Learning to reason about desires: An infant training study

Citation for published version:
Doan, T, Denison, S, Lucas, C & Gopnik, A 2015, Learning to reason about desires: An infant training study. in *Proceedings for the Annual Meeting of the Cognitice Science Society 2015.* pp. 1-4, CogSci 2015, Pasadena, United States, 23/07/15.

Learning to reason about desires: An infant training study

Tiffany Doan[a] (t3doan@uwaterloo.ca), Stephanie Denison[a] (stephanie.denison@uwaterloo.ca), Christopher G. Lucas[b] (c.lucas@ed.ac.uk), & Alison Gopnik[c] (gopnik@berkeley.edu)

[a]University of Waterloo, Department of Psychology

[b]University of Edinburgh, School of Informatics

[c]University of California, Berkeley, Department of Psychology

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- but not 14-month-olds to understand that different people can have different preferences (Lucas et al., 2014; Ma & Xu 2011; Repacholi & Gopnik, 1997). 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 18 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 could 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 liking different objects during training later provided the experimenter with the food she liked, even if it was something they disliked themselves. However, when infants observed two experimenters liking the same objects, they later incorrectly shared the food that they themselves liked with the experimenter. Experiment 2 controlled for an alternative interpretation of these findings. Our results suggest that training allows infant to overturn an initial theory in the domain of Theory of Mind for a more advanced one.

Keywords: Theory of mind; Desire-based reasoning; Infant learning; Social cognition; 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 acts, and 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?

This paper focuses on the development of desire-based reasoning, or the ability to consider a person's wants, likes, and dislikes when reflecting on their behavior. For example, children as young as two years understand that people's actions and emotions are influenced by their desires; they know that a person will attend to objects that they want to obtain and will be sad if their desires go unfulfilled (Wellman and Woolley, 1990).

The present experiments examine a shift that occurs in infants' desire-based reasoning, specifically in their reasoning about preferences. The paradigm is based on a study that asked whether infants understand that preferences can serve as an underlying cause of people's behaviors (Repacholi & Gopnik, 1997). Fourteen- and eighteen-month-old infants were presented with two different types of food: Goldfish crackers and broccoli. The experimenter determined which food the infants liked (the majority preferred Goldfish crackers). She then demonstrated, using emotional expressions and simple language, that she preferred either that same food (Goldfish crackers in a "matched" trial) or the opposite food (broccoli in an "unmatched" trial), depending on the experimental condition. When infants were asked to share some food with the experimenter, the two age groups differed in their responses. The 18-month-olds were able to correctly determine the experimenter's preferences based on her previous behaviors, and thus correctly gave her the food that she liked, whether the infant themselves preferred this food or not. However, the 14-month-olds gave the experimenter the food that they themselves preferred, regardless of her demonstrated preferences. This difference in performance has been interpreted to suggest that some time around 18 months of age, infants' desire-based reasoning undergoes a significant conceptual change, moving from a simple to a more complex model of preferences. That is, infants younger than 18 months may have a very simple notion of preferences in which they initially assume that preferences are universal, rather than varying between people[1]. In contrast, older infants seem to recognize that desires are diverse.

[1]For simplicity, we will characterize younger infants as assuming that preferences are universal. An alternative possibility is that infants are instead sensitive to the relative desirability of objects, reasoning that some things in the world are inherently more desirable than others. This reasoning would also result in infants always sharing the item that they personally like with the experimenter, as they would see it as the objectively better item. While this is an important distinction we will not discuss it further, because both processes result in identical behavior in our task.

What occurs between the ages of 14 and 18 months to promote such a significant advance in Theory of Mind? In a recent paper, Lucas et al. (2014) suggested that infants might first favor the simpler or "universal" model of preferences because it gives a parsimonious explanation for most of the data they encounter. For example, it is often the case that preferences converge – most people like the taste of pizza but they aren't as enthusiastic about lima beans. However, as children observe more choices, they have increasingly robust evidence that people have divergent desires. The hypothesis is that as children grow older they accumulate evidence pushing them away from the simple but incorrect initial model toward a more complex and flexible model, which allows them to consider the consequences of distinct preferences. The suggestion is that during this transition, children must observe or participate in many desire-based interactions where people make choices or produce other signals to suggest that their preferences are incongruent with one another or with the infants themselves.

