Can Infants Use Transitive Inference in Attribution of Goals to Others?

By

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A thesis submitted to the Graduate Program in Neuroscience
In conformity with the requirements for the
Master of Science

Queens University
Kingston, Ontario, Canada
July, 2012

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Abstract

Transitive inference refers to the ability to use knowledge of pre-existing relationships to infer relationships between entities that have not been directly compared. This form of logical inference is an important skill for many social species, and has been thought to arise in an immature form in humans between the ages of four and six years. The experimental methods used to test this ability in humans often require some verbal skill, gross or fine motor coordination, a memory capable of containing numerous relationships, and often a great deal of time and repetition in testing. These methods of testing may have been too demanding on other physical and cognitive abilities to be successfully completed by children under four years of age, regardless of their ability to make transitive inferences.

The present study used methods sensitive to infant cognition to test the current theory that the ability to make transitive inferences does not develop until the age of four. Nine-month-old infants were tested in three separate experiments using a visual habituation paradigm similar to that used by Woodward (1998) and through investigation of infants’ own imitative actions. Experiment 1 verified that infants can track the goals of others in a habituation paradigm when the goal object changes position throughout habituation trials, both through looking time measures and imitative action. Experiment 2 used an extension of this paradigm to examine the ability to make transitive inferences across a three item chain, serially ordered by the actor’s object preference, and no evidence of transitive inference was observed. Experiment 3 tested infants’ ability to habituate to and recall multiple goals using context as a cue to actor choice. Infants were able to consistently track only one of the pairings, suggesting that avoidance, in addition to selection, may play a role in infant performance in the visual habituation paradigm.
Acknowledgements

Thank you to Professor Valerie Kuhlmeier for her enthusiasm and encouragement, her dedication to science and to her students, and for always being supportive while challenging me to do better. I am truly lucky to have the opportunity to learn from you.

My thanks to Professor Mark Sabbagh, Professor Randy Flanagan, Professor Li-Jun Ji, and Professor James Reynolds for providing valuable time, advice, and criticism as members of my committee.

Thank you to Vivian Lee, a great friend and collaborator, without whom this work would not be complete.

Thank you to all the members of the Kuhlmeier lab, especially my office mate Amy O’Neill for helping me work and helping me to not work, and Lindsay Murphy, for her work on this project.

Thank you to Professor Mel Rutherford, Margarita Vera-Cruz, Angela Li, Marcus Morrisey and all of the members of the Rutherford lab who helped in this project.

Thank you to Professor Robbin Gibb and Professor Bryan Kolb for getting me started in research, and for all the help and encouragement along the way.

Thank you to my parents, Kim and Garnet Robson, for their love and encouragement, for always believing in me, and for being such great examples to try and live up to.

And lastly, my incomparable fiancée, Jessica Andrusiak. Thank you for your patience and humor, for your encouragement and distraction, and for keeping me grounded in the world outside of school. Thank you for moving across Canada so that I could pursue my dream. Without your love and support I would not be here.
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Chapter 1: Introduction

1.1 Transitive inference: definition and utility.

Transitive inference is a form of logical inference that involves the deduction of the relationship between two entities through their relation to other entities rather than by direct comparison. For example, if we know that bag A is heavier than bag B, and that bag B is heavier than bag C, we can logically infer that bag A is heavier than bag C without directly comparing their weights. Stevens (1951) claimed that transitivity was an emergent property of any arrangement having a serial order, along with the properties of being irreflexive, asymmetric and connective.

The ability to make transitive inferences is an important aspect of social, numerical and cognitive reasoning. It is used by human and some non-human animals as a means for determining social hierarchy in large or unfamiliar social groups (Grosenick, Clement, & Fernald, 2007) and is considered to play an essential role in mathematical understanding (Pears & Bryant, 1990). Transitive inference has been speculated to be crucial to reasoning across a number of domains, including measurement, class inclusion and comparative reasoning (Wright, 2001).

1.2 Transitivity and preferences.

Particularly relevant to the present study, another area in human cognition where transitivity is important is in the realm of decision-making. Whether people’s choices have the property of transitivity has been hotly debated by economists and psychologists for over 40 years. The controversy centers on formulating a means by which decision making outcomes can be variable, as experience suggests they must be, while at the same time satisfying the assumptions of rationality by being transitive. One way of formulating choice that satisfies these
requirements is ‘weak stochastic transitivity’, by which if an option is chosen over another (A>B) at least 50% of the time, and the second option is chosen over a third (B>C) at least 50% of the time, then the first option will be chosen over the third (A>C) at least 50% of the time (Block & Marschak, 1960; Luce & Suppes, 1965). In 1969, however, Tversky published a study in which participants made selections from a series of gambles in which increases in reward were offset by decreased probability of reward. The results demonstrated that under certain circumstances, reliable and predictable instances of intransitivity of preferences can be observed. The applicability of transitivity to the issue of choice and preference has been debated heavily since.

The proposal that choices are transitive was defended in a recent review of the literature on preference and transitivity (Regenwetter, Davis-Stober, & Dana, 2011). In this review, it is argued that people make variable choices, neither randomly or the result of error, but because preferences can vary with one’s mental states. One can imagine a person with a preference order that changes according to mental state (1-A>B>C, 2-B>C>A, 3-B>A>C). Each of these preference orderings can be fully transitive within each mental state, but when aggregated across trials where the mental states of the participant vary, it would look as though transitivity (A>C) only holds in 66% of trials. With this in mind, they instead propose a model of choice that posits weak stochastic transitivity within specific mental states.

In addition to these criticisms of the view that choice is intransitive, I add that all of the research on this subject is from a first-person perspective (e.g., are my choices consistent and transitive?) rather than from a third-person view (e.g., do I expect another’s choices to be consistent and transitive?). One area in which the expectation for consistency in others choices has been thoroughly examined is in the area of infant cognition, through use of visual...
habituation. It has been widely demonstrated that infants do expect others to act in line with their previously demonstrated goals, and some have argued, preferences (e.g., Woodward, 1998; Luo & Baillargeon, 2005). In light of these arguments, I make the contention that a consistently demonstrated preference does have the property of transitivity and that transitive inference can be used to predict the choices of others.

To revisit the earlier definition (Stevens, 1951), the relationship between the preferentially ordered objects must be irreflexive, asymmetrical and connected to also have the property of transitivity. An ordering is irreflexive if an item within that ordering cannot have the same relationship with itself as it does with other items in the set. Preferences have this property if they are consistently applied. If I always choose chocolate over vanilla ice cream and vanilla over strawberry, this ordering is irreflexive. If I choose flavours indiscriminately, this relationship becomes reflexive, as the arrangement of the preference order can be rearranged without becoming untrue.

