Lab for developmental Studies at Harvard University





Newsletter 2013







Table of Contents



Page	Title of Study	Age Group	Researcher
1	Responses to Goal Completion	8-11 Months	Amy Skerry
2	Sticky Mittens	3-4 Months	Amy Skerry
3	Explicit and Implicit Theory of Mind	2-3 Years	Alexander Bardis
4	Language and Abstract Concepts: Memory for Time	5-12 Years	Annemarie Kocab
5	Children's Expectations and Understanding of Kinship as a Social Category	3-5 Years	Annie Spokes
6	Benevolence	5-6 Years	Elizabeth Letvin
7	Bribery	5-7 Years	Carla Sebastian & Kerrie Pieloch
8-9	Seeing Sets	6 Months	Arin Tuerk
10	Desire, Understanding, and Helping	2-3 Years	Kate Hobbs
11	The Development of First Impressions from Faces	3-10 Years	Emily Cogsdill
12	Learning in Parallel	14-18 Months	Jean-Remy Hochmann
13	Same and Different	14 Months	Jean-Remy Hochmann
14	Process of Elimination in Infancy	10 Months	Jean-Remy Hochmann
14	Speech Perception	3-6 Months	Jean-Remy Hochmann
15	Infant Desire Understanding	14 and 24 Months	Kate Hobbs
16	Language Acquisition and Theory of Mind	17-27 Months	Kate Hobbs
17	Causes of Behavior	5-6 Years; 5-10 Years/Adults	Larisa Heiphetz
18	People's Behaviors	6-8 Years	Larisa Heiphetz
19	A Story That Will Make Your Eyes Grow Wide	4 and 6 Years	Manizeh Khan
20-21	Sentence Processing in Children	4 and 6 Years	Margarita Zeitlin
22	Understanding Scenes and Objects in Line Drawings	4 Years	Moira Dillon
23	Infants Chunk to Remember More Things	7 Months	Mariko Moher



🤹 Table of Contents 🤹



Page	Title of Study	Age Group	Researcher
24	Infants' Understanding of Causal Events	8 Months	Mariko Moher
25	The Process of Elimination	14, 17, and 23 Months	Shilpa Mody
26	Guessing and Knowing	2.5-5 Years	Shilpa Mody
26	Reasoning and Causality	14-24 Months	Shilpa Mody
27	Find the Friend	4 Years	Narges Afshordi
28	Speech is Social	9 Months	Narges Afshordi
29	Biology and Executive Function	5-8 Years	Nathan Tardiff & Deborah Zaitchik
30	Teaching Two and Three	2-4 Years	Paul Haward
31	Executive Function With Four-Year Olds	4 Years	Paul Haward
32	Measure Words	3-5 Years	Peggy Li
33	When do children ask for help?	3-5 Years	Alex Was
34	Strategic reciprocity in young children	3 and 5 Years	Carla Sebastian & Kerrie Pieloch
35	It's Not in the Bucket	22-28 Months	Roman Feiman
36	Do Infants Know Logic?	12 Months	Roman Feiman
37	Does logic underlie language?	4-7 Years	Roman Feiman
38	Selective Attention to the Singers of Familiar Lullabies	5 Months	Sam Mehr
39	Social Learning of Food	3-5 Years	Victoria Wobber
40	Third Party Intervention	5 and 6 Years	Jillian Jordan
41	Going Down the Garden Path	5-8 Years	Tanya Zhuravleva
42	She said WHAT?!	7-10 Years	Tracy Brookhyser
43	Bingo was his NAME-O	2 Years	Tracy Brookhyser
43	Oh, I know what happened!	2-5 Years	Tracy Brookhyser



tents	S. C.	
Age Group	Researcher	

Page	Title of Study	Age Group	Researcher
44	Finger Puppets study: Do young children understand exact quantities?	2 and 3 Years	Veronique Izard
45	Math and Social Games for Preschoolers	4 and 5 Years	Moira Dillon, Brian Reilly, Ellyn Schmidt & Conisha Cooper
46	Executive Function Depletion	3-5 Years	Lindsey Powell & Meg Barrow
47	Preferences for Imitators	4-6 & 11-13 Months	Lindsey Powell
48	Infants Learning About Groups	6-9 Months	Lindsey Powell

Responses to Goal Completion

Amy Skerry, Graduate Student

Expectations about Emotions (8-11 months)

From early in life, humans are sensitive to the emotional expressions of others, and can use them to learn about the world. While existing studies reveal that infants can detect emotional information from overt facial expressions or vocalizations, it is unknown whether preverbal infants are able to infer the emotional state of an individual in the absence of any observable affect. As adults, we understand emotions not only as observable communicative signals that tell us about objects or events in the world, but as expressions of internal states that a person might experience in response to various outcomes. Do infants understand that there are certain situations that make others feel happy, and situations that make others feel sad?

Across several studies, we presented 8- and 10-month-old infants with an animated character that pursues a goal, and either successfully completes the goal or fails to complete the goal. The character then gave an emotional response that is congruent or incongruent with the outcome. We compared infants' looking time to these four events (success+happiness, success+sadness, failure+happiness, failure+sadness). If infants expected the character to be happy upon completing its goal and sad when it fails, this might be reflected in increased looking time to emotional reactions that are incongruent with the observed outcome. Across several studies, we found that infants do distinguish between congruent and incongruent emotional reactions, and in particular look longer at the crying expression when it follows a completed goal than they do to any of the other events.

Ongoing studies extended this paradigm to a social context, asking whether infants this age understand the role that emotions play in social interactions, and in particular whether they understand that social relationships shape the way individuals will react to outcomes that occur for others. We first familiarized infants with two social groups and showed that a character is a member of one group but not the other. Then the character pursued a goal, as in the original studies, and successfully completed the goal or failed to complete it. Infants then viewed the ingroup or the outgroup react with positive or negative affect. If infants understand how social relationships shape emotional Stimuli for Expectations about Emotions reactions in this context they might look longer when the ingroup reacts incongruently, but show no reaction when the outgroup does so.



study.

Sticky mittens studies (3-4 months)

In these studies, we are interested in how infants' experience producing actions affects their ability to infer the goal of another agent's action (i.e. reaching for a ball). Recent research suggests that first-person experience manipulating objects leads 3-month-old infants to perform more like older infants on tasks assessing understanding of goal directed action. Based on these findings, some have concluded that the basic ability to interpret actions in terms of underlying goals or intentions is acquired from first person experience producing actions. In several studies, we seek to understand both the initial assumptions infants have about goal-directed actions, and the additional information that might be available in first person action experience to support making sense of particular actions performed by others.

In these studies, we gave infants velcro-covered mittens and allowed them to interact with velcro-covered objects, which they could lift and slide due to the velcro. We then used a looking time paradigm to assess their expectations about goal-directed action events. In our original study, we found that infants given action experience looked longer at events in which an agent took a longer than necessary path to the goal. Sensitivity to the efficiency of actions is a standard signature of goal understanding in older infants, and we found that infants given the velcro-mittened training demonstrated this effect, but that infants in a no-velcro control condition did not. This year, we replicated this finding and also found that effect occurs only when infants were familiarized with efficient actions. We also ran a follow-up study, which explored one hypothesis about what infants learn in the velcro-mittened condition. In this study, we examined whether the velcro-mittened experience shaped infants' expectations about basic properties of causal entraining events (i.e. that one ball will set another ball into motion only upon contact).



Stimuli for Sticky Mittens study.

Explicit and Implicit Theory of Mind Alexander Bardis, Research Assistant

By the age of four children are able to understand and verbally express when another person has a "false belief" (i.e. their belief is incongruent with the state of their environment). For example, in a situation where one person leaves their favorite toy in box A, and then in their absence the toy is moved to box B, 4-year-olds understand that when that person comes back looking for the toy they will look in box A, whereas the toy is actually in box B. In that context for example, that person has the "false belief" that the toy is in box A. By contrast, a 3-year-old would say that the person would look in box B for the toy, which means that they do not have a robust false belief understanding.

However, previous research has shown that infants, like adults, can keep track of other people's knowledge and use this information to guide their own actions. For example, if someone is looking for a toy in the wrong place because they don't know it has been moved, 18month-olds will help that individual by retrieving the toy from its actual location. However, infant and toddler performance in these kinds of helping situations contrasts starkly with their inability to talk and reason about knowledge and beliefs.

We are interested in understanding this discrepancy between toddlers' ability to act on information about "false beliefs" and young preschoolers' inability to discuss such false beliefs. In this study, one experimenter is looking for his toy, which is hidden in one of four containers. When he finds the toy, he suddenly realizes he needs to leave the room, but before he leaves, he places the toy back in the container where he found it. In his absence, a second experimenter comes from behind a curtain and moves the toy to a different container before returning behind the curtain. When the first experimenter comes back, we ask if 2- and 3-year-olds will help the experimenter find the toy by pointing to the toy's new location. This is a sign that the child understands that the experimenter will be guided by his false belief and will look in the wrong container.

Additionally, the 3-year-olds are asked an explicit "false belief" question by the second experimenter. Once the second experimenter moves the toy from one container to another, she asks the child where experimenter one will look now that the toy has been moved.

Our results show that 2- and 3-year-old participants exhibited correct "false belief" reasoning in the first task. However, the 3-year-olds failed to correctly verbalize their understanding of the experimenter's false belief when asked explicitly by the second experimenter. The findings demonstrate that failures to explain false beliefs do not disrupt the child's thinking about false belief and taking action to help based on that understanding.

Thank you to all the families that participated in this project!



Language and abstract concepts: Memory for time Annemarie Kocab, Graduate Student

Child language acquisition occurs in stages: infants first use one-word utterances dominated by social words like "bye" and concrete nouns referring to people and things, like "shoe" and "doggie". Then children start combing words and using more abstract terms such as adjectives and verbs. Are these increasingly sophisticated language abilities the result of a growing knowledge of the language the child is learning or more general cognitive maturation?

