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Infants use contextual contingency to guide their interpretation of others' goal-directed behavior

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ABSTRACT

To examine the extent to which infants encode the context of a goal-directed action, nine-month-old infants were tested in three separate experiments using a visual habituation paradigm similar to that used by Woodward (1998). Experiment 1, necessary to support methodology used in subsequent experiments, demonstrated that infants can track the goals of others in a visual habituation paradigm even when a goal object changes position. Experiment 2 examined the capacity of infants to make context-dependant judgments regarding an actor's two goal-directed actions (i.e., that object A would be grasped when paired with B, and B would be grasped when paired with C). Experiment 3 examined whether infants encode these contextually contingent goals in a linear order (e.g., A > B > C). Infants are able to use contextual information to correctly encode the actions of others, yet no evidence was found for encoding this information in a linear order.

Perceiving the goals underlying a stream of action is a social cognitive skill that appears to develop within the first year of life (Gergely, Nádasdy, Csibra, & Biró, 1995; Woodward, 1998, 2005). Recognizing that the actions of others are in the service of specific goals is crucial to early word learning

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(Baldwin & Moses, 2001; Baldwin et al., 1996; Buresh & Woodward, 2007) and the social learning of tool use (Gerson & Woodward, 2012), and is likely a foundation of mature theory of mind (Aschersleben, Hofer, & Jovanovic, 2008; Wellman, Lopez-Duran, LaBounty, & Hamilton, 2008; Yamaguchi, Kuhlmeier, Wynn, & vanMarle, 2009). Indeed, recognizing the goal motivating another's actions provides a powerful aid for making predictions regarding future actions in similar contexts (Cannon & Woodward, 2012).

Infants' attribution of goals to others has been shown to survive slight changes in context, such as the movement of a goal object from one location to another. For instance, in Woodward's (1998) seminal study, infants viewed a stage on which two objects rested. On each trial, a hand reached from the side of the stage to grasp the same object from the pair. After the infant habituated to this event, the positions of the two objects were switched. Six-month-old infants looked reliably longer at test trials in which the hand reached to the new object in the same spatial location as it had reached previously than at trials in which the old object was grasped in its new location, indicating that they had formed a goal-related, rather than spatially-related, expectation regarding the hand's movements (Woodward, 1998).

In Woodward's study, both objects were available to the experimenter's grasp such that, even when the locations were switched, it was possible to make predictions about the experimenter's likely actions. Contexts can also change in terms of the availability of goal objects. Indeed, our goal-directed actions are often guided by the availability of options. For example, we might buy vanilla ice cream only when strawberry is sold out, thus flexibly changing our goals in a context-contingent fashion depending on which options are available to us.

Changes in availability of options can influence how infants encode the target of a goal-directed movement. If no alternative is available (i.e., only one object is present), infants tend not to show differences in looking time to a novel or familiar selection at test when two objects are present (Biro, Verschoor, & Coenen, 2011; Luo, 2011; Luo & Baillargeon, 2005). This may be so because a reach to a single object is lacking the cues that prompt infants to see it as a goal- directed action at all (Biro et al., 2011; Hernik & Southgate, 2012). Alternatively, infants see the action as goal directed but do not encode the features of the solitary target object (Kuhlmeier & Robson, 2012) or do not have a basis for reasoning about the actor's preference between test objects (Luo & Baillargeon, 2005). In either case, the availability of options appears to have an impact on how infants encode goal-directed reaching.

The present study examined whether infants can recognize and encode the contextual contingency influencing a person's goal-directed actions. Woodward's (1998) methodology was adapted for this purpose through the presentation of two object pairs (A&B and B&C) to infants on alternating trials during a habituation phase. Infants saw an experimenter make selections from these pairings (A chosen over B, B chosen over C), with the experimenter's selection of object B dependent on the identity of the accompanying object. In order to succeed at tracking the experimenter's goal within each pair, the infant would have to encode both the goal and the context in which the goal existed.