Asymmetry is another property of a preferential ordering, and in this case refers to a relationship that cannot be applied in two directions. Preference is asymmetric in that I cannot simultaneously prefer chocolate to vanilla and vanilla to chocolate. Connectedness refers to the fact that the relationship implied between the ordered pairs is the same. An example of an unconnected relationship would be the following: Chocolate ice cream is darker than vanilla and vanilla has more calories than strawberry. There is nothing implied in those relationships that suggests an ordering, as one cannot validly infer from the example if chocolate is darker than strawberry or if chocolate contains more calories than strawberry without the inclusion of additional premises. Preferences between objects, however, can be ordered sequentially if they are consistently demonstrated.
The transitivity of preference flows from the other previously described properties of an ordered set. If I have been observed to always choose chocolate over vanilla, and to always choose vanilla over strawberry, it is a valid inference to believe that I would choose chocolate over strawberry if given the choice. An important distinction to be made here is that it would not be valid to say that I will choose chocolate, as being an agent I am not strictly subject to the rules of formal logic and could choose otherwise for myriad reasons. For example, it could be the case that I select ice cream flavours based by some other criteria than taste alone, and that this subtle principle could influence my future choices. It is, however, a valid inference to expect me to choose chocolate given your prior experiences.

1.3 Testing for transitive inference in human and non-human species.

It has been thought for decades that some form of transitive inference develops, without the need for any explicit instruction, in children somewhere between the ages of four and five years, becoming more adult-like around the age of eight years (Bryant & Trabasso, 1971; Breslow, 1981; Goodwin & Johnson-Laird, 2008; Pears & Bryant, 1990; Markovits, Dumas, & Malfait, 1995; Sodian & Wimmer, 1987, Wright 2001). Four years has been consistently seen as the youngest age at which the property of transitivity becomes understandable. A potential reason for the lack of demonstrable understanding in younger children could be the inherently verbal nature of much of the testing. Success in previous experiments relied not only on an understanding of transitive inference but also the verbal ability to understand the problems posed by the experimenter (Breslow, 1981; Markovits, Dumas, & Malfait, 1995). Another potentially interfering task demand is that the participant must be able to remember the relationships between the initial stimulus pairings at the time of testing (Bryant & Trabasso, 1971; Breslow, 1981; Pears & Bryant, 1990).
One way to test for transitive inference in children under the age of four years would be to utilize the experimental paradigms used to examine this form of reasoning in non-human animals. It has been suggested that transitive inference is utilized by a number of non-human animals, including many species of mammals (McGonigle & Chalmers, 1977; Treichler & Van Tilburg, 1996; Gillan, 1981; Davis 1992), birds (Von Fersen, et al, 1991; Bond, Kamil, & Balda, 2003; Weib, Kehmeier, & Schoegl, 2010), and fish (Grosenick, Clement, & Fernald, 2007) as a means for determining hierarchy within social groups. The laboratory methods by which animals have demonstrated transitive inference, however, require either extensive training, the ability of the subjects to form long term associations, some measure of physical coordination, or all three. The difficulty in creating an effective test of transitive inference in infants is that it must have a brief training period that can immediately be followed by testing, require limited ability of the subject to produce or understand language, and have little to no need for locomotion or fine motor coordination from the participants.

One method of testing infant cognition that meets the above criteria is the visual habituation paradigm. Visual habituation experiments rely on infant looking time as a measure of the infant’s understanding of events that are presented to them. Following repeated exposure, infants develop some type of understanding of the events they have seen, and as they do the amount of time infants spend looking at the event decreases. This phenomenon is referred to as ‘habituation’. In this style of experimentation, infants are habituated to an event that could be described along one of two possible dimensions. After they habituate to this event, the infants are shown a new event that is consistent with rules of one of those dimensions exclusively. If infants have encoded along one of the dimensions that is commensurate with the event displayed in test, their looking time remains similar to its level during before testing. If infants have
encoded along a different dimension than that presented, they are ‘surprised’ by what occurs in the test event and spend more time looking than they did at the point of habituation. This result is typically interpreted as recognition on the part of the infant that the test event was inconsistent with the previous demonstrations. The visual habituation paradigm has been widely employed in the study of infant reasoning and perception across all types of domains, including physical and social, the latter of which is specifically relevant to the present study, as the attribution of goals and preferences was examined.

1.4 Goal attribution, preferences, and learning from observation.

In a seminal paper, Woodward (1998) used a visual habituation paradigm to demonstrate that infants as young as six months of age attribute specific goals to an actor reaching for objects. In this experiment, infants viewed a stage upon which two objects rested. Each trial, a hand would reach from the side of the stage to grasp the same object from a pair. After the infants had habituated to this event, the positions of the two objects were switched. At this point, if the infants had habituated to the object as the goal of the actor’s reach, they would expect the hand to approach the same object in the new location. If the infants had habituated to the direction of the hand’s motion, regardless of the objects, they would expect the hand to make the same movement and approach the new object in the old position. Six-month-old infants looked reliably longer at the trials in which the hand reached to the new object in the same spatial location as it had reached previously, indicating that they had formed a goal-related rather than spatially-related expectation for the hand’s movements.

In another condition, infants observed a rod that approximated the dimensions and shape of the actor’s hand extend from the side of the stage and consistently approach one object from a pair across trials. After habituation, the objects positions were switched and the infants were
shown the same test events as in the previously described condition. This time, however, infants showed no significant differences in their looking time. The same results were found when the test stimuli were grasped by a moving claw. From these results, it was determined that not only are infants capable of encoding the action goals of others, but that they selectively apply that reasoning.

Indeed, it has been argued by others that, in addition to goals, infants in the Woodward task are attributing dispositions in the form of object preferences to the actor (e.g., Luo & Baillargeon, 2005). In this view, infants do not only attribute a goal to the actor’s reaching behaviour (e.g., to grasp that toy), but a preference for that specific goal object (e.g., to grasp that toy because it is preferred). This view stems from a series of experiments that suggest a great deal of complexity in how infants regard the actions of others.

In 2005, Luo and Baillargeon ran a study, similar in structure to Woodward (1998), with a self-propelled box as the agent that selected the objects on the stage. Self-propelledness has been posited as an important cue towards animacy, which was supported in this experiment when 5-month old infants looked longer at the box’s selection of a novel object in test. This matched results that had previously only been seen in response to a human actors’ reaching. In another condition in which the box was attached to a handle that went offstage (and thus gave no evidence of self-propelledness), there were no differences in looking time based on the selection of the box, more closely reflecting the results seen by Woodward (1998) in her inanimate conditions.

Of particular importance to claims of preference attribution was a control condition in this study, in which the self-propelled box was on the stage with only a single object during the familiarization, which the box approached on each trial. At test, two objects were shown onstage
with the box, a novel object and the object seen in familiarization, with the novel object in the previous position of the familiarized object. In this condition, the infants showed no increase in looking time for the selection of either object by the box. Because infants readily attribute goals to the self-propelled box when two objects were present on stage during familiarization, Luo and Baillargeon interpreted this null finding as resulting from a lack of information on the part of the infant. That is, having no information about the box’s disposition towards the novel object in test, the infants recognize that the box could change its target, leaving the infants with no expectations as to which object the box would select.