Clues from work with special populations, such as internationally adopted children, who learn one language in their birth country and another in their adoptive country, suggest that both of these possibilities may be correct. Some aspects of language acquisition seem to reflect experience with a language while other features seem to be driven by cognitive development. Of interest to us is the finding that older international adoptees show earlier acquisition of time words referring to the past and future than younger adoptees. One explanation for this finding is that older learners learn time words faster because they are better able to figure out what those words mean and represent their concepts.

The domain of time is interesting because all languages have ways of expressing temporal information, and children progressively develop more sophisticated notions of time. In this study, we are looking at developmental changes in children's memory for events ordered in specific temporal sequences and whether they can detect changes of different degrees. Because children are slow to learn and use time words correctly at first and do not seem to reach a full mastery of the concept of time until the middle school years, we are interested in whether detecting changes in temporal order is more difficult than other types of non-temporal changes, such as changes in the object that was acted on, or the manner in which it was acted on.

In this study, children see a sequence of movies of different events on the computer screen. Then they see another sequence of movies and are asked whether that sequence is the same or different from the original sequence. We have just begun collecting data and look forward to sharing our results in next year's newsletter!



Children's Expectations and Understanding of Kinship as a Social Category

Annie Spokes, Graduate Student

Humans are a highly social species, and we tend to divide the social world into groups. Research in this lab has shown that infants and children categorize others according to age, gender, race, and language. One social category that has yet to be explored in cognitive development is that of kinship, or family. Studies with adults have shown that they encode kinship as a social category as strongly as gender and age. In the current set of studies, we explored whether young children see kinship as a social category and how children expect social interactions to occur among kin and non-kin members. We presented children ages 3-5 years with fictional characters either on a computer or in an interactive storybook. In both versions, we told children about the different characters' relationships, including characters that were siblings, friends, and strangers. We then asked about the relationships and how they thought the characters might interact with each other. For example, if one character has an extra treat, would they choose to share with a friend or sibling? We varied the value of the resource to see if biases for friends or siblings might be stronger in high value situations.



Sample stimuli from computer version & storybook version.

In the computer version, we found that 3- and 4-year-olds did not expect preferences for siblings significantly over others. However, 5-year-olds expected family members to receive beneficial resources significantly more often than both friends and strangers. In the storybook version of the study with 3- and 4-year-olds, children of both ages expected resources to go to a friend or family member over a stranger. However, children expected a character to share with a friend and sibling about equally when choosing between the two. In questions asking about their understanding of different types of relationships, children showed clear understanding of the differences between friends and strangers as well as siblings and strangers, but they were not as clear when answering questions that distinguish between family and friends. Overall, we did not find any differences for children with or without siblings. Taken together, these results suggest that children have explicit knowledge and understanding of relationships among familiar individuals—friends and family—when they are compared to unfamiliar individuals strangers. However, 3- and 4-year-old children do not clearly differentiate between friends and family both in understanding and expectation for their interactions. This distinction may emerge as kids get older, because 5-year-olds do expect a kinship bias. Future work will further investigate children's understanding of these relationships and use different measures that can tap into more subtle expectations for social interactions using first person scenarios and behavioral measures.

Young Children's Distribution of Resources Based on Need (Benevolence) Elizabeth Letvin, Honors Thesis Student

Recent research has shown that young children are able to utilize situational information when deciding how to divide resources between themselves and a peer. This study examined at what age children will use the "Need" principle: choosing to allocate more resources to a peer in need of the resources being distributed compared to a peer who is not in need of the resources being distributed. We looked at whether five- and six-year-old children will vary how they share stickers with a partner based on the partner's need for the stickers.

In this study, the main experimenter presented the child and the puppet (representing a peer) with an equal number of stickers. During one trial, the puppet's stickers were lost, and the puppet was in need of more stickers. During another trial, the puppet's stickers were not lost, and the puppet was not in need of any more stickers. At the end of each trial, the children were asked to divide six additional stickers between themselves and the puppet.

The children preferred to divide resources equally in both situations and did not consider the puppet's need. It is possible that the children did not care how they divided the stickers because they did not find the stickers interesting or valuable. We made several minor changes to the procedure to ensure the children were paying attention to the stickers and believed their decisions were important. However, the five- and six-year-old children continued to divide the stickers equally between them



has opened the door for future studies to examine the intricacies of how young children incorporate "need" information into their sharing behaviors.





Bribery

Carla Sebastian, Visiting Graduate Student & Kerrie Pieloch, Lab Manager

When we hear the word "bribery," we commonly think of corruption and other kinds of undesirable behaviors. However, from a formal point of view, bribery does not necessarily have a moral connotation. Instead, it can be defined as a person giving a resource to someone in order to influence his or her behavior. In accordance with this definition, bribery is highly related to reciprocity as long as the recipient favors the donor in some way. Our study deals with this phenomenon. In a previous study (Strategic Reciprocity), we found that five-year-olds shared significantly more with a partner who had higher-valued resources than with another partner who didn't have the chance to reciprocate the gesture. But will five-year-olds further understand that acting prosocially toward the correct person can tip the scales in their favor? In addition, we know that children in middle childhood (around seven years of age) start using strategies to manipulate another's positive views of them. For example, they can enhance some aspects of themselves while downplaying others to convince other children to pick them as partner for a game (self-presentation). In this research, we were interested in whether five- and seven-year-olds could benefit another person in order to trigger preferential treatment from that person.



Children played with two adults (game owner & confederate). In the first step the child and the confederate each received two stickers, a high-valued and a low-valued sticker, and both were told to choose which one they wanted to keep for themselves and which one they wanted to give to the game owner. In the second step the game owner chose a partner to play a game with: she could choose either the child or the confederate. The crucial point of this task was that children knew in advance that the game owner was going to decide with whom to play in the second step. If children understand that they can influence the owner's decision by being nice to her, they will give the best sticker to the owner. Data collection for this study is ongoing, and we look forward to sharing the findings with you very soon!

Seeing Sets Arin Tuerk, Graduate Student

Previous research with adults shows that when we look around the world we are constantly grouping arrays of objects together and encoding them efficiently as "sets." Given the fact that our visual system is severely limited in the number of objects it can represent in parallel, encoding sets of objects instead of individuals allows us to remember information about more total things. For example, when we look at the leaves on a tree, although each leaf is a little different in color, length, width etc., we tend to represent the average properties of those leaves, averaging across the variation on each dimension. While we can't report whether the longest leaf on the tree was also the greenest, we can make general statements about how long and green the leaves were on average. Instead of attending to each member in the set, we save ourselves the extra cognitive load and represent the gist. In more controlled studies, we have seen that when adults are quickly shown an array of circles of varying sizes, they are actually more accurate at estimating the average size of the set of circles than the size of any one circle in the set. Additionally, adults are equally good at determining the average orientation, or tilt, of a set of items as they are at remembering the orientation of a single item. Our question is whether infants also engage in this type of perceptual averaging and efficient representation.



During this study, 6-month-old infants were in either the size or orientation condition. In the size condition, infants were habituated to cycles of homogeneously sized dot arrays and in the orientation condition, infants were habituated to cycles of homogeneously oriented shapes. In both conditions, we used arrays of identical items as this should be the easiest case for averaging. After the habituation trials, we presented infants with test arrays that had either the same dot size or the same orientation as the habituation arrays, and interspersed these familiar arrays with novel ones. In novel size arrays, dots were 2, 3 or 4 times larger or smaller than those seen during habituation. In novel orientation arrays, items were tilted 5, 7 or 9 degrees away from the familiar orientation. We then measured which of the test arrays the baby found more interesting, or spent more time looking at. We know that infants tend to look at things that are new or different, so if he or she spends more time looking at the arrays with the novel size or orientation, we will know that he or she has encoded the common feature of the habituation arrays.

We found that at six months, although infants successfully discriminated a twofold change in the size of a single dot, when habituated to homogeneous dot arrays, they could only successfully discriminate a fourfold change in item size. This result suggests that if the ability to compute average size is available in infancy, the acuity of these representations is significantly worse than that of individual items' size representations. Though our orientation results are more preliminary, we are finding that at six months, infants are already able to represent the average orientation of a set of items with the same acuity with which they represent the orientation of a single item. Taken together, these findings suggest that the developmental trajectories of the systems computing average size and average orientation are different. How does each of these systems develop and what makes these seemingly similar computations so different? Those are questions for the next newsletter!



Desire, Understanding, and Helping Kate Hobbs, Graduate Student

By about 14-months, infants seem to be genuinely helpful creatures. They often bring us toys and things to show us and will even help us when we can't reach an object. Of course, many parents report that this all changes when the "terrible twos" roll around! However, even if infants don't want to be helpful, they may still know how to be helpful. This study begins to explore what infants know about others' emotions and how to be helpful.

To be maximally helpful one must be motivated to help by meeting another's needs, and one must be aware of exactly what that person's needs are. If your friend is hungry and prefers goldfish crackers to broccoli, giving her broccoli is nice enough, but not as helpful as it would be to give her some goldfish. Previous research has shown that by 18 months of age infants can discern which of two food items someone likes based on her emotional responses to each, and will give the person her preferred food.

Our study seeks to explore the extent to which children can read others' emotions to figure out their preferences, and the extent to which children are intrinsically motivated to help accordingly. So far we have learned that even when they try to be helpful, 2-year-olds don't always know the best way to do so. In past studies 2-year-olds helped often by handing an adult one of two out of reach objects, but didn't consider which one she preferred when deciding which one to give her. Oftentimes the 2-year-olds simply gave the adult both objects, even when she really didn't like one of them. Thus 2-year-olds, while being exhaustively helpful, haven't yet mastered the art of selective helping, at least in our lab context.

