Learning to reason about desires: An infant training study

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Abstract
A key aspect of theory of mind is the ability to reason about other people's desires. As adults, we know that desires and preferences are subjective and specific to the individual. However, research in cognitive development suggests that a significant conceptual shift occurs in desire-based reasoning between 14 and 18 months of age, allowing 18- to 14-month-olds to understand that different people can have different preferences. 

Introduction
As social creatures, we are constantly trying to figure out what other people are thinking. The ability to infer others' mental states, such as their desires and beliefs, serves a number of important functions. It allows us to please or irritate others, to understand why they engage in particular actions or to predict their future behavior. These abilities hinge on our having a well-developed theory of mind—the understanding that people have mental states (e.g., desires, beliefs, intentions) and that these mental states can differ from person to person (Gopnik & Wellman 1994).

Explicit theory of mind undergoes significant development during infancy and early childhood, as children first reason based on knowledge about others’ desires and then later incorporate knowledge about others’ beliefs. How do children arrive at these more sophisticated beliefs about the minds of other people?

For simplicity, we will characterize younger infants as those who are younger than 18 months of age and older infants as those who are 18 months or older. The present research investigates the kind of evidence that is relevant for inducing this shift and whether younger infants can be trained to learn about the diversity of preferences. In Experiment 1, infants younger than 15 months of age were shown demonstrations in which two experimenters either liked the same objects as each other (in one training condition) or different objects (in another training condition). Following training, all infants were asked to share one of two foods with one of the experimenters—they either share a food that the experimenter showed disgust towards (and the infants themselves liked) or a food that the experimenter showed happiness towards (and the infants themselves did not like). We found that infants who observed two different experimenters like different objects during training later provided the experimenter with the food they liked, even if it was something they disliked themselves. However, when the two experimenters liked the same objects, they later incorrectly shared the food that they themselves liked (Experiment 2 controlled for an alternative interpretation of these findings). Our results suggest that training allows infants to overtly use an initial theory in the domain of Theory of Mind for a more complex one.

Keywords: Theory of mind; Desire-based reasoning; Infant learning; Social cognition; Preferences.

Procedure, Design and Predictions
In Experiment 1, 55 infants were tested. We used the strict criterion that only infants who did not share the correct item on an initial pre-test (described below) continued to training, therefore ensuring that infants completing training did not already know that preferences are diverse. Twenty infants per condition were tested in the full training procedure (DDT), with mean age 15.7 months; Range = 14.1 months to 17.5 months; N-DDT, mean age = 15.6 months; Range = 14.4 months to 17.2 months. An additional 15 infants were tested in a “Diverse Desires Training” condition (henceforth, DDT) where they observed multiple training trials with two experimenters demonstrating different preferences from one another. The other half completed a “Non-Diverse Desires” Training condition (henceforth, ND-TT), where they observed multiple training trials with two experimenters demonstrating the same preferences. Following training, infants were tested again on two unmatched test trials, one directly after training and the other approximately 24 hours later. The second test trial occurred 1 day later to examine how enduring the effects of training might be—would the effect still be evident following a delay? We predict that only infants in the DDT condition should show improved performance in attributing preferences on the test trials.

Materials
Food. Four sets of food pairs were used in the experiment. The pairs were broccoli and Goldfish crackers, celery and rice puffs, cucumbers and Cherrios, and green peppers and wheel-shaped infant crackers.

Toys. Two sets of toys were used during the training sessions: each set consisted of one type of animal and one type of vehicle in a transparent container. The sets of toys were 4 trucks and 4 dogs, and 4 planes and 4 monkeys. The toys in each type were not identical; they varied in color and shape.