While caution is necessary when interpreting a null finding, the results of Luo and Baillargeon’s (2005) single object condition are interesting in several ways. First, it appears to be a particularly ‘robust’ null result; this finding has been replicated in several other experiments across multiple laboratories using human actors, computer animated shapes, and infants of different ages (3, 5, 9, &12-month-olds) under conditions that with only slight modification (adding a second object, additional cues to goal orientation such as barriers or equifinal variation) reliably produce significant differences in looking time (Biro, Verschoor, & Coenen, 2011; Luo, 2011; Hernik & Southgate, 2012). Second, this result has been at the root of a series of experiments, by Luo and other research groups, designed to more thoroughly characterize infant goal attribution and determine whether or not infants consider the mental states of others in these types of experiments.

Supporting their claim that a lack of information regarding preferences was responsible for the null result in a single object condition, Luo and Baillargeon (2007) also demonstrated that 12.5-month-old infants take into account what an actor sees when they attribute goals to them. In this experiment, an actor reached for one of two objects on a stage, but in this case there was
either (1) an opaque barrier blocking the unselected item from the actor’s view (but not the infant’s), (2) a transparent barrier between the actor and unselected object, or (3) an opaque barrier that the actor was seen to place the unselected object behind. At test, the positions of the objects were switched and the barriers removed. In this case, infants displayed increased looking time to the actor’s reach towards the previously un-chosen object only in those conditions in which the actor was shown to have visual access to the identity of the second object during habituation. When the actor reached for the object that had been behind the opaque barrier (and not visibly placed there by the actor), the infant’s looking time patterns were similar to those in the single object condition described previously. Though the infants could see the second object themselves, their expectations for the actor’s actions were dependent on the actor’s own perspective. Further work, both using variably sized barriers to the actor’s view or by having the actor’s back turned to one of the objects, has demonstrated similar, perspective dependent results in 6-month-old infants (Luo & Johnson, 2009).

Taken as a whole, the research program of Luo and colleagues is strongly suggestive of an infant sensitivity to preferences in others. However, this point has been at the center of some debate in the field, with several researchers maintaining the non-mentalistic position the infants are sensitive to ‘goal attribution’ or ‘object-directedness’ (e.g., Woodward, 1998; Gergely et al., 1995), while others see the data as pointing to a more mentalistic ‘preference attribution’, which includes the attribution of both a goal and a disposition (e.g., Luo & Baillargeon, 2005; Song & Baillargeon, 2007).

1.5 Goal-directed imitation in young infants

Looking time measures indicate that infants ascribe goals to others by at least 6-months of age, yet other behavioural measures may provide additional information. For example, recent
studies have demonstrated infants as young as 7-months will selectively reproduce the goal directed actions of others (Hamlin, Hallinan, & Woodward, 2008). In that study, infants watched an actor reach for and grasp one of two toys, before being given the chance to choose between the toys themselves. Infants were significantly more likely to reach for the object that was the goal of the actor’s reach, even in a condition where the actor failed to contact their goal. To control for the possibility that the reaching was simply highlighting one of the objects over the other, another condition was completed in which the object was touched with the back of the actor’s hand, an act that prior research has shown not to viewed as goal directed by infants (Woodward, 1999). In this condition, infants were less likely to reach for the object the actor contacted than they were in the goal directed conditions.

While infant imitation of goal directed behavior has been studied on its own, little work has been completed that compares production of imitative behaviours and the sensitivity to goals that infants demonstrate in a visual habituation study. The current work considered these two constructs in tandem, following the hypothesis that if looking time and imitation are guided by the same mechanism then imitation and preferential looking time should occur in the same experimental conditions and, more often than not, in the same infants.

1.6 The current study

The current study begins with the consideration that a person’s consistently demonstrated preference has the property of transitivity, and with the assumption that infants are able to attribute preferences to others on the basis of their choices. This study used the transitivity of preference to test infants’ ability to make transitive inferences. A modified version of the Woodward (1998) paradigm was used to determine if infants are capable of this form of logical reasoning.
The use of preferential choice to measure infants’ understanding of transitive inference provided several advantages over other paradigms used to test for this ability in infants and young children. One such advantage is that in a preference task, nonsense items can be used as stimuli and counterbalanced across trials. This controls for any possibility of perceptual cues being used as a substitute for transitive reasoning, as in studies using comparative heights or weights (Breslow, 1981; Wright, 2001), as the stimuli have been designed so as not to differ significantly from other stimuli along any quantifiable dimension. Additionally, other tests used to examine the ability of infants to form associations between absent stimuli require weeks to perform (Cuevas, Rovee-Collier, & Learmonth, 2006), while a visual habituation paradigm testing for object preference takes only a few minutes. This shorter time course not only makes this paradigm easier to control experimentally, but also solves a host of other practical issues.

The current study required the administration of three different experiments. Experiment 1 was a proof of principle experiment that demonstrated whether infants have the ability to follow another’s goal object that frequently changes position, allowing for subsequent experiments using this design. Experiment 2 builds upon the design of Experiment 1 to test for the presence of transitive inference in infants, using three serially ordered stimuli. Experiment 3 tested infants’ ability to habituate to and recall multiple goals. In each of these three experiments, following test trials allowing for looking time measures, infants were given the chance to choose one of the test objects for themselves, and their selections in this regard were compared to the selections made by the actor during the study and tested for correlation with the infants’ looking time.
Chapter 2: Experiment 1

2.1 Introduction

As discussed in Chapter 1, the procedure developed by Woodward (1998) has been widely utilized by those interested in infant goal attribution; indeed, at the time of writing, her 1998 study has been cited over 750 times. One variation on this design that has never been previously implemented, though, is to examine if infants are able to habituate to an actor’s preference for a goal object that moves between habituation trials. This is likely the case because a large part of the appeal in Woodward’s original design is due to the fact that spatial location and actor goal are not dissociated until test. This creates a situation in which looking time is higher when infants view a scene that is featurally more similar to what they had previously viewed. This also allows for a control condition, such as using a stick in place of the grasping hand, in which a different pattern of looking emerges in response to scenes that are extremely similar to those in the reaching hand condition.

These potential outcomes are advantageous in most studies of infant goal attribution because they so finely separate infant goal attribution from other potential explanations of their increased looking time. In the following experiments, however, it becomes important to dissociate goal from spatial location early in the habituation process. The aim of Experiment 2 was to study transitive inference in infants using a visual habituation paradigm, which required infants to habituate to multiple object pairings. In doing so, the side of the stage where the goal objects were placed were required to alternate. If the actor selected multiple stimuli from the same side on each trial, infants could make the assumption that a particular side is important, regardless of which stimulus occupies that side.
To accommodate this need to switch the location of the goal object throughout habituation, modifications of some of the more traditional aspects of the Woodward (1998) design were required. As a result, it was also necessary to ensure that infants can habituate under these conditions when presented with a single pair of objects. Experiment 1 tested the ability of infants to track the preferences of an actor for an object that changes location as a way of determining the appropriateness of this procedure in Experiment 2. This experiment also examined whether infant’s own reaches imitated the goal of the actor under these circumstances.