We are currently piloting new-and-improved conditions with both 2- and 3-year-olds. We hope that by improving the helping context and making it clear to children that they don't have to give everything back to the experimenter, we will see selective helping behaviors emerge. That is, if Sally likes a block but doesn't like a ball, the child should hand Sally back the block but not the ball. This is one study you can try at home with your kids!



The Development of First Impressions from Faces Emily Cogsdill, Graduate Student

Previous research has shown that adults use facial characteristics to attribute personality characteristics to other people both rapidly and with a high amount of agreement. However, although research suggests that children begin to attribute personalities to other people starting at around age seven, little is known about how and when they use physical appearances to make such judgments.

In this study, we looked at the developmental origins of face-based personality attributions. In particular, we were interested in learning when children begin to attribute traits (like "mean" or "nice," or "strong," "smart," etc.) or behaviors (e.g., helping friends) to people based on their facial features in the same way that adults do this.

To test this question, we showed children ages 3-10-years old pairs of faces that had been rated by adults to appear either trustworthy/untrustworthy, dominant/submissive, or competent/incompetent. Each pair of faces consisted of one "high-trait" face (e.g. Trustworthy) and one "low-trait" face (e.g. Untrustworthy). We then asked children to either attribute a behavior to one of the faces (e.g., by asking, "Which of these people always tells the truth?"), or to attribute a trait to one of the faces (e.g., "Which of these people is very nice?"). We also had a sample of adults make these same judgments for comparison.

Our results suggested that adults and children of all ages made reliable personality attributions based on facial features. Children as young as 3 years of age were nearly as consistent as adults when judging trustworthy and competent faces as "nice," and dominant faces as "mean." We also found that children readily attributed trait-relevant behaviors to faces. For example, even 3-year-olds consistently identified the competent-looking faces as the ones that "can draw pretty pictures" or "know how to sing a lot of different songs."

In future studies, we hope to explore not only how children attribute traits and behaviors to faces, but also how they themselves might behave towards faces that they might associate with different traits and behaviors. We are currently studying this by showing children pairs of faces that have been rated to appear "nice" or "mean," and seeing whether they will more frequently give a single token (for example, depicting a cookie or a present) to the nicer-looking face instead of the meaner-looking face. This will further develop our understanding of not only how children interpret their social worlds, but also how they themselves might respond to them.



Learning in Parallel Jean-Remy Hochmann, Post-Doctoral Fellow

As they develop, infants need to learn about objects, people, numbers, language and many other domains. Importantly, they need to do all of this in parallel. We are working on designing a way to study infants' ability to learn (at least) two things in parallel.

During the study, children sat on their parents' lap, facing a computer screen. This screen is equipped with an eye-tracker that automatically detects the eyes, and allows us to precisely monitor the position of the children's gaze on the screen. On each trial, children saw a picture, after which a puppet appeared either on the right or on the left of the screen. The puppet appeared in a given location if the picture represented a dog, and in another location if the picture represented a car. By monitoring the location of their gaze on the screen, we asked whether children can learn to predict the location of the puppet's appearance. We found that from 14- to 18-months, infants are unable to learn the two predictions at the same time, but learn only one. Most infants learned to make correct predictions after seeing dog pictures, but not after seeing car pictures, evidencing a stronger interest for animals than man-made objects!

We are now testing older infants to understand at what age they can learn the two predictions in parallel. We are also trying to understand what could make the task easier for young infants in order to understand what conditions help them learn in parallel. Stay tuned!



Same and Different Jean-Remy Hochmann, Post-Doctoral Fellow

Aristotle famously stated: "There is nothing in the intellect that was not first in the senses." The research in our lab tends to disagree with that statement. In our current work, we approach this question by studying infants' ability to represent abstract relations such as the concepts "Same" and "Different."

In this study, 14-month-old infants watched a series of videos that always had the same structure: three cards were presented, initially face down; each card would then flip, revealing a symbol drawn on its surface. The middle card would always be the same, either as the right card or as the left card. What happened then differed for each infant. For half of our young participants, the card that had the same symbol as the middle card would start flashing. For the other half of our participants, the card that had a different symbol from the middle card would start flashing. The cards would then flip back. As we repeat the presentation of the videos, we observed that infants learned to anticipate, and looked at the card that would flash before anything actually happened! This shows that infants learned to predict which card would flash, base on its relation with the middle card (whether it was the same or different).

Furthermore, in some of the trials, one of the cards (either the right or the left card) did not actually flip, so that its symbol remained unknown. We observed that infants were better at making a choice when they saw only the card that was the same as the middle one, than when they saw the card that was different. Surprisingly, this was also true for infants who learned to look at the different card! This suggest that in one case infants learned to select the card that was the same as the middle one, and in another case they learned to avoid that card. In sum, we found strong evidence that 14-month-old infants can represent the abstract relation "same" between two cards, but they may not be able to represent the relation "different" yet.



Process of Elimination in Infancy Jean-Remy Hochmann, Post-Doctoral Fellow & Shilpa Mody, Graduate Student

Imagine I show you two cards face down, and tell you that one of them is the Queen of Hearts. If you pick up the right card and see it's a King, you can be confident that the left card is the Queen of Hearts. This is the process of elimination. We used an eyetracking method to investigate early and probably implicit abilities to use the process of elimination.

We showed 10-month-old infants two cards on a computer screen equipped with an eyetracker. In the first 8 trials of the study, both cards flipped over and one of them always revealed a smiley face that then began to flash. Infants learned to look and expect that smiley face. In the second phase of the experiment, one of the cards flipped and revealed a basketball. Would infants expect that the smiley face is on the other card? This is what we are interested in understanding, but it's too soon to tell. We'll keep you posted in the next newsletter!



Speech Perception Jean-Remy Hochmann, Post-Doctoral Fellow

Everywhere in the world, unless unable to speak or hear, human communities use speech to communicate. Studying how very young infants perceive speech is therefore crucial to our understanding of language acquisition. In this study, we are trying to understand what are the units of speech that infants represent. In particular do they realize that a syllable is composed of at least two elements: a consonant and a vowel. For example, a word such as bay is made of two elements: a consonant b and a vowel ay. If infants know this fact, they should easily realize that the words ball, bird, bee and bay all start with the same consonant, but that the word day start with a different consonant.

In this experiment, we simply exposed 3- and 6-month-old infants to a series of words that all start with the same consonant, (for instance ball, bird, bee and bay). Once in a while infants would hear a word starting with a different consonant (for instance day). We ask whether infants are surprised when they hear a word with a different initial consonant. To measure infants' surprise, we used an eyetracker that automatically detects the eyes of infants and measures the pupil diameter. Namely, we ask whether the diameter of the pupil increases when infants heard a word starting with a different consonant. Results showed that 6-month-olds, but not 3-month-olds, were surprised when the word day was presented compared to words such as bay, ball, bird and bee. This suggests that 6-month-old infants already know that a syllable is composed of two elements: a consonant and a vowel.

Infant Desire Understanding Kate Hobbs, Graduate Student

From the time they can walk, infants engage in acts of helping others. In particular, children are great at handing us objects that are out of our reach and helping us complete instrumental actions. But exactly what aspects of our needs, goals and desires are children actually considering when they help us in these ways? Research in our lab over the past few years has tried to address this question.

In previous work we investigated infants' abilities to help appropriately when an experimenter likes only one of two toys. We first familiarized children with the actor's preference (figure 1). In the subsequent test trials the objects were out of the experimenter's reach and sight (figure 2), and she asked the child for help. We found that 24- but not 14-month-olds help an experimenter

by giving her her preferred object reliably; 14-month-olds give either of two objects indiscriminately. While 14-montholds are not yet maximally helpful when the experimenter's goal is unclear at the moment they need to help, they can help appropriately when it remains clear during the test trial which object she prefers (figure 3). We are currently running a follow-up study to ask whether children prioritize past preferences of current goals in deciding how to help others. This experiment begins with the experimenter reaching for one of two toys, three times in a row. In the test trials, the toys are out of her reach, but now she tries to get the other toy. We are curious whether children will override her current reach to help in accordance with her past preference, or simply go with her present reach. The study is nearly complete, so we can't comment on the results yet!

A second follow-up study investigated the role of language in understanding others' desires. In the experimental condition of this study the experimenter used very specific language to describe her preference for one of two novel objects (eg "a blicket! I like the blicket. I really want the blicket. I'm going to get the blicket!"). She then reached for that object several times in a row. We then measured whether the child reliably helped her by handing her the object she said she wanted. In the control condition the experimenter talked about the object just as much, but didn't use any specific desire language about the object. The results of the study were inconclusive, with children in both conditions acting helpfully but not based on the actor's preferences.



Figure 1



Figure 2



Figure 3

Language Acquisition and Theory of Mind Kate Hobbs, Graduate Student

Our research project aims to investigate the role of language on the development of reasoning about others' thoughts, beliefs, feelings, goals and desires—what researchers call a "Theory of Mind (ToM)." In preschool-aged children, studies have found a strong link between language abilities and ToM. Our research aims to extend this kind of research to even younger children, asking where in development this relationship between language and ToM begins. We have tested both typically developing hearing children and deaf children between 17 and 27 months to find out whether differences in early language abilities are related to the development of social reasoning.



Imitaion Task Stimuli



Task Demonstration

Our study used three interactive tasks to measure children's social understanding. In the imitation task we asked whether children can figure out what the experimenter was trying to do with a toy, even though she never succeeded. In the pointing task we measured how children use pointing to request objects or inform others and how they respond appropriately to others' pointing. In our helping game we asked whether children use information about an actor's knowledge state to figure out her goal and help her appropriately. We also played a memory game with children to measure their cognitive development outside the domain of social reasoning. And to measure vocabulary knowledge, parents filled out checklists indicating the words their children say and/or understand.

