or the two-agent condition, Fisher's exact $p = 1$. There was an unexpected significant effect of sex such that, across the three conditions, boys chose the target toy more frequently than girls, χ^2 $(2, N = 60) = 8.19$, $p = .017$. This difference was significant for the consistent condition, with boys choosing the target toy more often than girls, Fisher's exact $p = .05$. However, there was no difference in

performance between boys and girls in the inconsistent condition, Fisher's exact $p = .133$, nor in the two-agent condition, Fisher's exact $p = 1$. As there was no a priori reason to posit sex differences, and no sex differences were found in Experiment 1, the differences found here may be inconsequential and not hold up to repeated testing. Further, the sex differences found here were primarily driven by the consistent condition and thus do not detract from the critical comparisons between infants' performance in the inconsistent and two-agent conditions.

A chi-square revealed that infants performance differed across the three conditions (consistent, inconsistent, two-agent), χ^2 (4, $N = 60$) = 11.215, $p = .024$. Further analyses revealed a significant difference between the consistent and inconsistent conditions, χ^2 (2, $N = 40$) = 9.821, $p = .007$, and a significant difference between the inconsistent and two-agent conditions, χ^2 (2, $N = 40$) = 13.694, $p = .001$, but no difference between the consistent and two-agent conditions, χ^2 (2, $N = 40$) = 2.44, $p = .295$. Figure 3 illustrates the number of times infants chose the target toy across the two test trials for the three conditions: consistent ($M = 1.35$, $SD = .67$), inconsistent ($M = .85$, $SD = .75$), and two-agent ($M = 1.45$, $SD = .51$).

Infants' responses in each condition are described below. In the consistent condition, across the two trials, two infants never chose a target toy, nine infants chose a target toy on one trial, and nine infants chose the target toys on two trials. This distribution is marginally different than would be expected by chance (chance probability distribution set at 5 = zero target choices, 10 = 1 target choice, and 5 = 2 target choices), χ^2 (2, $N = 20$) = 5.100, $p = .078$ (Test 1: target chosen on 11 of 20 trials, binomial probability, $p = .412$; Test 2: target chosen on 16 of 20 trials, binomial probability, $p = .006$). Test 1 is significantly different from Test 2, χ^2 (2, $N = 40$) = 7.813, $p = .005$, indicating that infants were more likely to choose the target toy in the second trial than the first trial.

In the inconsistent condition, across the two trials, seven infants never chose a target toy, nine infants chose a target toy on one trial, and four infants chose the target

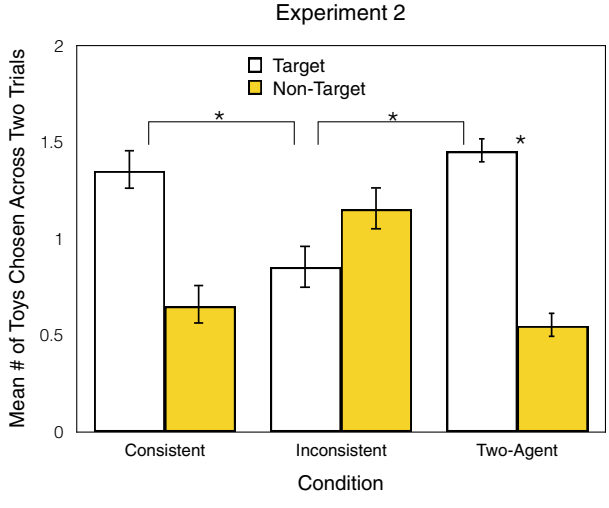

Figure 3 Mean number of toys (target and non-target) that infants chose during the two test trials in Experiment 2. An asterisk (*) indicates a statistically significant difference ($p < .05$) between infants' choices between and within conditions.

toys on two trials. This distribution is not significantly different than would be expected by chance, χ^2 (2, N = 20) = 1.1, p = .577 (Test 1: target chosen on 9 of 20 trials, binomial probability, p = .748; Test 2: target object chosen on 8 of 20 trials, binomial probability, p = .868).

Finally, in the two-agent condition, across the two trials, zero infants never chose a target toy, 11 infants chose a target toy on one trial, and nine infants chose the target toys on two trials. This distribution is significantly different from chance, χ^2 (2, N = 20) = 8.30, p = .016 (Test 1: target chosen on 18 of 20 trials, binomial probability, p < .001; Test 2: target chosen on 11 of 20 trials, binomial probability, p = .412).

Therefore, as in Experiment 1, when the agent consistently chose one toy over another across three or four familiarization trials, infants seemed to attribute a preference to her. During test, infants themselves were more likely to choose the agent's preferred toy when prompted. However, if the agent's choice was inconsistent, even though she chose one toy three times consecutively and the other only once during familiarization, infants did not appear to interpret her actions as evidence for her preference and hence chose equally between the two toys.

In the present task, infants were asked by the agent and then encouraged by the parent to choose a toy during test. It remains an open question whether infants at this age understood the agent's verbal request. It seems likely, however, given the situational change (i.e., the toys were close to the infant and out of the agent's reach) and the agent's request and gestures, that infants construed the test trial as choosing a toy for the agent, maybe even helping her get her preferred toy. Or, at minimum, infants' choices between the two toys were influenced by the agent's actions during the familiarization trials.