2.2 Participants

Twenty-four infants (12 male, 12 female) between the ages of eight months and twenty days and nine months and thirteen days (M = 8 months, 30 days) were recruited to participate from among the general population of a predominantly white, middle-class community in southeastern Ontario. An additional five infants were excluded from analysis due to experimenter error (n=2), not reaching habituation criteria (n=2), or for standing out of the camera view during the test (n=1). Infants who participated in the study were given a small toy and certificate of participation as compensation.

2.3 General materials and methods

In each experiment, infants watched an actor seated behind a large stage. Each trial, infants were exposed to two of a potential three stimuli, depending on the experiment, which were counterbalanced for the preferred/non-preferred stimulus selection in testing (Appendix A). Each of the stimuli was a novel object created from crafting clay (commercially known as ‘Fimo’). The stimuli were cylindrically shaped and of similar size (H= ~11cm, W= ~6cm), each composed of two different colors displayed in distinct patterns (Appendix B). For reasons of statistical power, the position of the objects within the preference order was not changed within
each experiment, but was instead changed between experiments to control for potential effects of inherent infant object preference. Video was recorded both of the actor (to provide verification of the procedure and to control for any differences in performance between actors) and of the face of the infant watching the performance. Infant looking time was measured using custom computer software by an observer watching the infant’s gaze through a curtain, who began timing each trial as soon as the object was lifted. The secondary coder observed looking time following testing while observing a recording of the infant’s gaze, and in cases of lower than 90% agreement between coders, the data were removed from analysis.

2.4 Procedure

Infants were seated on the lap of their caregiver and familiarized to the movement of the curtain by an unseen experimenter who controlled the curtain. After the curtain familiarization, the curtain was raised to reveal an actor behind two novel items on the stage. The stimuli stood fifty centimetres from each other and the actor was seated directly between them. The actor made eye contact with the infant and said “Hi Baby!” before lowering their gaze, looking at one of the stimuli, shifting their gaze to the other stimulus, and extending their arm to grasp the second stimulus. The actor lifted the target stimulus approximately ten centimetres up from the stage, shook the object, and exclaimed “I like this one” (Figure 1).
Figure 1. The first trial, in which the actor selects one stimulus (A) from a pair (AB).

Directly verbalizing the preference of the actor is not common in tests of infant goal attribution, as generally the goal in these experiments is to ascertain what the infants are learning from the actor’s selection alone. However, this experiment was not designed as a test of goal attribution, but rather to use the methods that are employed in studies of infant goal attribution in an examination of the ability of infants to make transitive inferences. With this in mind, the experimenters endeavoured to provide other cues to the goal directedness, and preference, underlying the actor’s actions. These cues included such actions as making eye contact, verbally addressing the infant in a high pitched voice, and gazing towards the object (Senju, Csibra, & Johnson, 2008; Senju & Csibra, 2008). Any detections of looking time differences in predicted directions were interpreted as being the result of the infants’ understanding of the actor’s previous goal directed actions, as these extra cues have been demonstrated as goal directed and all are congruently oriented towards the same goal.
This procedure differs from that used by Woodward (1998) in one other important way. In this experiment, the objects are moved between some of the trials, while in Woodward (1998) each object’s position remained the same outside of the test trial. That is, during the habituation trials the experimenter reached for the same object, yet this object was sometimes on the right, and sometimes on the left side of the stage.

The actor held the target object until the infant either looked away from the scene for two continuous seconds or until after 120 seconds elapsed, at which point a brief tone alerted the actor and experimenter and the curtain was lowered. While the curtain was down, the actor swapped the positions of the two items according to a predetermined order (Appendix A). When the curtain was lifted, the actor repeated the process as before, using the same hand to reach to the same object in its new position (Figure 2). This cycle was repeated until the infants habituated, using the criterion utilized by Woodward (1998). By this method, the looking times for the first three trials that sum to more than twelve seconds are used as a criterion. The looking time software automatically categorizes infants during testing as having habituated after the first three trials that have a total looking time totalling less than half of the sum of the original trio. Any infants who did not meet these criteria within 14 trials were excluded from analysis.
Figure 2. The second trial, in which the positions of the stimuli have been reversed. The actor selects the same stimulus, now in a new position.

When the curtain closed on the final habituation trial, the actor did not re-arrange the stimuli. The curtain was raised, and the actor made eye contact with the infant before saying “Hi Baby! Where is it?” The actor then lowered their gaze to the center of the stage without looking at either stimulus (Figure 3). This pose was maintained by the actor until the infant had looked away for at least two continuous seconds or until after 120 seconds had elapsed. This trial (modeled after Woodward, 1998) is referred to as the ‘presentation trial,’ and its purpose was to expose the infants to the location of the objects prior to test, so as to prevent a spike in looking time in the first test trial simply as a result of infant interest in the new configuration of objects.
Figure 3. The ‘presentation trial,’ in which the actor does not reach, but verbally draws attention to an unspecified difference

The each test trial consisted of one of two outcomes (order counterbalanced). The actor chose either the stimulus that had not previously been targeted for reaching (inconsistent), or acted in accordance with their demonstrated object preference and selected the previous target stimulus (consistent). If the infants had encoded the goal of the actor, it was expected that they would look longer at trials in which the actor selected the previously unselected object. Each infant also observed a second test trial in which the stimuli had not been rearranged, but in which the selected stimuli is the one not chosen in the prior test.

Previous work has shown that 7-month-old infants reproduce the goal-directed reaches of an actor (Hamlin, Hallinan, & Woodward, 2008). Directly following the test of infant looking time, the curtain was raised a final time and the actor said “now you choose one!” as they extended toward the infant a platform carrying both of the test objects. Infants were given
approximately 30 seconds in which to explore the objects themselves. The object that was first contacted by the infant was coded as the infant’s selection.

2.5 Results

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

A binomial test of the infants’ own reaching after testing showed a significant tendency for infants to reach for the actor’s target during habituation \((14/19 \text{ infants, } p = .032)\) (Table 2). A phi analysis found no significant relationship between the test event that infants looked longer toward and infant choice in reaching \((\phi = 0.015, p = .946)\) or between infant reach and test order \((\phi = 0.088, p = .701)\).

2.6 Discussion

Infants in Experiment 1 looked longer toward inconsistent reaches than to consistent reaches by the actor at test. This indicates that infants viewed the events during habituation as being goal directed or preference-driven towards one of the two presented objects. Thus, this experiment serves as a general replication of the findings seen by Woodward (1998) and Luo & Baillargeon (2005) with a slightly modified methodology.
As discussed in Section 2.1, this result supports the use of this procedure in the subsequent experiments designed to determine the ability of infants to make transitive inferences. The results of Experiment 1 also served as an initial verification of the hypothesis that infant imitative reaching would follow the results of infant looking time, although no correlation between reaching and the event at which infants looked longer was observed.
3.1 Introduction

This study examined the ability of infants to use transitive inference to attribute a preference between two objects to an actor. This study built upon the results of the Experiment 1 by exposing infants to an actor’s choice behaviour with two object pairings (AB & BC) during habituation. The objects were serially ordered by actor preference (A>B>C), which, with consistent reaching within each pair, should allow infants the opportunity make a transitive inference when tested on the non-adjacent pair (AC).