Of secondary interest is whether infants come to represent this contextually contingent selections in a linear fashion, such that A > B > C, a logical interpretation of the pairwise information provided them. To do this, we examined whether infants show evidence of transitive inference after observing the contextually contingent actions. In other words, after observing that A is grasped when A and B are paired (A > B), and that B is grasped when B and C are paired (B > C), will infants infer that A > C? Some form of transitive inference is thought to develop between four and five years, becoming more adult-like around the age of eight years (Breslow, 1981; Bryant & Trabasso, 1971; Goodwin & Johnson-Laird, 2008; Markovits, Dumas, & Malfait, 1995; Pears & Bryant, 1990; Sodian & Wimmer, 1987; Wright, 2001).

Past experiments have relied not only on an understanding of transitivity, but also on the ability to understand the problems posed verbally by the experimenter (Breslow, 1981; Markovits et al., 1995). Yet, it is clear that language is not a prerequisite for transitive inference, as this ability is observed in a variety of non-human animal species including mammals (Davis, 1992; Gillan, 1981; McGonigle & Chalmers, 1977; Treichler & Van Tilburg, 1996), birds (Bond, Kamil, & Balda, 2003; Von Fersen, Wynne, Delius, & Staddon, 1991; Weib, Kehmeier, & Schoegl, 2010), and fish (Grosenick, Clement, & Fernald, 2007). Infants have also been shown to possess some understanding of ordinality, the unchanging position of items in ordered sets (Brannon, 2002). Recently, Mou, Province, and Luo (2014) found evidence for transitive inference in 16-month-olds, using a modification of Woodward's (1998) original design. In the present study, using the widely replicated sensitivity of infants to the goals of others allowed us to test 9-month-old infant's capacity to encode contextual contingencies and to test whether they encode these contingencies in a linear fashion in tasks with no verbal demands.

The present study consisted of three experiments. Experiment 1 utilized a modified version of Woodward's (1998) study to examine whether infants have the ability to follow an actor's goal object that frequently changes position, allowing for the subsequent experiments to incorporate this experimental design. Experiment 2 examined whether infants encode contextual information about goals through the manipulation of object pairings. Experiment 3 employed a similar methodology to Experiment 2 and was designed to determine whether infants encode contextual contingencies in a linear fashion through examination of their capacity for transitive inference.

1. Experiment 1

The procedure developed by Woodward (1998) has been widely used to examine infant goal attribution. In Experiment 1, a variation on this procedure was designed such that infants were habituated to an actor's selection of an object that changed location between trials. We examined infants' looking behavior under this procedure because Experiments 2 and 3 required a similar design to dissociate object identity from spatial location in the habituation process. Each of these later experiments required infants to habituate to multiple object pairings, and the sides of the stage on which the goal objects were placed were required to alternate. (If the actor selected multiple objects from the same side of the stage on each trial, infants could potentially learn that a particular side is the actor's goal, regardless of which object occupies that side.) To accommodate this need to switch the location of the goal object throughout habituation, Experiment 1 tested the ability of infants to track the actions of an actor on an object that changes location.

1.1. Method

1.1.1. Participants

Twenty-four infants (12 female) between the ages of eight months and twenty days and nine months and thirteen days (M = 8 months, 30 days) participated. Infants were recruited from a database composed of parents approached during their natal visits at a hospital catering to the general population of a predominantly white, middle-class, mid-sized city and its surrounding area. An additional five infants were excluded from analyses due to experimenter error ($n = 2$)., failure to reach habituation criteria ($n = 2$), or leaving the camera's view during the test ($n = 1$).

1.1.2. Procedure

Infants observed an actor seated behind a large stage that contained two novel objects. Each object was created from crafting clay (Staedtler Fimo). The objects were cylindrically shaped and of similar size (H = 11 cm, W = 6 cm), each composed from two different colors displayed in distinct patterns.

Infants were seated on the lap of their caregiver (106 cm from the stage) and familiarized to the movement of the curtain by an unseen experimenter who used a pulley to raise and lower it. After the curtain familiarization, the curtain was raised to reveal the actor behind two objects (A and B, 50 cm apart) on the stage. The actor made eye contact with the infant and said, "Hi Baby!" before lowering her gaze, looking at one of the objects, shifting her gaze to the other object, and extending her arm to grasp the second object. The actor lifted this target object approximately 10 cm from the stage, shook the object, and exclaimed, "I like this one."