Procedure, Design and Predictions
All infants were tested individually in a quiet lab setting. They sat in a high chair in front of a table and their parent sat in a chair beside them. Before the study began, two experimenters played a passing game with the infant. This allowed the infant to warm up to the experimenters and to understand the procedure by imitating their actions. The experimenters used a child-friendly verbal protocol to talk with the infants about the objects. For example, they would say, “Which toy do you want?” followed by “What do you think (the experimenter) does?” The experiments then asked further questions about the objects and how the infant thought the experimenter would prefer them. The experimenters used this verbal protocol to elicit the correct item on the critical post-training trial.

Conclusion
While this is an important distinction we will not discuss it further, because both processes result in a similar behavior from the infants. In Experiment 1 we began by assessing infants’ understanding of preferences by testing them in a modified version of Repacholi & Gopnik’s Goldfish/broccoli task. All infants were tested in the critical unmatched trial type, wherein the experimenter’s preference conflicted with the infant’s preference. Only infants who were failed the experimenter the food that she liked continued to a training condition. The critical manipulation is that half of the infants completed a “Diverse Desires Training” condition (henceforth, DDT) where they observed multiple training trials with two experimenters demonstrating different preferences from one another. The other half completed a “Non-Diverse Desires” Training condition (henceforth, N-DT), where they observed multiple training trials with two experimenters demonstrating the same preferences. Following training, infants were tested again on two unmatched test trials, one directly after training and the other approximately 24 hours later. The second test trial occurred 1 day later to examine how enduring the effects of training might be—would the effect still be evident following a delay? We predict that only infants in the DDT condition should show improved performance in attributing preferences on the test trials.

Experiment 1: Methods
Participants
Infants in both experiments were recruited by phone and email from the California East Bay Area and Southwestern Ontario. In Experiment 1, 55 infants were tested. We used the strict criterion that only infants who did not share the correct item on an initial pre-test (described below) continued to training, therefore ensuring that infants completing training did not already know that preferences are diverse. Twenty infants per condition were tested in the full training procedure (DDT), with mean age 15.7 months; Range = 14.1 months to 17.5 months; N-DDT, mean age = 15.6 months; Range = 14.4 months to 17.2 months. An additional 15 infants were tested in a “Diverse Desires Training” condition (henceforth, DDT) where they observed multiple training trials with two experimenters demonstrating different preferences from one another. The other half completed a “Non-Diverse Desires” Training condition (henceforth, ND-TT), where they observed multiple training trials with two experimenters demonstrating the same preferences. Following training, infants were tested again on two unmatched test trials, one directly after training and the other approximately 24 hours later. The second test trial occurred 1 day later to examine how enduring the effects of training might be—would the effect still be evident following a delay? We predict that only infants in the DDT condition should show improved performance in attributing preferences on the test trials.

Materials
Food. Four sets of food pairs were used in the experiment. The pairs were broccoli and Goldfish crackers, celery and rice puffs, cucumbers and Cherrios, and green peppers and wheel-shaped infant crackers.

Toys. Two sets of toys were used during the training sessions: each set consisted of one type of animal and one type of vehicle in a transparent container. The sets of toys were 4 trucks and 4 dogs, and 4 planes and 4 monkeys. The toys in each type were not identical; they varied in color and shape.

Procedure, Design and Predictions
All infants were tested individually in a quiet lab setting. They sat in a high chair in front of a table and their parent sat in a chair beside them. Before the study began, two experimenters played a passing game with the infant. This allowed the infant to warm up to the experimenters and to understand preferences by testing them in a modified version of Repacholi & Gopnik’s Goldfish/broccoli task. All infants were tested in the critical unmatched trial type, wherein the experimenter’s preference conflicted with the infant’s preference. Only infants who failed to give the experimenter the food that she liked continued to a training condition. The critical manipulation is that half of the infants completed a “Diverse Desires Training” condition (henceforth, DDT) where they observed multiple training trials with two experimenters demonstrating different preferences from one another. The other half completed a “Non-Diverse Desires” Training condition (henceforth, N-DT), where they observed multiple training trials with two experimenters demonstrating the same preferences. Following training, infants were tested again on two unmatched test trials, one directly after training and the other approximately 24 hours later. The second test trial occurred 1 day later to examine how enduring the effects of training might be—would the effect still be evident following a delay? We predict that only infants in the DDT condition should show improved performance in attributing preferences on the test trials.
ensure that they could share with the experimenters. The warm up consisted of each experimenter passing a toy (e.g., a ball or toy keys) to the infant and asking her to pass it back by placing it in the experimenters’ hands.