The positive results of the consistent and the two-agent conditions support previous data showing that 7-month-olds imitated an agent's choice between two toys after she demonstrated her choice only once (Hamlin et al., 2008). After seeing the agent reach for and grasp one of two toys, the infants also touched the same toy first. The present results with 8.5-month-olds, however, differed from data from a recent study in which 24- but not 14-month-old infants chose more often an agent's preferred toy for her after seeing her demonstrate her preference in three familiarization trials (Hobbs & Spelke, 2015). One possible reason for the discrepancy may lie in the procedural differences. In Hobbs and Spelke (2015), after the agent reached for and grasped her preferred toy between two choices in three familiarization trials, the toys were placed out of view and out of reach for the agent during test. She reached between the two toys, as in the present experiment, and asked the infant for help. Because she could not see the toys, her request might have seemed opaque to the 14- but not to the 24-month-old infants. In contrast, in the present experiment, the two toys remained visible to the agent throughout the experiment. It was thus clear even to 8.5-month-olds that the agent might want her preferred toy. In fact, in Hobbs and Spelke (2015), 14-month-old infants did choose the agent's preferred toy for her when both toys were visible to the agent during test. She also reached toward, but failed to grasp, the preferred toy before asking the infant for help, making her intention of getting her preferred toy transparent.

GENERAL DISCUSSION

The present study is the first to show that at 8.5 months of age, infants consider the consistency of an agent's choice between two objects in their evaluation of her

preferences. When an agent consistently chose one object over another, three or four times consecutively, infants acted as if they interpreted her actions as evidence for her preference. When an agent inconsistently chose between the two objects, at the ratio of 1:3, infants did not seem to interpret her actions indicative of a preference. Converging evidence was obtained from two behavioral measures, infants' responses in a looking-time paradigm and an action task, demonstrating the robustness of infants' understanding of agents' preferences.

The present results can also be explained by a low-level, link-based account as follows. In the consistent and two-agent conditions, infants saw that Agent1 was linked with the target toy as she chose it over the non-target toy during familiarization. Therefore, they responded with prolonged looking to the new-goal event when the agent touched the non-target toy during test and disrupted the link, and they themselves also chose the target more often than the non-target toy, influenced by the familiarization agent-toy combination. In the inconsistent condition, however, the agent was linked with both toys as she touched both during familiarization. Infants therefore looked about equally at the two test events and also touched both toys themselves.

We see the link-based account as compatible with our preference-based account in that a preference between two options can be defined in terms of the strength of an agent-toy link. In the consistent and two-agent conditions, the agent-toy link during familiarization was sufficiently strong to be deemed as the preference for the target over the non-target toy. In the inconsistent condition, however, the link became weaker because of the agent's action directed toward the non-target toy during familiarization and therefore did not warrant a preference attribution, hence the negative results. The strength of the agent-toy link can also be invoked to explain previous negative results of one-object conditions in which the agent chose the only object available to her during familiarization (e.g., Luo, 2011a,b; Luo & Baillargeon, 2007; Luo & Johnson, 2009). Infants failed to respond with heightened interest during the test trials when the agent chose the new object, because they did not construe the agent's actions during familiarization as showing her preference. Although the agent-toy link was formed during familiarization, it was not strong enough for lack of the contrast provided by the second choice. In turn, this link has been shown to be strengthened and to lead to positive results if the agent went through all the trouble to always approach its target, for example, by going around different barriers, using different routes, or consistently conducting means-end actions to approach the only object available (e.g., Bíró, Verschoor, & Coenen, 2011; Hernik & Southgate, 2012; Luo, 2011b).

These analyses give rise to the question of how to quantify the strength of the agent-toy link. For instance, is there a strength threshold for the link to be interpreted as a preference between two options or the agent's positive disposition toward the only toy available, both enabling infants to predict that the agent will pursue the same target toy again? We have begun to address this question by conducting conditions in which the agent chooses inconsistently between the two toys at the ratio of 1:4, that is, she chooses the bird on four consecutive familiarization trials and the puppy on one trial (order counterbalanced). The test trials are identical to those in Experiment 1. Would infants respond differently to the two test events, which differs from their responding in the present inconsistent condition? Such results, if obtained, would suggest that although the agent had touched and hence been linked with both toys during familiarization, her association with the target toy was sufficiently strong with the 4:1

consistent/inconsistent action ratio to count as a preference. In turn, this might relate to the probabilistic nature of preferences (Tversky, 1969). Infants might consider different consistent/inconsistent action ratios to make decisions about whether or not the agent has a preference between two options. Note that for both the 1:3 and 1:4 ratios, the frequencies of agent's choices are coupled with conditional probabilities, which infants at 8 months of age are able to use to segment words from fluent speech in an artificial language (Aslin, Saffran, & Newport, 1998). Further research is necessary to determine how these two factors contribute to the present results.

In the present two-agent conditions, infants were able to zero in on Agent1's preference even though they were presented with two agents' different preferences during the familiarization trials. Positive results might also be obtained if Agent2 instead of Agent1 was involved in the test trials, if one consistent trial was sufficient for the agent-toy link to be counted as a preference at this age. In addition, these results highlight the interesting issue concerning under what conditions preferences are agent-specific or agent-general. For example, to what extent do communicative cues inform infants as to whether or not a certain toy preference is shared by different agents (e.g., Buresh & Woodward, 2007; Gergely, Egyed, & Király, 2007; Henderson & Woodward, 2012; Kampis, Somogyi, Itakura, & Király, 2013; Moore, 1999). More generally, this may shed light on how infants and young children learn about different agents' preferences, for example, for a certain food, person, or group of people, and how they use these preferences to decide who is like them (e.g., Fawcett & Markson, 2010; Ma & Xu, 2011; Mahajan & Wynn, 2012).

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