The actor held the target object until the infant either looked away from the scene for two continuous seconds or until after 120 s elapsed, at which point a tone alerted the actor and experimenter and the curtain was lowered. While the curtain was down, the actor switched the positions of the two items according to a predetermined order.[1] When the curtain was lifted, the actor repeated the

[1] This procedure differs from that used by Woodward (1998) in that, in this experiment, the objects are moved between some of the trials, while in Woodward's procedure each object's position remained the same across habituation trails. Here, in

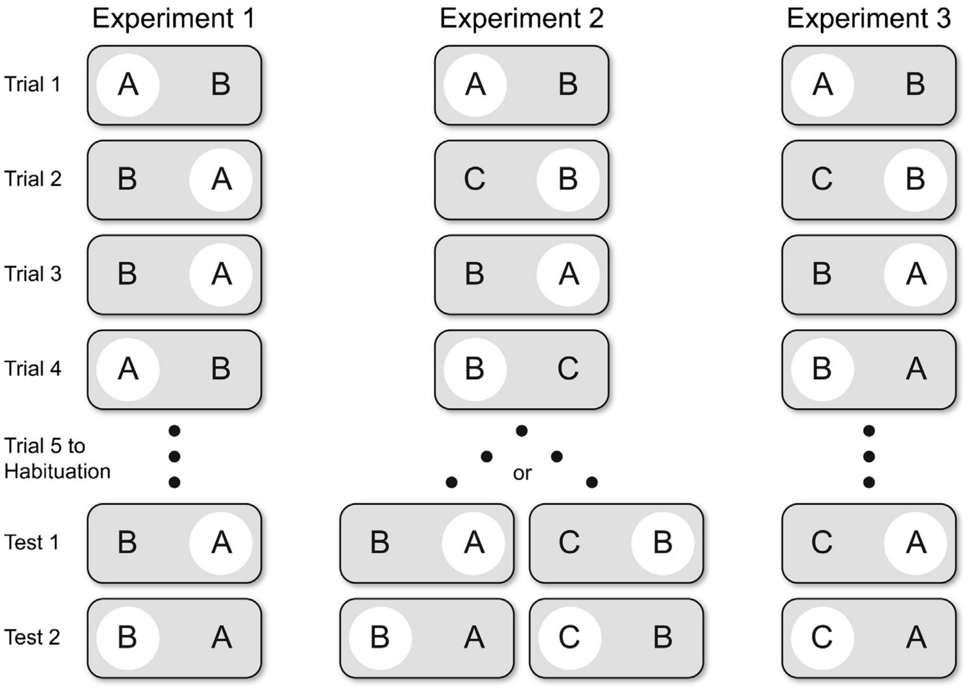

Fig. 1. The experimental design for Experiments 1–3. The letters A, B, and C represent the objects used in each experiment, with the un-shaded letter representing the actor's selection on each trial. Following habituation, infants were shown two test events, one consistent and one inconsistent with the actions demonstrated during the habituation trials. The objects used in testing and the ordering of test events were counterbalanced.

process as before, using the same hand to reach to the same object in its new position (Fig. 1). This cycle was repeated until the infant habituated, using the criterion utilized by Woodward (1998), by which looking times for the first three trials that sum to more than 12 s were used as a point of reference. Computer software automatically categorized infants as having habituated if three subsequent, consecutive trials had a total looking time of less than half of the sum of the original trio. Infants who did not meet this criterion within 14 trials were excluded from analyses.

When the curtain closed on the final habituation trial, the actor did not rearrange the objects. Instead, the curtain was raised, and the actor made eye contact with the infant before saying, "Hi Baby! Where is it?" The actor then lowered her gaze to the center of the stage without looking at either object (Buresh & Woodward, 2007). This pose was maintained by the actor until the infant had looked away for at least two continuous seconds or until after 120 s had elapsed, and the curtain was then lowered. Following this presentation phase were two counterbalanced test trials in which the actor chose either the object that had not previously been targeted for reaching (inconsistent), or selected the previous target object (consistent).