**Pre-test 1** was based on Repacholi & Gopnik (1997). Experimenter 1 slid a plate of food consisting of a few pieces of vegetables and snacks (e.g. raw broccoli and Goldfish crackers) towards the infant and encouraged the infant to try some. The experimenter gave the infant a 45 second time frame to taste the foods and the experimenter determined which of the two foods the infant preferred. We used the same coding as in Repacholi & Gopnik (1997) to determine food preferences on all trials (pre- and post-tests). Inter-coder agreement for preferences was 91%. When the infant’s preference was determined, the experimenter took out a container consisting of the same foods the infant had tried. The experimenter then demonstrated that she liked the food that the infant did not show a preference for and was disgusted by the food that the infant preferred. The experimenter showed her preferences by saying, e.g., “Eww! Crackers! I tasted the crackers! Eww!” and “Mmm! Broccoli! I tasted the broccoli! Mmm!” The experimenter showed a liking and disliking towards each food three times and she did this using facial expressions based on the descriptions of Ekman & Friesen (1975). Next, the experimenter placed broccoli on one side of a tray and Goldfish crackers on the other, placed her hand with her palm up towards the infant, said, “can you give me some?” and slid the tray towards the infant. The infant was given 45s to pass food to the experimenter. If the infant gave the experimenter the food that the experimenter had demonstrated a preference towards, then the infant passed the pre-test. If the infant gave the experimenter the food that she disliked, or did not provide the experimenter with any food, then the infant did not pass the pre-test.

**Training Trials**. Infants who failed the pre-test were introduced to either the DDT condition or the N-DDT condition. Infants in the DDT condition saw two experimenters liking and disliking different toys and infants in the N-DDT condition saw two experimenters liking and disliking the same toys.

Training proceeded as follows: Training trial 1 occurred right after the pre-test. During training trial 1, Experimenter 1 put a jar of toys (e.g., dogs and trucks) onto the table and subsequently pulled out three toys of one type (e.g., dogs) and placed them on the tray. Then, the experimenter pulled out three toys of the other type (e.g., trucks) and expressed dislike towards them. The dialogue and facial expressions that the experimenter used during the pre-test were also used during the post-test. The experimenter expressed her preferences by saying, “Yay! A dog! I got a dog! Yay!” and “Eww! A truck! I picked up a truck! Eww!” Once Experimenter 1 expressed her emotions for each type of toy three times, Experimenter 2 took over. Experimenter 2 showed liking and disliking towards the same toys as Experimenter 1 if the infant was in the N-DDT condition (e.g., liked dogs and disliked trucks) and she showed liking and disliking towards the opposite toys as Experimenter 1 if the infant was in the DDT condition (e.g., liked trucks and disliked dogs).

Training trial 2 involved Experimenter 2 and the infant. It was similar to the pre-test, except that it involved a different set of toys (e.g., a toy truck on one side of the tray and a toy dog on the other side). Experimenter 2 gave the infant a plate of food and demonstrated which food the infant preferred within 45s. In the DDT condition, the experimenter then demonstrated that she preferred the food that the infant disliked and disliked the food that the infant preferred. In the N-DDT condition, the experimenter demonstrated that she disliked and liked the same foods as the infant. The infant was not asked to share any food with the experimenter, as this was a training trial and not a test.