3.2 Participants

Twenty-four infants (12 male, 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 to participate from among the general population of a predominantly white, middle-class community in southeastern Ontario. 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). All infants were given a small toy and certificate of participation as compensation.

3.3 Procedure

Infants watched a presentation very similar to that seen in Experiment 1. In each of the habituation trials, infants watched an actor behind a stage select one object from a pair. Different from Experiment 1, however, pairs were made within three stimuli, designated A, B, and C. The stimuli were ranked in order of actor preference (A>B>C) and were presented in one of two pairings on each trial (AB or BC). During each trial, the actor followed the same script as in Experiment 1 before selecting one stimulus from the pairing (if AB selecting A, if BC selecting
B). The position of the stimulus that was selected each trial was either the same as in the previous trial, or moved to the opposite side of the stage, in accordance with a predetermined order (Appendix A).

After habituation, the presentation trial took place as in Experiment 1. In this case, the two objects presented were those designated A and C, a novel pairing. In each of the test trials, the actor selected one of the two items, either the highest value (A) or lowest value stimulus (C), in counterbalanced order. If infants were to look longer when stimulus C was selected, it would be taken to show that infants had encoded the actor’s goal as being directed toward the higher value stimulus. This result would suggest that infants are capable of using transitive inference to determine the relationship between objects that they have never before seen directly compared.

Directly following the looking time study, a platform holding both objects A and C was extended towards the infants, who were encouraged (“Now you choose one!”) to select one of the objects. Infants were given approximately 30 seconds in which to select an object, and the first object they contacted was coded as their selection.

It should be noted here, given that only a three object ordering is used, it is possible that increased looking time to the selection of the low-value target (C) in Experiment 2 could be explained in terms of association rather than in terms of inferential reasoning. Under this interpretation, it might be claimed that infants look longer when object C is chosen because they have formed either a positive association with object A, which is always selected when present, or a negative association with object C, which is never chosen outside of test. Since Bryant & Trabasso (1971) suggested this problem, most studies of transitive inference attend to this objection by exposing the subjects to a five object series (A>B>C>D>E) and testing on a comparison between an internal transitive pair, B and D. By this method, both B and D have
been seen selected or avoided with equal regularity, preventing positive or negative associations from being formed with either one.

In this case, it was a concern that so many pairings would create too many memory demands given the timescale of the general procedure. Using four stimulus pairings in the paradigm used in Experiment 2 would have required substantially more trials to expose infants equally to all of the pairings before test, which would likely be too taxing on the infant’s attention.

3.4 Results

Infants reached habituation criteria in Experiment 2 following a mean of 8.6 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 ($t(23) = 0.328, p = .746, \text{Cohen’s } d = -0.09$) between the mean looking time to consistent (M= 7.3s, SE= 1.4) and inconsistent reaches (M= 6.8s, SE= 0.7). A Wilcoxon Signed-Rank Test also returned no significant differences ($Z = -0.46, p = .964$) in infant looking time to either of the actor’s reaches in test.

A binomial test of the infant’s reaching patterns also revealed no significant reaching preference to object A (15/22 infants, $p = .067$) (Table 2). While not significant, the infants still showed a trend to reach for the goal object of the actor, despite the absence of any such trend in the looking time data. A phi analysis found no significant differences between the infant’s reach and the direction of the difference between the infants’ looking time to consistent and inconsistent reaches ($\phi = 0.001, p = 1.000$) or between infant reach and test order ($\phi = -0.232, p = .277$).
3.5 Discussion

The absence of differences in looking time between consistent and inconsistent reaches in Experiment 2 could be explained in one of two ways. The first is that infants are simply unable to make transitive inferences. This conclusion would be in keeping with historical data on this topic, but it is not the only possible explanation for the observed pattern of results.

The habituation design used in this experiment is a complex one. To the author’s knowledge, habituating infants to multiple pairings of object preferences has not been previously reported. Additionally, while infants looked longer towards inconsistent test events in Experiment 1, it is possible that the patterned movement of the preferred object in that experiment may have taxed infant’s ability to attribute goals to near-threshold levels. Further study is required to determine if infants showed no looking time preference in this experiment due to an inability to make transitive inferences or because of extreme task demands.

While not significant, infants demonstrated a tendency to imitate the goal of the actor when given the chance to reach for an object on their own. This presents a mismatch between imitation and looking time that was not present in Experiment 1, and is discussed further in the General Discussion (Chapter 5) in conjunction with the observations from Experiments 1 and 3.
Chapter 4: Experiment 3

4.1 Introduction

In Experiment 2, infants were exposed to a habituation paradigm more complex than has been previously reported, in that it simultaneously required infants to habituate to multiple overlapping pairs of stimuli (AB and BC) while the positions of those stimuli were switched between trials. Infants were unable to attribute goals using transitive inference in that experiment, raising the question of whether infants were unsuccessful in due to excessive task demands.

Experiment 3 followed a habituation procedure identical to that used in Experiment 2, and then tested infants on the pairs presented within the habituation trials. That is, infants were tested on the pairs they learned during habituation (AB or BC), with no transitive inference required. Increased looking time towards inconsistent events at test would indicate that infants are indeed capable of tracking the actor’s preferences across multiple overlapping pairs and that the results of Experiment 2 were not the result of task demands.

4.2 Participants

Forty-three infants (22 male, 21 female) between the ages of eight months and three days and nine months and nineteen days (M = 9 months, 0 days) were recruited to participate from among the general population of a predominantly white, middle-class community in southeastern Ontario. 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 because of statistically outlying looking time (n=1). Infants who participated in the study were given a small toy and certificate of participation as compensation.
4.3 Procedure

The habituation procedure was unchanged from that of Experiment 2. At the presentation and test phase, however, the infants were presented with pairings they had already seen demonstrated, with 23 infants (11M, 12F) being shown the high-value (AB) pairing at test and 20 infants (11M, 9F) being tested on the low-value pairing (BC). If infants were to look longer when the non-preferred stimulus was selected, it would be taken as evidence that infants are capable of tracking multiple preferences simultaneously, even if they lack the ability to make transitive inferences using their knowledge of those preferences.

As in Experiments 1 and 2, directly following the looking time study, a platform holding both of the objects that were present in the test phase of the looking time experiment was extended towards the infants. Infants were encouraged (“now you choose one!”) to select one of the pair. Infants were given approximately 30 seconds in which to select an object, and the first object they contacted was coded as their selection.