Video was recorded both of the actor and of the face of the infant watching the events. Infant looking time was measured by an observer watching the infant's gaze through a curtain; the observer began timing each trial using custom computer software as soon as the object was lifted. Following testing, a secondary coder, blind to the purpose of the study, recorded looking time from the video recording of the infant's gaze. Coders surpassed 90% agreement for all infants tested.

all habituation trials the experimenter reached for the same object, but in some trials this object was on the right side of the stage and in others the left. The placement of the target object for each habituation trial was (from the actor's perspective): (1) Right, (2) Left, (3) Left, (4) Right, (5) Left, (6) Right, (7) Right, (8) Left, (9) Right, (10) Left, (11) Left, (12) Right, (13) Right, (14) Left.

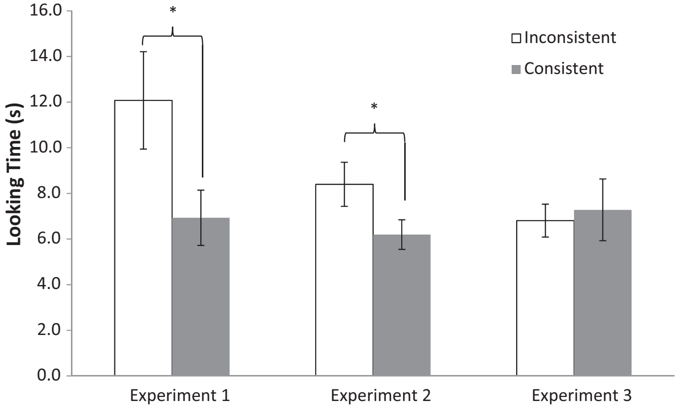

Fig. 2. Mean looking times to consistent and inconsistent test events in each experiment. Error bars depict standard error, and asterisks denote statistical significance at $p < .05$.

1.2. Results

Infants reached the habituation criteria in Experiment 1 in a mean of 8.6 trials (SE = 0.5 trials). Preliminary Analysis of Variance (ANOVA) revealed no main effects of sex, $F(1, 20) = 1.358$, $p = .258$, or trial order, $F(1, 20) = 0.810$, $p = .379$); thus for subsequent analyses, data were collapsed across these variables. A two-tailed matched-samples t-test revealed a significant difference, $t(23) = -2.305$, $p = .031$, $d = 0.58$, in mean looking time for consistent ($M = 6.9$ s, SE = 1.2) and inconsistent reaches ($M = 12.1$ s, SE = 2.1) (Fig. 2). A Wilcoxon Signed-Rank Test confirmed longer looking times on trials in which the actor selected the object that had not been targeted during habituation ($Z = -2.486$, $p = .013$).

1.3. Discussion

Infants looked longer toward inconsistent reaches than to consistent reaches by the actor at test, suggesting that infants viewed the events during habituation as being goal directed toward one of the two objects. Thus, this experiment serves as a general replication of the findings reported by Woodward (1998) and others (Scott & Baillargeon, 2013), thus supporting use of this procedure in the subsequent experiments designed to determine the ability of infants to track contextual contingencies in the goals of others.

2. Experiment 2

Experiment 2 built on the results of Experiment 1 by testing whether infants use contextual information to guide their expectations as to an actor's goal directed actions. Here, infants were habituated to an actor making selections within two overlapping object pairs (AB and BC). At test, they were shown one of the pairings previously presented during habituation, from which the actor made selections that were either consistent or inconsistent with those made during habituation. The objective is to determine whether infants are able to encode a person's goals within two alternately presented object pairings and whether infants encode the identity of the non-selected object as an indication of the actor's goal.

2.1. Method

2.1.1. Participants

Forty-three infants (21 female) between the ages of eight months and three days and nine months and nineteen days ($M = 9$ months, 0 days) participated. An additional ten infants were tested but later excluded from analysis due to experimenter error ($n = 1$), parental interference ($n = 1$), standing ($n = 3$), not reaching habituation criteria ($n = 4$), or outlying looking time of greater than 6 times the group average ($n = 1$).

2.1.2. Procedure

Infants watched a presentation similar to that seen in Experiment 1 (Fig. 1). In each of the habituation trials, infants watched an actor select one object from a pair of objects. Different from Experiment 1, however, the two object pairings were constructed from three stimuli, A, B, and C. The objects were presented in one of two pairings (AB or BC) alternately each trial. During habituation trials, the actor followed the same script as in Experiment 1 before selecting one object from the pairing (i.e., selecting A if AB, selecting B if BC) until the infant habituated. The position of the object that was selected was either the same as in the previous trial or moved to the opposite side of the stage, in accordance with a predetermined order.