We have completed testing of hearing children and are nearly finished testing our sample of deaf children. In the hearing group we have found no relationship between how many words a child knows and how they perform on our tasks of social understanding. In comparing the deaf children to same-age hearing children we do find that on average deaf children know fewer words. But despite this difference in vocabulary size, there are no apparent differences in social understanding between the deaf and hearing children in our study.

These results suggests that early social cognitive abilities—such as reading others' intentions, using and responding to pointing communicatively, and reasoning about others' goals and desires—develop independently of language acquisition. These early abilities provide a strong foundation for later development of more complex ToM skills, such as reasoning about others' thoughts and beliefs. While we will continue to work with additional deaf children between the ages of 18 and 26 months, we also hope to begin a longitudinal study that follows deaf children into the preschool years.

Causes of Behavior Larisa Heiphetz, Graduate Student

Earlier studies in our lab have shown that children typically attribute more positive rather than negative behaviors to peers who share their religious beliefs. In this study, we were interested in whether the opposite might also be true. That is, do children think that behaviors done for a religious reason are somehow better than behaviors done for non-religious reasons?

We told 5-10 year old children and adults about pairs of characters, one of whom performed a behavior for a religious reason and the other of whom performed the same behavior for a nonreligious reason. For example, we said that one character helped her friends because she thought that would make God happy and another character helped her friends because she thought that would make her parents happy. We asked children which person's behavior was better and which person they liked more.

We found that the youngest children (5-6 year olds) showed a slight preference for the religiously-motivated behaviors regardless of their own family's religious background. With age, however, the responses of children from religious and secular families diverged. Religious participants of all ages showed a slight preference for the religiously-motivated behaviors. However, secular participants showed stronger preferences for the secularly-motivated behavior as they got older. By the time they reached adulthood, secular participants preferred the secularly-motivated behavior much more strongly than religious participants preferred the religiously-motivated behavior.



Following up on this study, we tested 5-10 year old children and adults using a slightly different method. Instead of asking participants to decide which character they liked better, we asked them how much they liked each character, thereby allowing participants to say that they liked all characters equally. In addition to testing the religious motivations used in Causes of Behavior 1 (making God happy and making one's parents happy), we included a second secular motivation (making one's self happy) as well as a control condition where the experimenter did not give any reason for the behavior.

Data analyses for this study are still on going, but preliminary results suggest that religious background may exert a stronger influence on adult's rather than children's responses. Whereas children from religious and secular families reported liking the religiously motivated characters equally, religious adults reported liking religiously motivated characters more than did secular adults. This difference between children and adults appears to be specific to religiously motivated characters; religious background did not seem to differentially influence children's and adult's liking of the other characters. It is important to remember, however, that these results are preliminary and may change as we analyze more of the data we collected.

People's Behaviors Larisa Heiphetz, Graduate Student

Previous work in our lab suggests that children prefer peers who share their beliefs in a number of domains (e.g., fact, preference, religion) and selectively attribute positive behaviors only to characters who share their religious beliefs. In this study, we examined children's preferences in belief domains to see whether some beliefs exerted a stronger influence than others.

We asked 6-8 year old children about their own beliefs in the domains of fact (e.g., "Some people think that the Nile is the longest river in the world, and some people think that the Amazon is the longest river in the world. Which do you think?"), preference (e.g., "Which color do you think is the prettiest one?"), and religion (e.g., "Some people think that God can do miracles, and some people think that no one can do miracles. Which do you think?") Then, we showed children pairs of characters. In each pair, each character shared a belief with the participant in one domain and had an opposing belief in another domain. For example, a child who said that she thinks the Nile is the longest river in the world and that she thinks God can do miracles might see a trial where the experimenter says, "This person [pointing to the left of the screen] thinks that the Nile is the longest river in the world, but she does not think that God can do miracles. This person [pointing to the right of the screen] thinks that God can do miracles, but she does not think that the Nile is the longest river in the world." Children then answered questions intended to measure their social preferences (e.g., "Which of these children do you think you would rather be friends with?").

We found that children preferred characters that shared their religious beliefs to characters that shared their factual beliefs. This may have occurred because children prioritize religious beliefs over factual beliefs in general or because we used factual beliefs to which most children did not know the right answer and with which most children were unfamiliar. Children may care more about factual beliefs that are more familiar to them. We did not find a difference between religious and preference-based beliefs; that is, children seemed to like characters approximately equally regardless of whether they shared their religious beliefs or their preferences.

A Story That Will Make Your Eyes Grow Wide

Manizeh Khan, Graduate Student



'The eyes are the windows to the soul', the saying goes, and indeed we all intuitively know the value of looking into someone's eyes when we want to know how they're feeling or what they're thinking. In our lab, we've been taking this intuition in a scientific direction by measuring children's eyes to figure out how they're thinking about the information they're taking in, especially with respect to language.

One challenging aspect of studying child language is that often you want to know what's happening in their minds at the very moment that they're hearing a word or sentence, not just what they think after they've finishing listening to it...but you can't keep asking them questions while they're still listening to the sentence. So instead we try to find indirect ways of measuring children's language comprehension. One technique we are currently exploring is monitoring children's pupil size while they listen to sentences. We know from decades of work with adult participants that people's pupils dilate when they are thinking hard about something, whether it is making a difficult decision, solving a mental arithmetic problem or remembering a long list of items. Our question in this study was to ask whether preschool-aged children's pupils would dilate when they had to think hard about what a sentence means, and then using this method we can explore what sorts of sentences are difficult for children to understand.

Children who participated in this study watched a cartoon character tell stories about Dora, D.W., Arthur and Diego, while sitting in front of a computer that can remotely monitor their pupil size and eye movements. The stories they heard all included a pronoun, either "he" or "she". Sometimes it was easy to figure out who the pronoun referred to, for example the story was about Dora and Arthur and the pronoun "he" was used. Other times the child would to figure out who the pronoun referred to using the wider context, for example hearing "he" in a story about Arthur and Diego. We also looked changes in pupil size for "silly" sentences. For example: "The man fried the trumpet and then buttered the toast". Preliminary results suggest that children's pupils dilate when they hear the word "trumpet", showing that they immediately detected how silly that sentence was, well before the end of the sentence.

Sentence Processing in Children

Margarita Zeitlin, Lab Tech

In our lab, we are interested in understanding how children process sentences as they hear them, but this is no easy task! As we listen to a speaker, we start to build the meaning of the sentence we're hearing long before the sentence is complete. How can we tap into this process without interrupting it? One tool that we have at our disposal is looking at eye movements. When we speak, we tend to look at the things in the world around us that we're talking about; we can certainly talk about things that don't exist or aren't in the room, but eye movements are generally a good measure of what is happening during language comprehension. This year, we've applied this method to two studies.

What are you looking at?

The goal of this study is to see how children process sentences when they are preceded by different, unrelated sentences. Children listened to a story and were then given instructions that they acted out with the toys laid out in front of them. Sometimes, the sentences they heard in the story had the same structure as the sentences they heard in the instructions, and sometimes they were different. We wanted to see if children would make predictions during the instructions based on the sentences they heard in the story. For instance, when children were presented with sentences that had an animate subject after the verb (i.e. "She sang the boy a story. Then she read the girl a song."), they looked more at the animate toys on the stage than the inanimate ones. Some of the objects on the stage started with the same sound (i.e. money and monkey below). In these cases, children looked more at the animate monkey than the inanimate money before they heard the whole word, even though it wasn't clear which toy was being talked about!



How do you do that voodoo that you do?



Before you keep reading, take a look at the picture above. Suppose you heard the sentence "Point at the monkey with the flower." How would you act it out? Would you use the flower in the upper right hand corner to point at the monkey, or would you point at the monkey with your finger? These are the kind of ambiguities adults and children face every day in language. However, we have some tools at our disposal. One of these tools is verb bias: some verbs will push the interpretation of the sentence in one direction, and some verbs will push it in another. For example, if instead you heard the sentence "Look at the monkey with the flower," you would be more likely to use your eyes to look at the monkey than use the flower to "look" at it. However, the verb "tickle" would more likely lead you to use the flower to tickle the monkey. In this study, we are interested in how children interpret sentences with equi-biased verbs (i.e. verbs that are just as likely to lead you to one interpretation as they would the other, such as "point"), and whether their own biases are malleable enough to be affected by our training session.

Understanding Scenes and Objects in Line Drawings Moira (Molly) Dillon, Graduate Student

Adults across human cultures can interpret drawings that represent the spatial world. However, it is unclear how humans use the 2D information in drawings to understand 3D scenes and objects. We hypothesize that our ability to understand geometric information in spatial symbols like drawings is built from our ability to navigate the surroundings and to recognize objects in the environment.

In this study, we examined how tightly linked navigation and object recognition were to interpreting perspective line drawings during the critical point in development where children are starting to understand that drawings represent real 3D scenes and objects. We tested more than 200 four-year-old children on a number of different line drawing interpretation tasks including tasks depicting a bare room, a small Lego object, and either or both the scene structure or the objects in a room with objects in it. With the help of Mr. Monkey or Baby Monkey, our dedicated participants found lots of locations using information in drawings.



Our results indicate that children's ability to navigate and to recognize objects contributes differentially to their ability to interpret drawings. Critically, as children develop these spatial skills, they seem to rely on the information available in the environment. For example, children's ability to navigate is recruited when they are presented with line drawings of scenes, while their ability to recognize objects is recruited when they are interpreting drawings of objects. Even when children are given both scene and object information in a drawing, they rely on one kind of information or the other, but not both, based on the location of the target information in the environment.

We are excited to delve deeper into children's understanding of drawings and hope to uncover more information about how children's early-emerging spatial abilities give rise to their later, more complex spatial understanding. We think that such understanding might contribute to children's appreciation of more complex spatial properties, like those that support the geometric learning taught in school.