Training trial 3 was identical to training trial 1, but with a different set of toys (e.g., monkeys and planes). Experimenter 1 expressed liking to one type of toy and dislike towards the other type of toy. Experimenter 2 had a turn expressing her emotions towards each of the toys. The experimenter expressed happiness and dislike towards the same toys as Experimenter 1 if the infant was in the N-DDT condition and expressed happiness and dislike towards the opposite toys as Experimenter 1 if the infant was in the DDT condition. After Experimenter 2 finished her demonstrations, infants completed training task 1. Experimenter 2 put one of each type of toy on both sides of a tray (e.g., a monkey on the right, a plane on left), placed her palms face up towards the infant, pushed the tray towards the infant and asked the infant to share one with her. The infants were given 45s to share a toy with the experimenter. Once the infant shared a toy with Experimenter 2, Experimenter 1 had a chance to ask the infant to share with her the toy that she liked.

Training trial 4 was a repetition of training trial 3 and included a training task 1 that was identical to the one completed after training trial 3.

The purpose of the training tasks, where infants were asked to share one of two toys with each experimenter, was simply to ensure that the infants did not get bored and continued to share throughout the study. We did not expect that infants would remember the experimenters’ preferences in either condition of Experiment 1 or in Experiment 2 (all p’s > .25 for ANOVA’s examining infants’ passing behavior on the experimenters’ preferences). Post-training test 1 immediately followed training. It was identical to the pre-test, except with different food (e.g., cucumbers and Cheerios). Once the infant shared a food on a post-test 1, the first day of the study was complete.

Infants returned on Day 2 to complete post-training test 2. Infants again warmed up with Experimenter 1 by playing the warm-up game from Day 1. This was followed by post-training test 2, which was identical to the pre-test and post-training test 1, but again with a different set of food (e.g., green peppers and wheel-shaped crackers). For the first 10 infants in both training conditions, the food on post-training test 2 was identical to the food on training trial 2 (which the infant used with Experimenter 2 on Day 1 but did not share). We switched this to a new food type to ensure that any improvement in infants’ performance on Day 2 in DDT could not be explained by already being familiar with these foods.

**Experiment 1: Discussion**

Our results suggest that the type of information provided during training was crucial in learning about other’s desires. When infants were provided with a large number of instances indicating that two different people can like different things, they appeared to share the information that they disliked but the experimenter preferred. However, infants’ performance did not improve when they saw preferences that were not diverse: infants in the N-DDT condition did not share the correct food with the experimenter on any post-training tests. This suggests that training with appropriate evidence can result in significant changes to children’s explicit Theory of Mind.

Predictions about what infants in the DDT condition only demonstrate advances in understanding on Day 2 of the experiment, during the second post-training test? We see at least two possible explanations. One possibility is that post-training test 1 served as a final training trial, giving infants the minimum number of examples required to change their model of how preferences work (i.e., to learn that they apply to the individual). A second possibility is that a night of sleep resulted in improved learning of this general knowledge about other’s minds, allowing infants to pass the post-test on Day 2 but not on Day 1. We will address these possibilities more fully in the General Discussion. Before we can speculate as to why children appeared to learn something new about preferences in the DDT condition, we must first investigate an alternative interpretation of the Experiment 1 data. It is possible that the infants in the DDT condition did not learn that preferences are diverse, but instead learned something less conceptually powerful like, “In this game I’m playing, people always get opposite things!” Infants in the N-DDT condition might have interpreted the N-DDT condition was significantly above chance (p=0.04, binomial).

**Experiment 1: Results**

Of the initial 55 infants who participated in the experiment, 15 passed the pre-test by giving the correct food (p < .01, binomially, significantly fewer than chance), 34 infants shared the incorrect food, and 6 infants shared nothing, replicating that infants this age perform below chance on this task (Repacholi & Gopnik, 1997). This confirms that, in general, infants below 18 months are inclined to share the item that they themselves prefer, not the item for which another person has shown a preference. For the 40 infants that failed the pre-test and continued on to training, performance on post-training test 1 was identical across training conditions (DDT: 7/20 correct; N-DDT: 7/20 correct). Differences in performance were isolated by training condition for post-training test 2 (DDT: 15/20 correct; N-DDT: 7/20 correct; X2(1, N=40)=64.66, p<.01). Only the performance on post-training test 2 for infants in the DDT condition was significantly above chance (p=.04, binomial).
test 2, even though the experimenter demonstrates that she likes the food that the infant also prefers. We maintained the exact same procedure as in the DDT condition of Experiment 1, including using an “unmatched” trial type for post-training test 1, as the effect was observed only in post-training test 2 and so every aspect of the experimental session must remain the same until that point.