4.4 Results: High- and low-value pairing groups combined

Infants reached the habituation threshold after a mean of 8.1 trials. A repeated measures ANOVA using trial type (consistent or inconsistent reach) as a within subjects variable revealed a main effect of trial type \((F(1,35) = 5.499, p = .025, \text{Cohen’s } d = 0.40)\), with infants looking longer towards inconsistent \((M=8.4s, \text{SE}=1.0)\) than to consistent test events \((M=6.2s, \text{SE}=0.7)\). There were no main effects of sex \((F(1, 35) = 0.158, p = .694)\) or trial order \((F(1, 35) = 1.308, p = .260)\) on looking time during test trials, and no significant interactions between these variables. A main effect of the value of the test pairing (i.e., AB or BC) was observed \((F(1,35) = 7.855, p = .008)\), suggesting that infants looked longer during test trials if they were in the low-value BC group. There was, however, no interaction between the value of the test pairing and the type of
trial (consistent or inconsistent) \((F(1,35) = 1.351, p = .253)\). This suggests that while there was an overall difference in looking time that was attributable to the value of the test pairing, there was no overall difference in the pattern of the looking time response to consistent and inconsistent test events. A Wilcoxon signed-rank test did not show significant differences between infant looking times to either of the actor’s reaches in a test across both groups \((Z = -1.660, p = .097)\).

A binomial test of the infants’ own reaching after the final looking time test trial showed that infants reached for the higher value object significantly more often that would be expected by chance \((32/42\,\text{infants, } p < .001)\)(Table 2). A phi analysis found no significant relationship between infant choice in reaching and the test event infants looked longer toward \((\phi = -0.111, p = .470)\) or between infant reach and test order \((\phi = 0.054, p = .726)\).

While it is interesting that there was an overall pattern of looking time suggesting that infants looked longer to inconsistent test events, the question remaining from Experiment 2 was whether or not infants were able to track each individual pairing. Indeed, this question provided the initial justification in using a sample size in Experiment 3 nearly twice that of Experiments 1 and 2, so as to provide enough statistical power to make valid comparisons within each of the test pairings. This question, coupled with the significant difference resulting from the value of the object pairing indicated by the ANOVA prompted further investigation into how infants responded to testing on the individual pairings. As a result, data in Experiment 3 has been analyzed both as a complete set, and within the groups of infants who were tested on high-value pairings (AB) and those who were tested on low-value pairings (BC), to determine if each pairing was remembered individually.
4.5 Results: High value (AB) pairing

A two-tailed matched-samples t-test revealed no significant differences ($t(22) = -1.058, p = .302, \text{Cohen’s } d = 0.29$) between mean looking time to consistent ($M= 5.1s, SE= 0.8$) and inconsistent reaches ($M= 6.2s, SE= 0.9$). A Wilcoxon signed-rank test also showed no significant differences between infant looking times to either of the actor’s reaches in test ($Z= -0.958, p = .338$).

A binomial test of the infants’ own reaching after the final looking time test trial showed that infants did not reach towards the high-value object (A) more frequently than chance would predict ($13/22, p = .262$) (Table 2). Phi analyses found no significant relationship between infant choice in reaching the test event infants looked longer toward ($\phi = -0.092, p = .665$) or between infant reach and test order ($\phi = 0.277, p = .193$).

4.6 Results: Low-value (BC) pairing

A two-tailed matched-samples t-test revealed a near significant difference ($t(19)= -2.039, p = .056, \text{Cohen’s } d = 0.53$) between mean looking times to consistent ($M= 7.5s, SE= 1.0$) and inconsistent reaches ($M= 10.9s, SE= 1.7$). A Wilcoxon signed-rank test, however, revealed no significant differences between infant looking times to either of the actor’s reaches in test ($Z= -1.568, p = .117$). Figure 4 displays the mean looking durations of infants across all three experiments.
A binomial test of the infants’ own reaching showed that infants reached with significantly greater frequency than would be expected by chance to the middle-value target (B) (18/20 infants, $p = .001$) (Table 2). Phi analyses found no significant relationship between infant reach target and the direction of the difference in looking time between consistent and inconsistent events ($\phi = -0.068$, $p = .761$) or between infant reach and test order ($\phi = 0.333$, $p = 0.136$).
Table 1

*Overview of experimental results*

<table>
<thead>
<tr>
<th></th>
<th>Looking Time</th>
<th>Reaching</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do Infants Track Multiple Goals?</td>
<td>$p = .031^*$</td>
<td>$p = .032^*$</td>
</tr>
<tr>
<td><strong>Experiment 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can Infants Make Transitive Inferences?</td>
<td>$p = .746$</td>
<td>$p = .067^\dagger$</td>
</tr>
<tr>
<td><strong>Experiment 3</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can Infants Remember Multiple Pairs?</td>
<td>$p = .026^*$</td>
<td>$p &lt; .001^*$</td>
</tr>
<tr>
<td>High Value Pair (AB)</td>
<td>$p = .173$</td>
<td>$p = .262$</td>
</tr>
<tr>
<td>Low Value Pair (BC)</td>
<td>$p = .056^\dagger$</td>
<td>$p &lt; .001^*$</td>
</tr>
</tbody>
</table>

Note. *Significant (p<0.05) † Approaching Significance (p<0.1)

Table 2

*Infant reaches*

<table>
<thead>
<tr>
<th></th>
<th>Higher-Value Reaches</th>
<th>Total Reaches</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 1</strong></td>
<td>14</td>
<td>19</td>
<td>$p = .032^*$</td>
</tr>
<tr>
<td><strong>Experiment 2</strong></td>
<td>15</td>
<td>22</td>
<td>$p = .067^\dagger$</td>
</tr>
<tr>
<td><strong>Experiment 3- Combined</strong></td>
<td>32</td>
<td>42</td>
<td>$p &lt; .001^*$</td>
</tr>
<tr>
<td><strong>Experiment 3- High-Value Pair (AB)</strong></td>
<td>13</td>
<td>22</td>
<td>$p = .262$</td>
</tr>
<tr>
<td><strong>Experiment 3- Low-Value Pair</strong></td>
<td>18</td>
<td>20</td>
<td>$p &lt; .001^*$</td>
</tr>
</tbody>
</table>

Note. *Significant (p<0.05) † Approaching Significance (p<0.1)

4.7 Discussion

The aim of Experiment 3 was to shed light on why infants did not apply transitive inference in Experiment 2. While the overall results appeared to support the idea that infants can track the goal-directed actions and preferences between multiple pairings, yet fail at the level of
making transitive inferences, a closer look at the infant responses to the individual test pairings suggests that the results might not be so easily explained.

While infants appeared to be able to track the actor’s preference within the low-value pairing (though note that the non-parametric Wilcoxon test only approached significance), the high-value pairing appears to be more difficult. The infant’s own reaches toward offered targets at test matched this pattern; infants reached significantly more often to the object B than to object C, but when presented with object’s A and B reached at chance frequency.