Infants Chunk to Remember More Things Mariko Moher, Post-Doctoral Fellow

Working memory allows us to temporarily store information necessary for carrying out various tasks. Working memory has a limited capacity, but adults have several strategies for keeping more items in memory. For example, we divide phone and credit card numbers into smaller groups of three to four numbers each to remember them. We might also choose to divide a long grocery list into categories such as "vegetables" and "dairy" rather than struggling to remember "milk, asparagus, cheese, lettuce, yogurt, spinach." Grouping information into easy-to-remember units like this is called "chunking."

What are the origins of these chunking strategies? We know that this ability exists in some form in infancy. When seven-month-old babies see three identical objects being hidden, they forget the number of items they saw. But when the objects are separated into distinctive groups, babies can remember all three items. For example, if a baby sees two green balls being hidden together behind a screen on the left, and one blue cube being hidden behind a screen on the right, she will remember that there are three objects. So chunking cues do let infants hold more items in memory.

But how much do infants remember about the very cues that help them to keep, say, three items in memory? The previous findings told us that babies could remember how many items were hidden, but not necessarily that babies remember what exact items were hidden. Take the example from above – do babies remember that there were exactly two green balls and one blue cube? Or do they just vaguely remember that the three objects



had some sort of shape or color differences? In an ongoing study, we are investigating such questions about the specificity with which infants remember chunked items.

We know that infants tend to look longer at events that are surprising or unexpected, so in this study, seven-month-old babies sit on their parents' laps while facing a puppet stage. We show them several objects of different colors and shapes being hidden behind two screens. On some trials, we secretly switch out the objects for other ones. If babies can keep track of the specific colors and shapes of individual objects, they should look longer when the screens are lifted and a surprising outcome is revealed – for example, when we switch out a green ball for a blue cube.

The study is still in progress, but the early data suggests that when it comes to what babies remember, the type of secret switch we make matters. It's likely that babies are sensitive to some changes in the display, but aren't remembering the exact toys we showed them. So despite infants' sophisticated ability to chunk items and remember them in memory, it looks like chunking only gets them so far.

Infants' understanding of causal events Mariko Moher, Post-Doctoral Fellow & Mirta Stantic, Research Assistant

We know that a tower of blocks can fall down when we knock it over, and that one ball hitting another ball can make it roll in the same direction. Without understanding of causality, however, we would have no idea that the first event was necessary for the second to occur, and the world would be a much more chaotic place than the one we know. Events would happen for seemingly no reason, and we would be unable to predict them or react appropriately. Previous research has already demonstrated that infants have a deep understanding of simple causal events such as launching (one ball hitting another), and that this knowledge emerges in infants as young as 6 months.

However, not all causal events are as obvious or simple as launching. For example, a fragile box might be broken by a clumsy hand, or a specific button on a toy, pressed, might play music. Although these relationships maintain a similar causal structure, they don't have the overt transfer of energy like launching events. Studies in the lab over the last few years have demonstrated that 8-month-old babies see these events as causal, too, expecting the two items to touch, for example, before the event occurs.

The fact that events that vary so much in their specifics (a ball being launched, a box being broken) can all be seen as causal by infants suggests that infants' understanding of causality relies on a rich representation of components. In all of these events, there is an agent, which initiates the event, a patient, who undergoes some kind of change following contact, and an event, whether it be launching or breaking. In the current experiment, we are examining infants' rich understanding of these components.



Our overall goal is to examine whether infants can remember multiple causal interactions, and when things start to fall apart, whether they tend to preserve the agent-patient-event relationships they saw. For example, if they saw a hand break a box and a ball launch another, will they be surprised if they see a hand launch a ball? Over the last few months in the lab, we've started by exploring whether infants can represent simple events shown on a computer screen. Infants first saw movies where a cartoon character approaches a box and upon contact, the box breaks. When they became bored with the display and their looking times declined, we showed them a display that violated the causal relationship - the box broke before the character touched it. We're expecting infants to tend to look longer at this unexpected, non-causal event than they did to the causal, familiar event.

Next, we'll be testing other causal events and ultimately move on to asking whether individual babies can remember multiple causal events at the same time. Thanks to all of the babies and parents who have participated so far, and we hope to see you again soon!



The Process of Elimination Shilpa Mody, Graduate Student

What kinds of logical reasoning skills emerge early in development, and how do those skills change as we grow older? In this study, we asked whether toddlers at different ages could use one particular reasoning tool: the process of elimination.

Children and adults use the process of elimination effortlessly in everyday settings. For example, if you know you left your cellphone either in your bag or on the counter, and you've already searched in your bag, you can assume that it's on the counter without having to check. To reason like this, you have to be able to consider multiple alternatives, then update your beliefs with new information about where your cellphone is not, and finally combine all this to infer where your cellphone must be.

We investigated this line of reasoning in toddlers by playing a searching game. They watched while we hid a toy in one of two buckets, but couldn't tell which one we'd put it in. Next, we showed them that one of the buckets was empty. Then we asked them to look for the toy. Using the process of elimination, they should reason that since the toy isn't in the empty bucket, it must be in the other one. 23-month-olds and 17-month-olds looked in the correct bucket about 75% of the time, suggesting that they're successfully using the process of elimination. However, 14-month-olds only chose the correct bucket 40% of the time, instead preferring to look inside the empty bucket!

Currently, we're trying to understand the reason behind the 14-month-olds' behavior. Can they really not use the process of elimination at all, or were they simply not applying it in this particular case? What aspects of cognition are changing between 14 and 17 months? Is the change related to infants developing language skills? Thanks so much to all the families that participated!

Guessing and Knowing Shilpa Mody, Graduate Student

Theory of mind - the ability to understand others' desires, intentions, and beliefs – undergoes striking development during the preschool years. However, much less is known about preschoolers' developing ability to reason about their own mental states. In this study, we explored how young children reason about their own beliefs of certainty and uncertainty. Can they tell the difference between things they are sure about and things that they have to guess at?

To investigate this, we had 2.5- to 5-year-old children (in the lab and at the Boston Children's Museum) play a game where they competed with an experimenter to find stickers. The participants watched as two identical stickers were hidden inside four cups, then took turns guessing which cup contained a sticker. On some rounds, the child could be sure that one cup contained a sticker, but didn't have enough information to know where the other sticker was. On other rounds, the child could be sure that one cup did not contain a sticker, and again couldn't be sure about the location of the other sticker. Our question was whether preschoolers can reflect upon this knowledge – do they use information about their own certainty and uncertainty to guide their choices?

So far, our results suggest that children's choices in this situation change a lot between 2.5 and 5 years old. Our older participants were very likely to pick the sure bet rather than guessing, and to guess rather than picking the surely empty cup. However, our youngest participants tended to choose all the options equally often. This suggests that children's ability to monitor their levels of certainty and uncertainty may be developing through the preschool years – they may still be learning about the difference between guessing and knowing. We're very thankful to all the families who helped us with this research!

Reasoning and Causality Shilpa Mody, Graduate Student



Deciphering cause and effect relationships is an important skill for understanding the world around us. In some situations, there are multiple possible causes of an event; for example, a headache could be due to stress, a lack of sleep, a lack of coffee, or any number of other things. However, if you always get a headache when you haven't had your morning coffee, regardless of your sleepiness or stress levels, the coffee is the most likely cause of the headache. In this study, we're looking at toddlers' ability to use different patterns of evidence to determine the most likely cause of an event.

We introduce children to a toy that lights up when some – but not all – blocks are placed on it. On each trial, we demonstrate the effect of two or three blocks on the toy, including some combinations of the blocks. In some cases, it's unambiguous which block is causing the effect, while in others children must combine the different bits of information they've seen to infer which block is the likeliest cause. We then encourage children to choose one of the blocks to try out. Based on their choices, we can infer what kinds of reasoning patterns they use to understand cause and effect.

This study has just gotten started, so it's too early to tell what the results may be. However, we're looking forward to seeing how toddlers from 14 months to 24 months old will do, and we hope to have some interesting results to share with you in the next newsletter!

Find the friend Narges Afshordi, Graduate Student

As members of a highly social species, we pay attention to and remember the relationships between people. For instance, it is typically easy for us to figure out who is friends with whom. As adults, we can observe people's behavior and judge whether they are friends or not. But how good are four-year-old children at this?

In this study, we examine the types of information that young children can use to decide who a person is friends with. To test this, we showed children pictures of three kids and provided some information about them. In each trial, there is a target child and two potential friends. In the Social-Random condition, children were told that the target had socially interacted with one child (e.g. by helping him clean up his room), and that he had something random in common with the other child (e.g. they had both been to the aquarium recently). We then asked children who the target child's friend was. In this condition, children typically thought that previous social interaction went with friendship.

In the second condition, called the Similar-Random condition, the target child was similar on some dimension to one of the children (e.g. they were both good at running) and once again had a random commonality with the third child. Again, four-year-old children thought that the similar characters were more likely to be friends.

So far, so good! However, what happens if we compared social interaction with similarity? This is exactly what we did in the third condition, in which the target child has interacted with one child before and is similar to the other child on some dimension. We don't have enough data yet to be able to tell what children expect in this more subtle comparison. Our intuition as adults suggests that having already engaged in behaviors that are natural to friendship (e.g. inviting someone to your birthday party) should be strong evidence that you are in fact friends with that person. However, young children may see things differently for a number of reasons. Chief among them could be the fact that many young children are 'friends' with whomever they are around. Their friendship choices usually do not carry the more voluntary flavor that comes with choosing friends later on. Stay tuned for more results as we continue to explore what friendship means to young kids!



Speech is social Narges Afshordi, Graduate Student

Language is integral to human life. It allows us to communicate with one another in an unparalleled way. We can talk to others about our ideas, our emotions, the past, the future, and so much more. But not all of language's power lies in its communicative function. There is also rich social information embedded in our speech. For instance, we can tell where someone comes from by their accent, and we can make guesses about their emotional state based on their tone.