The idea that infants might shift from a simple to a more complex model was formalized as part of a broader look into whether children learn preferences in a way that is rational or optimal under certain assumptions (Lucas et al., 2014). Lucas et al. explored the idea that children have tacit hypotheses about others' behaviors or underlying mental states, and evaluate those hypotheses against incoming data in a manner consistent with Bayes Theorem. If children expect others to have consistent preferences for options or features (like goldfish crackers, or saltiness) and choose the most attractive option based on the combined desirability of its features – including some features that might be hidden to the child – their preference attributions should be consistent with the predictions of a widely-used economic model, the Mixed Multinomial Logit (MML).

The MML is generally used to predict consumer behavior, but it also succeeded in providing a unified account of data from a wide range of experiments on children's understanding of preferences. It accounts for preschoolers' ability to infer preferences from the statistical properties of a collection of objects and an agent's choices (Kushnir, Xu, &, Wellman, 2010) and for children's ability to use shared preferences, as well as their knowledge of category membership, as a means for making generalizations (Fawcett & Markson, 2010) – see Lucas et al. for details.

This modeling work also yielded an important empirical prediction about the development of desire-based reasoning: if younger children were provided evidence of diverse desires through lab-based training, then they might be able to transition to the more complex model of preference attribution. We test this hypothesis here using a training study with 14- to 17-month-old infants in two experiments. In Experiment 1 we began by assessing infants' understanding of preferences by testing them in a modified version of Repacholi & Gopnik's (1997) 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-DDT), 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, increasing our confidence that infants completing training did not already know that preferences are diverse. Twenty infants per condition were tested in the full training procedure (DDT: 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 but excluded from analyses due to failing to complete the study because of fussiness (2) or refusing to share on the pre-test and all test trials (13).

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 Cheerios, 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 within 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 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 him/her to pass it back by placing it in the experimenters' hands.

Pre-test. The pre-test 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 showed 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 failed 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 toy of one type (e.g., dogs) and expressed liking towards them. Then the experimenter pulled out three toys of the other type (e.g., trucks) and expressed dislike towards them. The dialogue and facial expressions used were similar to that used during the pre-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 food (e.g., celery and puffs) and excluded the testing part of the pre-test. Experimenter 2 gave the infant a plate of food and determined 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 liked and disliked 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. She 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 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 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 which experimenter preferred which toy and in fact we found that infants did not reliably 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 based on the experimenters' choices).

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 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).[2]

Design The foods used on each trial were randomized (some infants saw broccoli and Goldfish on the pre-test, some on training trial 2, some on post-training test 1 and some on post-training test 2). The side of the tray that each food item appeared on during the sharing part of the pre-test and post-training tests was randomized. For training trials, if Experimenter 1 liked animals and disliked vehicles in the first training trial, she would continue to like animals and dislike vehicles in subsequent training trials. For half the participants, Experimenter 1 liked animals and for the other half, Experimenter 1 liked vehicles. This was crossed with half of the infants seeing dislikes expressed first and half seeing likes expressed first. None of these counterbalancing factors led to any systematic differences in the data (when entered into ANOVAs, all *p's* > .5 for these factors).

Predictions We predicted that infants in the DDT condition would be more likely to offer the experimenter the correct food on the post-tests than infants in the N-DDT condition even though both conditions provided infants with practice in considering other people's preferences and desires. In the N-DDT condition, infants saw two experimenters liking the same objects – this does not provide the infants with any information that allows them to learn that different people can have different mental states. In the DDT condition, infants saw two experimenters display different preferences from each other, which would provide a great deal of evidence to suggest that different people can have different preferences.

Experiment 1: Results

Of the initial 55 infants who participated in the experiment, 15 passed the pre-test by giving the correct food ($p < .01$, binomial, 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 who failed the pre-test and continued to training, post-training test 1 performance was identical across training conditions (DDT: 7/20 correct; N-DDT: 7/20 correct). Interestingly, performance differed by training condition for post-training test 2 (DDT: 15/20 correct; N-DDT: 7/20 correct, $X^2(1, N=40)=6.46$, $p=.01$). Only the performance on post-training test 2 for infants in the DDT condition was significantly above chance ($p=.04$, binomial).

[2] 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 those foods.

Experiment 1: Discussion

Our results suggest that the type of information provided during training was crucial to infants' learning about diverse desires. When infants were provided with a large number of instances indicating that two different people can like different things, they appeared to learn to share the item that they disliked but the experimenter preferred. However, infants' performance did not improve when they sawpreferences 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.

But why did 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 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, so I should just give the other person the thing that I didn't take". If this is the case, then the participants did not learn that preferences are specific to the individual; they learned to play a game of opposites. We ran a second experiment to tease apart these explanations.