This result is possibly related to the frequency with which infants viewed each object being chosen and grasped by the actor during the time before testing. Objects A and B were selected with equal regularity, but object C was grasped only once by the actor, and only within the low-value test pairing. This potential explanation for these results will be revisited and discussed in greater detail and in the context of the observations from Experiments 1 and 2 within the General Discussion (Chapter 5)
Chapter 5: General Discussion

5.1 Review

Across three experiments, the present study examined the ability of infants to attribute goals and preferences to others under a variety of situations. Experiment 1 utilized a variation on the procedure implemented by Woodward (1998), and demonstrated the ability of infants to track an actor’s goal even as that goal object changed locations between trials. This result was consistent with the outcomes of many other similarly designed experiments, and served as a verification of the method for later use in Experiments 2 and 3. Experiment 1 also replicated the results of Hamlin, Hallinan, and Woodward (2008), also with a slight variation. In the present study, infants viewed the selection of the target object several times (and the non-target object once) in the context of a visual habituation paradigm before being offered a chance to reach themselves, whereas in Hamlin, Hallinan, and Woodward (2008), an object was selected only once before presentation to the infant. While these findings are consistent with the established literature on these two topics, these results were both novel and necessary before moving on to further experimentation.

Experiment 2 was designed to determine if infants were capable of making transitive inferences in the context of preferences established within a Woodward paradigm. However, looking time and reaching results provided no evidence of transitive inference. This null result prompted further study in Experiment 3 to examine the ability of infants to learn the individual pairings presented within the habituation procedure utilized in Experiment 2. This experiment demonstrated an overall significant tendency for infants to look longer towards inconsistent test events, but within the test pairs individually, looking time was only significantly increased to inconsistent events within the lower-value (BC) test pair. To consider potential explanations for
the observed pattern of results, separate examinations of the looking time data from each experiment will be of use.

5.2 Looking time

Infants in Experiment 3 (and by extension, Experiment 2) appeared to be able to track only one of the two presented test pairs, the low-value BC pair. Considering potential explanations for the results of Experiment 3 will help in characterising the results of Experiment 2 and the overall significance of the current study. One potential reason for the pattern of results seen in Experiments 2 and 3 could be the nature of the habituation paradigm itself. The visual habituation paradigm is directed by the infant’s own interest in the scene, and infants are considered to have habituated when their looking time falls below a certain threshold that is determined by their initial looking time. The advantage of this method is that it is well suited to each individual infant, and the test occurs at a time based on cues from the infant themselves. The obvious corollary of this, however, is that across infants, differences in arousal, intelligence, and interest in what is being shown all have an effect on this rate of decline. This means that while one infant might watch six trials before test, another might see twelve, effectively doubling the level of exposure to the stimuli.

Familiarization is another method of testing infant looking time, and this method trades being infant led for control over exposure. While the length of each individual trial is determined by looking time, as in the visual habituation paradigm, the total number of trials is predetermined. The number of trials prior to testing is determined by the experimenter, but experiments with questions similar to those of the present study often use three or four (Luo & Baillargeon, 2005; Luo & Baillargeon, 2007; Luo & Beck, 2010). While control is maintained over exposure, familiarization experiments run the risk of testing infants before they are ready.
The infant-led nature of the habituation design was considered to be more advantageous in the present study, given the complexity of the design, but it is possible that infants might habituate to only one of the presented pairs. In each of the three experiments, infants watched a minimum of six trials and habituated following a mean of 8 trials. That is, in Experiment 1, infants watched one event (AB pairing) on approximately eight occasions, but in Experiments 2 and 3 they watched two events approximately 4 times each prior to testing. If one of the pairings were easier for infants to follow than the other, it could lead to infants habituating to one event while not yet having a firm grasp of the more complex event due to limited exposure. Future experimentation, in which a familiarization design featuring more than four exposures to each test pairing is used, could shed light on this issue.

As discussed briefly in Section 4.7, one potent ial reason for the pattern of results in Experiment 3 is the number of occurrences in which infants saw each object reached for by the actor. To review, in both Experiments 2 and 3, infants were habituated to two pairs of objects, AB and BC. These pairs were presented in alternating trials; object A was selected when the high-value pair (AB) was on the stage, and object B was selected when the low-value pair (BC) was present. With some slight variation due to individual differences in habituation rate, this results in each infant seeing object A selected on roughly 50% of trials, object B selected on the other 50% of trials, and object C never being selected prior to test. It is likely the case that the equal frequency with which objects A and B are chosen made the high-value pairing confusing, while the low-value pairing, in which only one of the objects was regularly selected, was relatively straightforward. If the low-value pairing is indeed easier for infants to understand because of relative selection frequency, it is possible that infants in Experiment 3 habituated to this pairing more quickly than they did to the high-value pairing.
It is difficult to evaluate whether infants could have habituated to only one of the two presented pairings from examination of the looking time alone. The nature of the habituation criteria (the sum of the final three trials is less than half the sum of the first three trials) is such that both pairings are embedded within the trials during which the infants habituate. The habituation criteria also preclude noting a particular trial at which an infant habituates, as habituation is not a distinct event but rather a general tendency of the infant to look less than they did to the same stimuli when they were first presented.

To the author’s knowledge, there exist no other studies of visual habituation in which two distinct pairs are presented to the infants prior to testing. In other studies where the stimuli vary from trial to trial prior to test (i.e., Xu & Spelke, 2000), the stimuli all shared some particular quality that was of interest to the researchers (i.e., the number of shapes on the screen was constant though size and positioning varied), whereas in the current study this was not so. In other studies where infants are shown different events during habituation, it is a pair of agents (both of whom are always present) that differ in their actions towards a single third party rather than a single agent acting variably in a context dependent fashion (Kuhlmeier, Wynn, & Bloom, 2003; Hamlin, Wynn, & Bloom, 2007). As a result, it is difficult to say with certainty if infants habituate to distinct, alternately presented events with differing frequencies, and this question deserves future study. At present however, differences in rates of habituation to the pairings presented in the current study seem a reasonable explanation for the results of experiment 3.

These speculations may help make sense of the results of Experiment 3, but they are not entirely satisfactory. While the frequency argument could explain the results of Experiment 3, it does little to shed light on the outcome of Experiment 2. In the high-value (AB) pairing of Experiment 3, two objects that had previously been selected with equal overall regularity are
presented. However, by the selection frequency explanation, the test pairing presented in Experiment 3 should have been completely unambiguous; object A is always selected when it is on stage, and object C is never chosen. Were frequency of selection a complete explanation, a stronger effect would have been expected in Experiment 2 than in the low-value (BC) pairing in Experiment 3.

One possible conclusion is that infants cannot make transitive inferences. This is a strong possibility, given the lack of historical evidence for this ability in children prior to the age of four years. However, because the data in Experiment 3 do not provide evidence that infants fully understood the premises required to make transitive inferences, it would not be prudent to make this strong, though very plausible claim.

Another potential answer to this apparent conundrum could be found through consideration of the structure of Experiments 2 and 3 and Luo and Baillargeon’s (2005) suggestion of infant consideration of actor preference. If indeed infants in Experiment 2 were habituating only to the low-value test pairing, and the relation between objects A and B was unclear to them (as the results of Experiment 3 suggest), it is plausible that infants treat object A as an unknown when it is paired with object C, and thus have no expectations for the actor’s reach. That is, the result of Experiment 2 may be explained not by an inability to make transitive inferences, but because infants respond to the pairing of AC the same way they respond to the addition of a novel second object in Luo and Baillargeon’s single object condition.