Sometimes, it's less about what we say and more about who we say it to. Imagine walking into a crowded room of people and observing people's interactions. You may see some people engaged in conversation, talking in happy enthusiastic tones and gesturing wildly. You may also see a few people standing close to each other, but not really talking much. The room is very noisy and you can't really hear what anyone is saying, but having just seen this brief scene, you can make a relatively educated guess as to who knows whom and who doesn't. Although you can't be sure, it's pretty likely for people to know those they are speaking to. But do babies make similar guesses when they see people

talking to each other?

In this study, we show 9-month-old infants videos involving three people sitting on a bench. The person sitting in the center (let's call her the 'actor') turns to one side, smiles and speaks a short sentence with positive intonation. The actor also turns to the other side and coughs in the general direc-



tion of the person sitting on that side. The babies see these two events a few times so that they are able to absorb what is happening. Then in the test trials, babies watch the actor in two new events: she takes turns between scooting over to the person she talked to and the person she coughed at. If our hypothesis is correct and infants do in fact expect the actor to show more liking for the person she talked to, they would be surprised to see her approach the person she coughed at. In line with many prior experiments, we monitor and record the duration of time that babies look at each test event as a way of measuring their surprise. The basic idea in this method is that infants typically look longer at things that surprise them. So in short, we expect infants to look longer when the actor approaches the person she coughed at.

Although preliminary results seem to suggest that infants are distinguishing between the two test events, we don't yet have enough data to fully test our hypothesis. If 9-month-old infants do turn out to expect the actor to approach the person she talked to and not the person she coughed at, there are other interesting questions to pursue. For instance, would babies have reacted the same way if the actor didn't smile as she talked? Would infants younger than nine months have similar expectations? Stay tuned as we explore what goes on through babies' minds when they watch people interact with each other!

Biology and Executive Function Nathan Tardiff, Lab Tech, Deborah Zaitchik, Research Associate, & Alexandra Hasse, Research Assistant

Children's understanding of living things undergoes a profound transition between the ages of 5 and 8. Preschool children associate life with movement and activity. This leads them to make "animist" judgments, such as saying that the sun is alive, and to deny life to plants. By age 8, children have developed their first biological understanding of living things, in which the body is understood to be a system whose parts work together to maintain life.

In this study we are seeking to understand what mental skills help children make this transition. Previous work in our



has implicated executive function in the learning process. Executive function includes working memory (holding things in mind and operating on them), inhibition (stopping yourself from making a habitual or dominant response), and setshifting (switching between different rules).Executive function supports goal-directed behavior and has been shown to be more predictive of success in school and life than IQ. When learning about biology, executive function may help children monitor their comprehension, inhibit prior animist understandings in favor of biological responses (e.g., denying life to the sun), and switch flexibly among different meanings depending on context (e.g., between spiritual and biological understandings of death).

The study takes place in two sessions. The first session is like an interview. We ask questions about biological concepts like what it means to be alive and what it means to die, and we also assess knowledge of the functions of various body parts and their role in sustaining life. During the second session we test children's executive function skills with short games. In one game, for example, children see a row of fish. When the fish are blue, they must press a button indicating the direction the middle fish is facing and ignore the outside fish, which may be facing a different direction. When the fish are pink, they must press a button indicating where the outside fish are facing and ignore the middle fish. This game tests their ability to filter out distractions (from the fish they are to ignore) and to switch between rules. We also give standardized tests of academic knowledge, IQ, and vocabulary to account for these factors in the development of children's biological reasoning.



So far we have collected data from about 60 children ages five and a half to seven. Preliminary results seem to confirm our original finding that executive function plays a role in the development of children's biological reasoning. We'll keep you posted as the project continues!

Teaching Two and Three Paul Haward, Lab Tech

How do children learn the full meanings of number words?Previous research shows that children learn the full meanings of the numerals long after they have learned to recite a verbal count list (1-10). For example, at around two years old, children may be able to articulate the words "one", "two", "three", "four" while touching each item in an ordered set of objects. However, they do not yet know that "one" identifies a set of exactly one individual. During this stage, if you asked a child for one ball, they would probably give you back a handful.

Children acquire these exact meanings slowly, which is at odds with how they are learning other concepts at this age (e.g. concepts such as dog, cat, person). By two and a half years old, most children's representation of "one" has developed such that they may use this understanding to reliably identify sets of exactly one individual (one-knowers). At around three years, they have an understanding of two (two-knowers), and several months later they understand three (threeknowers). By the time they acquire the meaning of four, most children can also correctly interpret all other numerals in the count list. Why are these meanings acquired so slowly? What types of knowledge do children use to develop a full understanding of "one", "two" and "three"?

One way to get at this question is to attempt to train children on the next number in their count list and vary the feedback given to them based on the different number systems that we know they are using implicitly. For example, children at this age have developed rich systems of singular-plural morphology and quantification as part of their natural language; at 22 months of age they understand the difference between 'book' and 'books'.

In order to gain a better insight into which systems of knowledge account for the development of early numerals, we attempt to train one-knowers on the number two, and two-knowers on the number three through a series of computerized take home training games in which feedback differs based on a natural language morphology condition, a counting condition, and an visual feedback condition.

We're still in the process of collect-

ing data, but preliminary results show that some of the conditions may have more of an effect on learning an exact meaning for the next numeral than others. We'll keep you posted on our results, so make sure you look for the study in next year's newsletter!

Executive Function with Four-Year Olds Paul Haward, Lab Tech

Executive function is a set of mental capacities that allow us to think flexibly, inhibit some thoughts and impulses, and hold several pieces of information in working memory at a given time. We are interested in discovering how these capacities might help children to progress from one system of understanding to another. For example, one way they may play a role is in helping children go from an initial understanding of the first few numerals, to a full understanding of the natural number system.

We're in very early stages and are currently trying to determine exactly when a child's executive functions develop, and at what point their executive function recourses can be "depleted." In order to test this, we manipulate the use of one task that taps executive function resources in between two other executive function tasks. In our particular design, 4-year-old children first played a puppet game involving two puppets – a bear and a crocodile. If the bear pressed a button, the child had to press the same button. However, if the crocodile pressed a button, the child had to press the other button. This kind of task requires the child to hold these two rules in mind while executing an action. We then played a second game where we placed an unopened box of toys in front of the child. One group of children was allowed to open the box and play with the toys for 5 minutes, while the other group had to wait in silence. This is what is called a "depletion task" -- children have to inhibit their proponent response to look inside the box. After the depletion task, children then played the puppet game for a second time.



We were interested in how children would perform on the second puppet game if they were in the "depletion" condition where they had to wait with an unopened box for 5 minutes. However, our preliminary results show that there is no difference between the two groups. This could be for two reasons: perhaps a) one of our tasks is not tapping into executive function as it should or b) children do not have executive function capacities that are depletable at this age. Check back next year to see how our research is progressing!

Measure Words Peggy Li, Research Associate

In this series of studies, we are interested in how children talk and reason about quantities. Specifically, we are interested in whether there is a relationship between children's acquisition of measure-words (as in, a piece of a fork, a slice of apple, a cup of sand) and their concepts of quantification. If you have a preschooler at home, you may have noticed that while your child can count pretty well, there are times when he or she seems to have a different understanding of what makes up a unit than you do. For example, many children will describe a fork broken into three pieces as "three forks" rather than "three pieces of a fork" or "a broken fork."

In one study, we are exploring whether knowing the language that distinguishes whole objects from pieces allows children to better represent and remember the objects that they see. For example, if children are shown two forks and three fork pieces being placed into an empty box, are they representing the number of whole forks separately from the pieces of forks (e.g., two whole forks and three pieces of one fork, and not "five forks")? Could they figure out what are the remaining contents of the box after some of the forks or fork pieces are then taken out?

In another study we are looking at whether learning measure-word phrases such "a cup of sand" or "a pile of sand") is related to children's ability to make use of containers to quantify and compare amounts of substances. Some researchers have found that preschoolers cannot tell that four cups of sand has "more sand" than three. This is not because they do not know how to count cups as they can correctly determine that four cups has "more cups" than three. This is also not because they do not understand what is meant by "more sand" as they can correctly identify which side has more sand when given larger discriminable volumes of sand (e.g., 4 cups vs. 1 cup). Thus, the findings suggest that three-year-olds are failing to notice that they can use cups as units when quantifying substances.

In yet another study, we are trying to teach children measure-word language, in hopes that they start to treat units more like adults. For example, to get children to stop counting three pieces of a fork as "three forks," we introduce the term "a piece." We teach them the contrast between a piece and a whole: both that a whole fork would never be called "a piece of a fork," and that a third of a fork would never be called "a fork." Our training has moderate success in getting children to correctly label whole objects and parts of objects.

We are hopeful that studies like these, whose goal is to better understand how children come to apply measurement and counting language, and how to encourage their progress toward more adult-like use of quantificational terms, will have positive implications for early math education.



When do children ask for help?

Alex Was, Graduate Student

From a very young age, children exhibit a persistent curiosity about the world around them. In addition to actively experimenting within their surroundings, children frequently seek out information from others. Children seem to have a fundamental desire to learn, which can commonly be seen through persistent question-asking and paying special attention to adults' teaching. When given a choice between teachers, even preschoolers are able to figure out who is the best person to learn from!

However, we don't currently have a firm understanding of how children approach learning situations. When faced with a difficult problem, do children prefer to find a solution on their own, or do they look for help from more knowledgeable others? Moreover, what kind of help are children looking for? For example, do they want to be taught how to build a sand castle, or do they just want someone to build it for them?



This study investigates how preschool-aged children approach problem-solving tasks. In particular, we are interested in when and how children ask for assistance (help or instruction) in these situations. Children are given a chance to explore a set of "puzzle boxes" (boxes that contain a reward and require several steps to open) and to decide whether or not to ask an experimenter for assistance in discovering how the boxes open. Sometimes, these boxes are identical to ones that children have encountered before, but sometimes they are completely different!