At the presentation and test phase, the infants were presented with pairings they had already seen demonstrated, with 23 infants (12 female) being shown the AB pairing at test and 20 infants (9 female) tested on the BC pairing. The actor made a reach consistent with their previously demonstrated goal (A if AB; B if BC) and a reach that was inconsistent (B if AB; C if BC).

2.2. Results and discussion

Infants reached the habituation criterion after a mean of 8.0 trials (SE = 0.4 trials). No main effects of sex, $F(1,35) = 0.158$, $p = .694$, or trial order, $F(1,35) = 1.308$, $p = .260$, were observed, and data were collapsed across these variables for subsequent analyses. A main effect of test pairing (AB or BC) was observed, $F(1,35) = 7.855$, $p = .008$, indicating that infants looked longer overall on both consistent and inconsistent test trials if they were in the BC group. However, there was no interaction between test pairing and type of trial (consistent or inconsistent), $F(1,35) = 1.351$, $p = .253$, meaning that while infants in the BC group looked longer in general on each test event, there was no difference in looking time patterns of the groups resulting from the object pairing they were tested on. As a result, data from the two groups were collapsed for further analysis.

A repeated measures ANOVA using trial type (consistent or inconsistent reach) as a within-subjects variable revealed a main effect of trial type, $F(1,35) = 5.499$, $p = .025$, $d = 0.40$, with infants looking longer at inconsistent ($M = 8.4$ s, SE = 1.0) than consistent test events ($M = 6.2$ s, SE = 0.7) (Fig. 2). A Wilcoxon signed-rank test for this difference approached significance ($Z = -1.660$, $p = .097$).

We had considered the possibility that the AB pairing would be more difficult for infants to understand than the BC pairing. Although object B is never chosen while object A is present, both objects are selected with equal frequency during habituation. This potential for ambiguity prompted us to examine the AB and BC groups individually, despite the absence of an interaction in the ANOVA. Infants in each group demonstrated a pattern of looking longer at inconsistent than consistent events (AB group: $M = 6.2$ s, SE = 0.9 s versus $M = 5.1$ s, SE = 0.8; BC group: $M = 10.9$ s, SE = 1.7 s versus $M = 7.5$ s, SE = 1.0 s), although a t-test reached marginal statistical significance only for the BC group (AB: $t(22) = 1.058$, $p = .302$, $d = 0.29$; BC group: $t(19) = 2.039$, $p = .056$, $d = 0.53$). It remains conceivable that ambiguity within the AB pairing, due to the subsequent choice of B in BC, makes the AB pair more difficult for infants to interpret; however, in the absence of a statistical difference between the looking time patterns of each test group in the initial ANOVA, this interpretation cannot be supported with the present data.

Because infants were presented with pairs during habituation in an alternating fashion (AB, BC, AB, BC. . .), some infants ($n = 16$) saw the AB pair one more time than the BC pair due to reaching the habituation criterion on an odd-numbered trial. A Fisher's Exact Test indicated that this difference in frequency of exposure had no effect on whether infants looked longer on consistent or inconsistent reaches at test ($p = 1.000$).

Results of Experiment 2 suggest that 9-month-old infants are able to use contextual information when encoding the goals of others' actions. It has been unclear from previous work the extent to which infants encode the features of the alternatives to the goal object in tasks such as this. Experiment 2 suggests that infants attend to the available alternatives to others' goals, at least in cases in which the alternative provides information important to correctly anticipating those goals. A remaining question regards the nature of infants' encoding of this information. If infants encode the contextual goal information (A over B, B over C) in a linear fashion (A > B > C), they could make transitive inferences about unfamiliar pairings. Experiment 3 built upon the results of Experiment 2 by exposing infants to an actor's choice behavior within two pairings of objects (AB and BC) during habituation and then testing the capacity for making transitive inference regarding the actor's selections with a previously unobserved pairing (AC).