**Experiment 2: Methods**

**Participants**

Participants included 29 infants and, as in Experiment 1, only children who failed to give the correct food on the initial pre-test continued to training with 20 infants tested in the full training procedure (mean age = 15.5 months; Range = 14.4-17.0 months). An additional 10 infants were tested but not included in data analyses due to failing to complete the study because of fussiness (1), parental interference (1) or refusing to share anything with the experimenters on all test trials (8).

**Materials**

Food. The food was the same as in Experiment 1 except that the wheel-shaped crackers were replaced with Animal Crackers. This was done because we could no longer find the wheel-shaped crackers.

Toys. The sets of toys were 4 hippo and 4 trucks, and 4 cats and 4 planes. Again, all of the toys within an individual type were slightly different in shape and/or color.

**Procedure and Design**

The experimental procedure, counterbalancing and randomization were identical to Experiment 1 DDT.

**Predictions**

We predicted that infants would perform at chance on post-training test 1, as they did in Experiment 1. If infants did not give the experimenter the correct food on post-test 2 (the food that both the experimenter and the infant like), then this will suggest that infants in Experiment 1 did not simply learn to play a game of opposites but instead learned that preferences are diverse.

**Experiment 2: Results**

Again we replicated the findings from Reapchol & Gopnik (2009). As in Experiment 1, infants passed the pre-test (p = .06, binomial, marginally significantly fewer than chance), 18 infants shared the incorrect food and 2 infants shared nothing.

Six out of 20 infants were correct on post-training test 1 and 13 out of 20 were correct on post-training test 2, both not significantly different from chance (p = .12 and p = .26, respectively).

The critical comparison is between infants’ performance on post-training test 2 in the Experiment 1 DDT condition and in Experiment 2. This comparison addresses whether infants in Experiment 1 simply learned to play a game of opposites and would have shared the opposite food type to their own preference regardless of what the experimenter demonstrated on post-test 2. For this analysis, we coded infants’ performance in terms of whether they gave the experimenter the opposite food to what the infant preferred (which is correct in Exp 1 DDT but incorrect in Exp 2). We gave infants a score of 1 for sharing the opposite food and a score of zero for sharing the same (non-opposite) food. This resulted in a score of 7/20 in Experiment 2 and 15/20 on post-training test 2 in the DDT condition of Experiment 1. Using a Fisher’s Exact test, we found that infants’ performance on these trials was significantly different from one another, X²(1, N=40)=6.46, p<.01, suggesting that infants in Experiment 1 were more likely to share the opposite food than infants in Experiment 2, where they would have been incorrect in doing so.

**Experiment 2: Discussion**

Overall, most infants gave the experimenter the food that they preferred (and the infant also preferred) on post-training test 2 (this was not significantly different from chance using a binomial test). Though we would have expected infants to share the correct food at higher than chance levels in this “matched” trial, we suspect that the non-significant result is due to a lack of statistical power caused by having relatively few participants for binomial statistics. In general, the percentage of infants offering the correct, “matched” food on this trial is very similar to the percentage of younger infants who did so in Reapchol & Gopnik (1997) (65% vs. 72%, respectively).

The purpose of Experiment 2 was to eliminate the possible explanation that participants in the Experiment 1 DDT condition only learned to give the experimenter the opposite food of what they themselves wanted. Comparison of Experiments 1 and 2 suggest that this was not the case, as infants shared the food that they preferred in Experiment 2 and not reflexively give the experimenter the opposite food following training.