Initial findings suggest that children are more likely to ask for assistance with new problems, although they do enjoy attempting these problems themselves as well. Thus, children appear to be overestimating their ability to solve new boxes. We are now exploring whether children's tendency to seek assistance is related to their ability to assess and predict their own performance or their ability to follow rules.

Strategic reciprocity in young children Carla Sebastian, Visiting Graduate Student & Kerrie Pieloch, Lab Manager

Most social relationships that we build throughout our lives are based upon reciprocal exchanges of resources, support, and help. We expect people we benefited to return the favor, and we feel obligated to give back kindness to those who have been generous with us. Reciprocity is considered a key feature of prosociality in adults. Moreover, we are probably more willing to give resources to a person who would be able to give it back than to another who wouldn't be able to do reciprocate. Imagine that you have a plate of common broccoli whereas your partner has a delicious cake. You might generously share your broccoli with her with the expectation to be reciprocated with yummier food. This example represents a more elaborate kind of reciprocity, since it requires thinking about the future before making a decision (planning abilities), and overriding an immediate reward in order to obtain something better later (delayed gratification).

In this study, we were interested in whether young children strategically share with others, keeping in mind what those others could do for them in the future. We studied this by presenting three- and five-year-olds with a game situation in which they interact with a Puppet (their partner). Each player received the same amount of toys. However, the Puppet got highvalued toys whereas the kid got lowervalued toys. Both players engaged in a turn-taking game in which they were given the opportunity to alternate sharing their resources with the other



on subsequent trials. Children always decided first, and then the Puppet copied whatever the kid did. If children understand that they are able to gain access to the high-valued resource by being strategically nice to the Puppet, they will share more in this situation than in another condition (control condition) in which the Puppet had no toys to share. Additionally, we presented two tasks to assess children's ability to delay immediate gratification and to plan ahead. In the delay of gratification task, participants were given an amount of resources that they could use for playing either with a low-attractive toy immediately or with a high-attractive toy later. The planning task consisted of making a puzzle in two steps. Children could choose between two sets of incomplete puzzles (e.g., the incomplete body of a giraffe and the incomplete body of crocodile), taking into account which piece was available in the next step (e.g., the head of a crocodile).

We found that five-year-olds shared more resources when the Puppet had attractive toys (and thus when she was able to reciprocate them) than when she had no resources. However, three-year-olds shared at a very low rate, regardless of whether the Puppet had resources or not. This developmental pattern was also found in the delay of gratification task (older children saved more resources for a delayed but more attractive toy than younger children), and in the planning task (five-year-olds outperformed three-year-olds). Interestingly, children at both ages who saved more resources for the delayed but more attractive toy also shared more resources with the Puppet. Additionally, within the 3-year-old group, children who were better in planning ahead also shared more with the Puppet. These findings suggest that there are dramatic improvements between 3 and 5 years in children's ability to act in the present in such a way as to anticipate future events, and that these skills are somewhat related to this elaborated kind of reciprocity: the strate-gic reciprocity.



It's Not in the Bucket Roman Feiman, Graduate Student

When do babies and toddlers understand what the word "no" means? This question might have a lot of interest to parents worried about when their child can understand a prohibition or reprimand, but it is also interesting for its broader logical meaning. As adults, we think thoughts and say sentences about someone not doing something very frequently. When do we come to understand what that means -- that not means something like "take the opposite." In an ongoing study, we are exploring this question by setting up a hiding-and-seeking game with kids, where we hide a ball in either a bucket or a truck behind a screen that prevents the child from seeing which one we hid it in. In one study, we removed the screen and then told the child that it's not in the truck. We then asked the child to find the ball and see if they would go to look in the bucket spontaneously. In a complimentary study, we showed the child that the bucket is empty, and then asked them to find the ball. We wanted to know if they would use the concept of "no" without language to guide them -- whether being shown that the bucket is empty would tell them that the ball is not in that one, and therefore must be in the truck. We are still collecting data, and so don't know how either of these studies are going to turn out, but it will be exciting to find out whether the ages at which kids can do the linguistic and non-linguistic versions of these tasks are the same, or whether one task precedes the other.



Do infants know logic? Roman Feiman, Graduate Student

What do infants understand about logic? Can 12-month-old infants understand a very abstract concept like "not"? Imagine what is required to understand the difference between "I am not going to the store" and "I am going to the store," or "this is not a book" and "this is a book." We tried asking whether infants can understand a concept like "not" by seeing if they could learn a rule using that concept. Infants in this study heard many different sounds, while watching two objects on a stage. One sound predicted the right object floating up in the air and dancing, while all of the other sounds predicted the left object doing the same thing. We predicted that if infants learned what each sound predicts separately, they should look in the correct direction (left or right) after every familiar sound played, but they should have no predictions about a new sound that they hadn't heard yet. If, on the other hand, infants formed rules like "That sound predicts something interesting happening on the right side" and "Everything that's not that sound, predicts something interesting happening on the left", they should predict that because a new sound they'd never heard isn't the same as that first right-predicting sound, it should be followed by something interesting happening on the left -- just like all the other sounds.

Unfortunately, we ended up not being able to test this prediction directly, because what we found is that infants had trouble learning any of the rules at all! We do know from other studies that, in general, 12-month-olds can learn that a sound predicts something interesting happening on either the left or the right. However, those studies were done with infants looking at a screen, and the "something interesting" was a flashing new shape that was changing sizes. In between them hearing different sounds, those shapes would disappear. We don't know if any of these differences between those studies and ours might have made a difference, but we're planning on finding out. We're starting a new set of studies, using a method that's more similar to the rule-learning studies that have succeeded before in other labs. Once we have an experiment where we can show that infants consistently learn at least two rules, we can resume asking whether they can learn the two rules -- "that one sound means right" and "not that one sound means left".

Does logic underlie language? Roman Feiman, Graduate Student

One of the most amazing things about language is that it is productive. It allows us to take concepts we know -- words we've learned -- and assemble them together in new ways to express thoughts we've never expressed before. I bet you've never thought or said, "If there was a blue bear on Neptune, he would probably be hungry". But you have no trouble understanding it and I had no trouble writing it. The project we have been working on looks at what underlies this productive ability. It turns out that one answer might be a formal logical system.

Some sentences in language are ambiguous in a systematic way. These sentences have two quantifier words (words like "some", "every", "most", and so on), or one quantifier and a negation (the word "not"). Take, for example, the sentence, "Every boy climbed a tree". This sentence could mean that every boy has a particular property -- that of climbing some tree -- meaning that each boy might have climbed a different tree than the others. Or it could mean that a particular tree has some property -- that all boys climbed it -- meaning the boys must have all climbed the same tree. It turns out that this ambiguity is well characterized by a type of formal logic (called "first order", or "predicate" logic), where logical operators (which include quantifier words like "every" and "a") can stand in different relations to each other in a way that produces exactly both meanings of this ambiguous sentence. Is this a coincidence? Or is it possible that what underlies the way we combine words like quantifiers with ideas like boys and climbing a tree is a lot like the structure of this formal logical system?

We investigate this question by presenting 4 to 7-year-olds with a sentence and giving them a choice between two pictures. For example, they would hear, "Every boy climbed a tree" and have to pick between a picture where all of the boys climbed different trees or all climbed different ladders. In this case, there was a clear correct answer, and kids almost always chose the right picture. Then we would give them a different sentence, like "Every hiker climbed a hill", and a choice between two pictures that this time, did give them a genuinely ambiguous choice between both possible readings. One picture showed one hill and a bunch of hikers on it, and the other picture showed many hills and hikers with one hiker per hill. We wanted to see whether kids would be more likely to choose the many-hills interpretation of this sentence after they had previously had to choose the many-trees interpretation of the last sentence (we would then bring kids back for a second session where they would get all of the same items, but the opposite type of picture on the first trial -- all boys on a single tree or all boys on a single ladder). We found that indeed, much like adults, kids were more likely to pick the interpretation involving many hills after having picked the interpretation involving many trees than they were if they had previously had to pick the interpretation with one tree. This means that the structure of the previous sentence influenced their interpretation of the next, where the main similarity between the two sentences was the two-quantifier form of both. This suggests that kids, like adults, use a predicate logic structure in language to interpret sentences such as these. We have more recently run follow-up studies to probe the exact boundaries of this effect. In the study we ran first the only difference between the two sentences was in the nouns; we have now also changing the verbs across the two sentences (eg. from "Every boy climbed a tree" to "Every dog chased a squirrel") to see if the effect persists. While in adults it does, in kids the effect seems to go away.

This suggests some interesting possibilities. We get an effect of the first picture choice trial on the second, like with adults, which suggests kids are also representing an abstract relationship between the two quantifiers. But the fact that the effect goes away when the two sentences have different verbs suggests that kids need more cues to notice the similarity between sentences.

Selective Attention to the Singers of Familiar Lullabies Sam Mehr, Graduate Student

Infants are exposed to music from a variety of sources before they are even born, but little is known about what information infants glean from this exposure. In this study, we asked whether infants selectively respond to adults with whom they share musical knowledge. We selected two obscure songs that we anticipated would be unfamiliar to our participants (songs were originally Russian or Appalachian) and re-wrote them to further obscure their familiarity. First, we adapted their rhythms so that they matched each other. Then we wrote new lyrics that fit both songs so that they had the same linguistic content. Lastly, we made small changes in each song's melodic content, in an attempt to make them equally easy to learn and equally pleasant to sing.

To assess the quality of the songs, we conducted two pilot studies. First we played them to a group of adults and asked them to report which was their favorite song. Responses were evenly split across the two songs, indicating that adults showed no preference for one song or another. Second, we showed 5-month-old infants videos of people singing these songs and tracked their gaze. Infants looked equally to the singers of each song: because the songs were unfamiliar to the infants, we infer that the songs were equally pleasing and interesting to the infants.