3. Experiment 3

3.1. Method

3.1.1. Participants

Twenty-four infants (12 female) between the ages of eight months and one day and nine months and twenty-eight days (M = 8 months, 29 days) were recruited in the same manner as in Experiment 1. An additional 11 infants were tested but removed from analysis due to experimenter error ($n = 1$), not reaching habituation criteria ($n = 6$), fussiness ($n = 2$), standing out of camera view ($n = 1$), and parental interference ($n = 1$).

3.1.2. Procedure

The habituation procedure was unchanged from that of Experiment 2 (Fig. 1). At the presentation and test phase, however, the infants were presented with the novel pairing of objects A and C. If infants were to look longer when the inconsistent stimulus (C) was selected in test, it would be taken as evidence that infants are capable of making transitive inferences and that they have represented the choices in a linear, context dependent fashion.

3.2. Results and discussion

Infants reached habituation criteria in Experiment 3 following a mean of 7.9 trials (SE = 0.4 trials). A preliminary ANOVA revealed no main effects of either sex, $F(1, 20) = 2.611$, $p = .122$) or trial order, $F(1, 20) = 0.023$, $p = .880$, and thus for subsequent analyses, data were collapsed across these variables. A two-tailed matched-samples t-test revealed no significant differences, $t(23) = 0.328$, $p = .746$, $d = -0.09$, between the mean looking time to inconsistent (M = 6.8 s, SE = 0.7) and consistent (M = 7.3 s, SE = 1.4) reaches (Fig. 2). A Wilcoxon Signed-Rank Test showed no significant differences ($Z = -0.46$, $p = .964$) in infant looking time to either of the actor's reaches in test. As in Experiment 2, a Fisher's Exact Test showed no differences ($p = 0.400$) resulting from infants habituating on an odd-numbered trial ($n = 8$) and thereby receiving different levels of exposure to the pairings during habituation.

One reason infants may have failed to demonstrate a capacity for transitive inference may have been our choice to intersperse the object pairings (AB and BC) with each other rather than to train them on each pair individually. We chose this design for several reasons. First, a concern was that habituating infants to a block of AB trials followed by a block of BC trials would lead infants to be exposed to each pairing in variable amounts, as a result of variation in habituation rates. Additionally, such a design would include disparities in the proximity of exposure to each pairing and test. Finally, it was thought that habituating infants separately to each pair might extend testing periods and increase infant fussiness and drop out. A counterbalanced familiarization to each pairing might have addressed some of these issues, but not completely.

A recent study in which 15-month-old infants were familiarized to blocks of stimulus pairings (BC trials followed by AB trials) also showed no evidence for application of transitive inference of dominance relationships (Mascaro & Csibra, 2012). Yet, a study of 16-month-olds did find evidence for transitive inference using familiarization to blocks of stimuli, but only when the blocks were presented in a particular order (AB trials followed by BC trials, not BC followed by AB), suggesting that the ordering of presentation has an influence on infants' ability to form a linear order from overlapping pairings (Mou et al., 2014). Although infants in the present study were all shown AB followed by BC pairings, the alternating presentation style has not been used in other studies of transitive inference in infants.

As the infants in the present study were quite young compared to the infants in the study by Mou et al. (2014), it is difficult to say if it is the difference in age or presentation style that is responsible for the divergent results. However, the results of Experiment 2 show that the method used in this study is not so confusing to infants as to prevent them from encoding individual pairings, suggesting that the difference in the age of the infants tested may be responsible.

4. General discussion

Across three experiments, the present study examined the ability of 9-month-old infants to encode the relationship between an actor and goal objects across a change in context, specifically, a change in the availability of alternative objects. Experiment 1 tested the effectiveness of a modification of Woodward's (1998) procedure, supporting its use in the subsequent experiments. On its own, however, Experiment 1 also suggested that infants are capable of encoding goal-directed actions toward an object that changes position between instances of these actions. This effect was also recently demonstrated by Scott and Baillargeon (2013). What remains unclear is whether or not the shifting of a goal-object's location throughout the habituation process affects the ease with which infants encode this information. For example, it may be easier for infants to encode goals under these circumstances, as the spatial location of the goal object is no longer in contention as a possible goal in itself, or because the movement of the objects serves as an additional cue to encode their specific properties. Conversely, it may be more difficult for infants to encode under these situations, as the visual makeup of the scene is so frequently changing.