**General Discussion**

Together, these findings show that infants younger than 18 months can learn about the subjectivity of preferences when provided with divergent preferences during training, infants were able to reason correctly about another person’s preferences, providing the experimenter with the food that they liked. In contrast, the infants who only saw congruent expressions of liking and disliking options did not learn to reason correctly about another person’s preferences, and continued to give the experimenter the food that they themselves preferred, regardless of the experimenter’s preference.

Experiment 2 helped to clarify these findings, providing evidence that infants did not simply learn to always give the experimenter the opposite food type to their own preference regardless of what the experimenter demonstrated on post-test 2. For this analysis, we coded infants’ performance in terms of whether they gave the experimenter the opposite food to what the infant preferred (which is correct in Exp 1 DDT but incorrect in Exp 2). We gave infants a score of 1 for sharing the opposite food and a score of zero for sharing the same (non-opposite) food. This resulted in a score of 7/20 in Experiment 2 and 15/20 on post-training test 2 in the DDT condition of Experiment 1. Using a Fisher’s Exact test, we found that infants’ performance on these trials was significantly different from one another, X²(1, N=40)=6.46, p<.01, suggesting that infants in Experiment 1 were more likely to share the opposite food than infants in Experiment 2, where they would have been incorrect in doing so.

An interesting finding in these experiments is that the participants performed identically during the pre-test and post-training test 1, but performed significantly above chance on post-training test 2 in Experiment 1. Both tests occurred after training and we had not predicted this pattern of results, so we now return to the question of why we only saw improvement on post-training test 2.

One possible explanation for this improved performance on post-training test 2 is that post-training test 1 might act as another piece of evidence to train the infants to better understand diverse preferences. That is, post-training test 1 gives infants yet another trial in which the experimenter demonstrates that they like the opposite food to the infant. It is possible that this extra trial is what allows the infants to learn that preferences are subjective. This possibility can be examined by manipulating the number of training trials, to include an additional trial before post-training test 1 on Day 1. Related to this, we can also examine what type of evidence is more informative – events that involves first-person experience such as training trial 2 and post-training test 1, or training trials that involve observing two actors display divergent preferences. By manipulating the number and type of training trials across various conditions in future experiments, we can answer these questions.

Another possible explanation for the improved performance only on Day 2 is the role of memory consolidation in sleep. Post-training test 2 occurs the following day, whereas post-training test 1 occurs on the same day as the training trials. Therefore, a potentially critical difference between the two tests is sleep. Research has shown that sleep is important for the consolidation of memories, and improvements in children’s and adults’ learning performance is with longer and more intense sleep (Wilhelm, Prehn-Kristensen & Horn, 2012). For example, Hupbach, Gomez, Bootzin, and Nadell (2009) found that when 5-month-old infants napped after they were exposed to an artificial language, they were more likely to remember the general grammatical pattern of that language 24 hours later, compared to infants who did not nap. It is possible that the infants in our experiment performed better on post-training test 2 because they had slept. To address the sleep hypothesis, one could conduct an experiment similar to those here, except with the entire procedure occurring on the same day. After infants complete post-training test 1, half of the infants would take a nap and half would experience a similar delay without taking a nap. Follow up that infants would complete post-training test 2. If the infants who napped performed better than those who did not, then this would suggest that sleep consolidation is a crucial aspect of their improved performance.

**Conclusion**

Research on children’s desire-based reasoning has persisted for decades. Here we examined a prediction from a particular model of how children attribute preferences to others, namely that appropriate training regarding the diversity of desires could result in infants undergoing a significant shift in conceptual development (Lucas et al., 2014). We found that following exposure to different people demonstrating divergent desires, infants were able to move from a model of universal preferences to a model that allows for the individualization of preferences. The success of this training procedure more broadly suggests that early advances in Theory of Mind could be due to experience.

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**References**