Experiment 2

Experiment 2 explored the alternative interpretation that infants in the DDT condition of Experiment 1 only learned to give the experimenter the opposite food from what they liked. Infants completed the same training as in the DDT condition of Experiment 1 but with a "matched" trial on post-training test 2. In a matched trial type, the experimenter demonstrates the same preference as the infant, instead of demonstrating opposite preferences. In this case, if infants in Experiment 1 DDT condition learned that preferences are specific to the individual, and that is why they tended to share the correct food with the experimenter on post-training test 2, then they should give the experimenter the food she likes even though this is also the food that the infant herself likes. Conversely, if infants in the DDT condition of Experiment 1 learned through the course of the session that people should simply always be given opposite things to their partner, then they will give the experimenter the food that they themselves do not like on post-training 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 were 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 months to 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 hippos 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 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 Repacholi & Gopnik (1997), as 9/29 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 coding resulted in a score of 7/20 for post-training test 2 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, $X^2(1, N=40)=6.46$, 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 she preferred (and that 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 Repacholi & 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 did 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 appropriate training. Before infants were exposed to any training, they provided an adult with the food that they personally liked and not one the experimenter liked, presumably because they incorrectly believed that preferences are universal. However, when provided with diverse preferences during training, infants were able to reason correctly about another person's preferences, providing the experimenter with the food that she 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 of what they themselves desire. Post-training test 2 of Experiment 2 was a "matched" trial, meaning that the experimenter showed the infant that she liked the same food as the infant. Because the majority of infants gave the experimenter the food that the experimenter (and the infant) liked, we can be confident that infants in Experiment 1 learned that preferences are diverse. Taken together, our results suggest that infants learned through training about the diversity of desires, moving from a less to a more sophisticated understanding of other's preferences. On a broader level, these findings suggest that young children can learn from experience to make an important advance in explicit reasoning about Theory of Mind.

One concern regarding these data is the relatively low statistical power that results from our experimental design and the small sample size for each experiment. Although the results in the Experiment 1 DDT condition were significant, it will be prudent to replicate these findings. This replication experiment is currently underway in the lab.

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 she likes 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 most informative – evidence that involves first-person experience such as training trial 2 and post-training test 1, or training trials that involve observing two actors display diverse 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 infants' learning is correlated with longer and more intense sleep (Wilhelm, Prehn-Kristensen & Born, 2012). For example, Hupbach, Gomez, Bootzin, and Nadel (2009) found that when 15-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. Following this, all infants would complete post-training test 2. If the infants who napped perform better than those who do 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.

Acknowledgments

We thank Justine Hoch and Sophie Bridgers for an immense amount of help with data collection and infant recruitment. We also thank Elizabeth Attisano, Emily McIntosh, Meghan McGrath, Julia Heunis, Christen Calsada, and Gina Mandracchia for assistance with data collection. Thanks also to the parents and infants for their participation.

References

Ekman, P., &. Friesen, W. (1975). *Unmasking the face: A guide to recognizing emotions from facial clues*. Englewood Cliffs, NJ: Prentice-Hall.

Fawcett, C., & Markson, L. (2010). Children reason about shared preferences. *Developmental Psychology, 46*(2), 299-309.

Gopnik, A., & Wellman, H. (1992). Why the Child's Theory of Mind Really Is a Theory. *Mind & Language, 7*, 145-171.

Hupbach, A., Gomez, R. L., Bootzin, R. R., & Nadel, L. (2009). Nap-dependent learning in infants. *Developmental Science*, *12*(6), 1007-1012.

Kushnir, T., Xu, F., & Wellman, H. M. (2010). Young children use statistical sampling to infer the preferences of other people. *Psychological Science*, *21*(8), 1134-1140. doi: 10.1177/0956797610376652

Lucas, C. G., Griffiths, T. L., Xu, F., Fawcett, C., Gopnik, A., Kushnir, T., … Hu, J. (2014). The child as econometrician: A rational model of preference understanding in children. *PLoS ONE*, *9*(3), e92160. doi:10.1371/journal.pone.0092160

Ma, L., & Xu, F. (2011). Young children's use of statistical sampling evidence to infer the subjectivity of preferences. Cognition, 120(3), 403-411

Repacholi, B. M., & Gopnik, A. (1997). Early reasoning about desires: Evidence from 14- and 18-month-olds. *Developmental Psychology*, *33*(1), 12-21.

Wellman, H. M., & Woolley, J. D. (1990). From simple desires to ordinary beliefs: The early development of everyday psychology. *Cognition*, *35*(3), 245-275.

Wilhelm, I., Prehn-Kristensen, A., & Born, J. (2012). Sleep-dependent memory consolidation – What can be learnt from children?. *Neuroscience & Biobehavioral Reviews*, *36*(7), 1718-1728.