Experiments 2 and 3 examined infants' incorporation of contextual contingency when interpreting goal directed behavior. In Experiment 2, after observing an actor grasp object A when it was paired with B, and grasp B when it was paired with C, infants showed greater looking time on test trials in which the actor grasped the object previously unchosen within a particular pairing. This suggests that infants are capable of using contextual information to inform their expectations of the actions of others. Further, these findings suggest that infants can encode at least two object-directed goals simultaneously.

When the identity of the alternative to the goal object is necessary to predict future action, infants appear to consider a person's goals in the context of the options available to them. Luo and Baillargeon (2005) alluded to this possibility when infants who had been exposed to an agent approaching a lone object during habituation showed no difference in looking time when a novel object was selected over the previously approached object. Here, we have demonstrated this phenomenon through the use of two overlapping pairings; since one of the objects was present in both pairings, whether or not it was to be the goal object was entirely dependent upon the identity of the object it was presented with. This result also suggests that infants do not employ a simple 'goal-not goal' mental notation for the objects, as they would not succeed in the overlapping pairs if this were the case.

The results from Experiment 2 indicate that infants are able to encode goals in a context dependant fashion, although it is not clear that they always do so. It is possible that infants typically only encode the actor's goal object in paradigms such as those used by Woodward (1998), but that the presence of an additional pairing cues the infants to encode the features of each individual item. That is, infants may only encode all of the presented items in cases where it becomes necessary to do so in order to discriminate potential outcomes. Determining whether this is the case requires future experimentation.

Previous research has made it clear that infants encode the targets of agents' goal directed actions, but there is currently debate regarding how infants construe this information. Some have suggested that infants encode the *preferences* of an actor; that is, infants may represent the actor's positive disposition toward one of the objects, relative to the other object (Luo, 2011; Luo & Baillargeon, 2005, 2007; Luo & Johnson, 2009). In relation to the present study, infants may be representing the preferences of the actor, such that A is preferable to B and B to C. It is also possible, however, that infants are sensitive to context without the attribution of mental states to the actor (Hernik & Southgate, 2012; Woodward, 2005, 2009). Infants may encode the actor's relation to a goal object in a way that is contingent on its being presented with a particular alternative without inferring the mental state of the actor. In this formulation, infants may encode the actor's behavioral tendencies as 'A chosen from AB, B chosen from BC'. The present study does not distinguish between these two accounts.

Experiment 3 tested how infants represent the actor's two goals given the observation of actions during the habituation phase. One possibility is to create a linear ordering that represents the actor's actions in relation to all three objects, such that A > B > C, since A was always chosen when it was present but C was never chosen. (Note, again, that this ordering does not imply an ordering of actor's preference, as order can be based on a non-mentalistic value such as frequency of selection when available.) However, no evidence was found for transitive inference regarding the actor's likely goal within the unfamiliar AC pairing, which would have implied a representation of the three goals on a common continuum.

The results of Experiments 2 and 3 align closely with those of a recent study that examined the way 18-month-old infants understood the property of dominance and whether infants spontaneously created linear orders from dominance pairings (Mascaro & Csibra, 2012). In that study, while infants showed expectations regarding the previously observed pairings (AB & BC), infants were not able to make transitive inferences about the novel AC pair, much as in the present study. Mascaro and Csibra discuss this finding as meaning that infants view the property of dominance as being specific to a particular paired relationship, not as a property that extends across other relationships. In this interpretation, infants do not view A's dominance over B and B's dominance over C as being predictive of the quality of the relation between A and C and thus do not make transitive inferences about that relationship. Following Mascaro and Csibra's reasoning, it is possible that the null result in Experiment 3 occurred because infants viewed the actor's choices as being specific to a particular pairing and thus did not create a linear order from overlapping choice pairings presented during the habitation phase.

In sum, the present study suggests that infant goal attribution survives frequent changes of goal location (Experiment 1), takes into account the context of available goal objects, and encodes multiple goals when contextual cues are present (Experiment 2). The manner in which the relation between the agents and the objects is represented remains unclear; the present study showed no evidence that infants represent the goal-directed behaviors in a linear manner (Experiment 3). These results suggest that infants use goal attribution in a flexible and context-dependent fashion and suggest new avenues for study of this phenomenon.

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