A third potential explanation lies in the results of a recently published study by Mascaro and Csibra (2012), which are similar to the results seen in the present study. That study used infant understanding of social dominance hierarchies in an attempt to determine whether fifteen-month-old infants could use transitive inference. While infants were sensitive to inconsistent
events within the individual pairings, infants were not able to make transitive inferences about the novel AC pair. In their discussion, Mascaro & Csibra (2012) interpret these findings as demonstrating that infants view dominance as a property specific to certain paired relationships. They suggest that if the infants attributed a transferable competence from viewing the dominance displayed within a pair, the infants would have made transitive inferences regarding the dominance in the unfamiliar AC pairing, as A would have been viewed as ‘competent’ while C was not.

Following Mascaro and Csibra’s reasoning, it could be that infants view the actor’s preferences as being specific to a particular pairing; that is, it is not because infants lack the ability to make transitive inferences that we see a null result in the Experiment 2 looking time, but because infants do not create a serial order from overlapping preferences. As discussed in the introduction, whether or not preferences have the property of transitivity is debateable, and it is possible that infants do not attribute transitivity to preferences or to dominance relations.

5.3 Infant reaching

One result of note is that no correlations were observed in any of the experiments between the objects selected by the infant and the order of the test trials. This means that infant reaches were not just a direct copy of the last reach observed, but tended to fall along the lines of the more commonly viewed choices of the actor. Additionally, when taken as a whole, the results of these experiments are suggestive of differences between goal attributive looking and goal directed imitation in young infants (Table 1). In Experiment 1, both the infants’ reaching and looking time patterns were as predicted. However, there was almost no correlation between whether an infant looked longer towards the consistent or inconsistent test event and whether they reached to high- or low-value object. In fact, there was almost no relationship between
these two dimensions in any of the three experiments. Additionally, while there was no sign of a looking time difference in Experiment 2, a near-significant tendency for infants to reach to the high value target was observed.

There are several potential explanations for the differences observed between looking time and imitation. One possibility is that imitation is a more sensitive means to tracking attribution of goal directedness in infants than looking time. For instance, in the study by Hamlin, Hallinan, and Woodward (2008), infants only viewed one selection by the actor before being given the opportunity to reach for themselves, while looking time studies require several trials prior to testing. It could be the case that the results of Experiment 2 are due to infants being able to make transitive inferences in the imitative domain but not through looking time. This interpretation is possible, but seems unlikely given the known complexity of infant goal attribution through looking time, as discussed at length in the introduction.

Another possibility is that looking time operates on a different mechanism than goal directed imitation, with looking time asking ‘why?’ while imitation asks ‘what?’ In Experiment 2, a null result in looking time could be due to any of the previously discussed explanations, while the imitative trend is explained because infants have seen object A grasped several times while object C is only grasped once during test. This would also explain why, in Experiment 3, infants so consistently imitate when presented with the lower value pair (BC) while being close to chance when tested on the high value pair (AB).

While the data presented in this study does merit raising the possibility of dissociation between looking time patterns to goal directed actions and imitation of goal directed actions, no direct evidence of this has been presented here. This issue is raised as a point of discussion and as a direction in future work more directly suited to answering this question, not as a strong
claim that imitation and looking time operate via distinct mechanisms. A more suitable test of this dissociation might be to perform a replication of Luo and Baillargeon’s (2005) single object condition; by the predictions made in this discussion, infant looking time would show no differences based on the actor’s reach, but infant’s would reach themselves for the object present during familiarization.

5.4 Conclusion

From this study we can conclude that infants are capable of habituating to goal directed action towards an object that changes position between these actions. Infants show no evidence of ability to make transitive inferences in a visual habituation paradigm, though it remains unclear if this results from poor understanding of the pairings that formed the serial order, infants not forming serial orders from preference relationships in general, or an overall inability to make transitive inferences. Experiment 3 demonstrated that infants can habituate to at least one of two simultaneously presented object pairings. That the infants in Experiment 3 showed stronger evidence of learning in the lower-value (BC) pairing suggests that avoidance of an object (C), in addition to selection of the other object (B), may play a role in infant performance in the visual habituation paradigm.
References


Hernik, M., & Southgate, V. (2012). Nine-months-old infants do not need to know what the agent prefers in order to reason about its goals: on the role of preference and persistence in infants’ goal-attribution. *Developmental Science, 1*.


Appendix A

These counterbalancing tables illustrate the pattern of object selection that will be used by the actor during testing. The order of the test trial presentation (consistent event and inconsistent event) will be counterbalanced between participants to ensure that each event will be seen first and last by an equal number of infants.

<table>
<thead>
<tr>
<th>Reach Order- Experiment 1</th>
<th>Reach Order- Experiment 2</th>
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## Reach Order - Experiment 3 (AB)

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Pres (No Choice)

A B

Test 1 A B
Test 2 A B

## Reach Order - Experiment 3 (BC)

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Pres (No Choice)

C B

Test 1 C B
Test 2 C B
Appendix B

Approximation of Objects Used as Stimuli
Appendix C

Ethics clearance for the current study

June 27, 2011

Dr. Valerie Kuhlmeier
Department of Psychology
Humphrey Hall
Queen’s University
Kingston, ON K7L 3N6

GREB ref. #: GPSYC-374-07
Title: “Cognitive Development in Infants and Young Children”

Dear Dr. Kuhlmeier:

The General Research Ethics Board (GREB) has reviewed and approved your request for renewal of ethics clearance for the above-named study. This renewal is valid for one year from July 30, 2011. Prior to the next renewal date you will be sent a reminder memo and form to reapply.

You are reminded of your obligation to advise the GREB, with a copy to your unit REB if applicable, of any adverse event(s) that occur during this one year period (details available at webpage http://www.queensu.ca/orc/researchethics/Grebelb/forms.html - Adverse Event Report Form). An adverse event includes, but is not limited to, a complaint, a change or an unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that may affect human participants must be cleared by the GREB. For example you must report changes in study procedures or implementations of new aspects into the study procedures on the Ethics Change Form that can be found at: http://www.queensu.ca/orc/researchethics/Grebelb/forms.html – Research Ethics Change Form. These changes must be sent to the Ethics Coordinator, Gail Irving, at the Office of Research Services or irvingg@queensu.ca prior to implementation. Your request for protocol changes will be forwarded to the appropriate GREB reviewers and / or the GREB Chair.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

Joan Stevenson, Ph.D.
Professor and Chair
General Research Ethics Board

cc.: K. Dunfield, Lindsay Murphy, Amy O’Neill, Scott Robson, Co-investigators
Dr. Leandre Fabrigar, Chair, Unit REB
Marie Tookey, Dept. Admin.

JS/gi