After the completion of piloting, the full study began. The study had three parts: an initial lab visit, a period of at-home singing, and a follow-up visit. At the initial visit, parents were given a music lesson from a professional musician, where they were randomly assigned to learn one of the two songs – importantly; they only learned that song, and not the other song. Parents also filled out a questionnaire about demographics, arts activities, and opinions about the arts. After the initial visit, there was a 1-2

week period during which we asked parents to sing their new lullaby with their infant. We provided parents with a practice website that included printed words and media players to help remember the words and melody of their song. Parents also completed a "lullaby diary" each evening, to keep track of the frequency and type of musical activities occurring in the home.

After 1-2 weeks, parents and infants returned to the lab for a follow-up visit. We showed infants alternating videos of adults singing each of the two songs. Critically, because we had randomly assigned parents to learn one song or the other, only one song was familiar to the infant. The other song had the same words, but a melody that was completely unfamiliar to the infant. After hearing each woman sing, we showed infants the two women side-by-side, standing silently, and tracked how long infants would attend to each singer (see Fig. 1). Parents also completed an auditory skills test and participated in a short, videotaped play session with their infant.



Figure 1

Our preliminary results indicate that infants selectively attend to the singers of the familiar song, over and above the amount attributable to chance, and over and above any initial preference for one person over the other. That is, if an infant preferred to look at Sally before any singing occurred, but then Susan sang a familiar song and Sally sang an unfamiliar song, on average, infants overcame their initial preference and directed their attention to Susan on subsequent test trials.

These results show that infants recall the songs that parents sing after only minimal exposure, and suggest that infants selectively attend to adults with whom they share cultural knowledge. This work is the first in a series of studies we've planned in the lab to assess how music works in infancy, which hopefully will yield clues as to how the human capacity for music came to be in the first place. Many thanks to all the parents and infants for their participation!

Social Learning of Food Victoria Wobber, Post-Doctoral Fellow

This project looks at how children learn about the world from others. Children are proficient at learning from parents and teachers, who in turn go out of their way to demonstrate specific behaviors for children. But how much do children learn from "unintentional" demonstrators, like peers? Are they sensitive to which peers they should copy and which peers they should ignore?

In this study we are looking at whether children will copy a demonstrator's preference between two novel food items. We began this study by looking for pairs of food items that children would be willing to eat but that they were unlikely to have tried previously. This allowed us to make sure that they were learning about new foods from the demonstrators. After finishing that portion of the study, we are now presenting children with two possible demonstrators who show preferences among these novel food items. Both demonstrators are puppets, to simulate a peer interaction. One of the puppets shows a food preference



(is cooperative with the child), while the other puppet breaks the rules of the game in order to show his/her food preference (takes his/her food when it is the child's turn). After children view these demonstrations, we then ask them which of the food items they prefer. We are interested in whether children will copy the food preferences of one or both of these demonstrators.

In the first part of our study, we found that most children between 3 and 5 years of age had not tried the obscure dried fruits that we used in the study: dried papaya, dried pineapple, dried cherries, and dried dates. At the same time, most children were willing to taste these food items and ultimately did not show any preferences between these four – they were equally likely to prefer a date over a cherry as they were to prefer a cherry over a date. Our work with the puppet demonstrators is still ongoing - be sure to check back for more results from this study in next year's newsletter!



Third Party Intervention Jillian Jordan, Honors Thesis Student

How do children develop a sense of fairness? Previous research from our lab has revealed that children prefer equal to unequal distributions of candy between themselves and another child. Specifically, around age four, children begin to dislike "disadvantageous" unequal distributions in which they receive less candy than a peer child, and are sometimes willing to sacrifice their own candy to prevent getting a bad deal. Around age eight, children also begin to dislike "advantageous" unequal distributions in which they receive more candy than another child, and are sometimes willing to sacrifice their own candy to prevent another child from getting a bad deal. In the present study, we were interested in understanding if third-party children dislike unequal distributions of



candy between two other children. Might children be willing to intervene to prevent another child from getting a bad deal, even if they are not personally affected by the distribution?

In our study, children come into the lab and are told that their job is to make decisions on behalf of two third-party children that came into the lab yesterday, Jane and Annie. They are told



that Jane's job was to be the divider, and that Jane wrote down how she wanted to divide Skittles between herself and Annie. Then, they are shown a set of distributions of candy that Jane proposed, and have the option to accept or reject each distribution. If they accept the proposed distribution, they are told that it will be enacted: the Skittles that Jane wanted to keep for herself will go to Jane's bag, the Skittles that Jane wanted to give to Annie will go to Annie's bag, and Jane and Annie will come in to collect their Skittle bags at the end of the day. If they reject the distribution, however, they are told that the Skittles will be thrown out and nobody will get to take them home. Then, children have the opportunity to accept or reject

twelve distributions, six of which are fair (three for Jane and three for Annie), and six of which are unfair (six for Jane and none for Annie). Children also receive some Skittles of their own at the beginning of the game, and in one version of the game, children have to give up some of their Skittles if they want to reject. Thus, in this condition, it is costly for children to intervene against unequal distributions. However, in the other version of the game, there is no cost to rejecting.

Our results suggest that children are motivated to get as many Skittles for themselves as possible: participants reject fewer distributions in the condition where rejection is costly. Nonetheless, we found that in both the costly and cost-free versions of the game, both five- and six-year-old children were more likely to reject unequal than equal distributions of candy. Thus, children made personal sacrifices to prevent another child from getting a bad deal. However, six-year-olds showed a much stronger sensitivity to fairness than five-yearolds, suggesting that third-party intervention develops between the ages of five and six. Thanks so much for your help with this study!



Going Down the Garden Path Tanya Zhuravleva, Graduate Student

One of the fascinating things about language is how quickly and efficiently we are able to understand the sentences we hear. This seems very simple, but it is actually a very difficult task – in order to do this, we need to identify all the sounds, figure out the meaning of all the words, determine the grammatical structure, and put all those things together. We are able to accomplish this feat by making commitments along each of these steps (sounds, words, grammar) and using those commitments to build up the meaning of the sentence before we finish hearing it. Importantly, adults are also able to go back and revise those selections if the incoming information becomes inconsistent with what they have predicted. This is most clearly visible in sentences called "garden path sentences", such as the following; "The woman felt the soft white fur was too expensive". When you got to the word "was" you probably paused, had to go back and rework the sentence, but finally understood what is meant.

Prior to age 5, children seem able to make early commitments to interpretations, but seem to struggle in revising those once more information is available. In my study, we are interested in studying the developmental changes that allow kids between the ages of 5 – 8 to become much better at understanding sentences as they get longer and more complicated. Does the improvement reflect simply an increase in linguistic experience? Or, does it reflect a more general development, specifically of executive functions? Executive functions describe cognitive skills such as mental flexibility, attention control, and working memory.

In order to study this, we asked children to play different games aimed at testing executive functioning. For example, in some of these games, children were taught to press a left button when they see a particular image (which appears on the left side of the screen) and the right button when they see a particular image (which appears on the right side of the screen). Sometimes, the images switch sides. When this happens, the child must control how they react - they must stop themselves from pressing the button on the same side as the image in order to correctly press the button associated with that specific picture. In other games, we tested skills such as working memory by seeing how many numbers the child can hold in his or her mind. The children that participated also got to play three different computer games designed to see how they understand different sentences. These games were performed with an eye-tracking computer, which allows us to see moment by moment how the child is interpreting what they hear. In these games, kids were shown pictures while they listened to different sentences, some of which contained different ambiguities. In one game, the ambiguity was in determining the correct word. For example, children would hear "click on the lock" while they are shown pictures of both a "lock" and a "log". Until the last sound in lock is said, the word is consistent with both pictures. In another game, children heard instructions with an ambiguous grammatical structure, where the instructions could be interpreted in two different ways. We were interested in seeing if kids are able to use context in order to select the more likely interpretation. In the last game, the sentences they heard contained ambiguous pronouns, where the pronoun "he", for example, was used when both characters on the display were male.

Eventually, we hope to see whether children's' executive functioning ability is related to the types of information they are able to use in order to make commitments and build up predictions and to their ability to revise those commitments once they are made.

She said WHAT?! Tracy Brookhyser, Lab Manager

Communication involves both understanding the literal meaning of what is said (semantics) as well as making inferences about what is meant (pragmatics). We study how adults, typicallydeveloping children, and children with Autism Spectrum Disorders (AS/ASD) comprehend and produce language with pronouns and prosody. Our study involves several tasks. Your child may have participated in one or more of these tasks, and we are very grateful for your family's contribution.

In the Animals and Objects task, participants heard stories about animal characters. The stories are sometimes ambiguous. For example: "Henry the horse and Marky the monkey are playing in the snow. He is wearing red mittens." Participants said whether the story was true or false. If it was false, they explained why. Adults usually think that "he" refers to the subject of the first sentence. So we expect participants to look more towards Henry when they hear "he," and to say, "False, he is wearing yellow mittens!"

In the People and Places task, participants also heard stories about characters. Again, the stories were sometimes ambiguous. For example: "Michael called Jason about the assignment. Then he emailed Mary about the book. Who emailed Mary?" Again, we expect participants to look more towards Michael when they hear "he," and to answer "Michael," because he was the subject of the first sentence.

In the Character Movies task, participants made up stories about characters in pairs of movies. In some pairs, we expect participants to say pronouns, because when characters are repeated, we tend to replace the subject of the first sentence with a pronoun in the next sentence. For example, "The biker played with the ball. Then she (the biker) read the book."

In the Find-the-Object task, participants saw pictures and heard 2 sequential instructions. For example: (1) Touch the yellow mitten. (2a) Now touch the GREEN mitten. (2b) Now touch the yellow BIKE. (2c) Now touch the GREEN bike. Adults use prosody very quickly to decide what object the speaker is talking about. When they hear the second instruction in (2c), they first look at the green mitten, because we tend to emphasize words that contrast one object from another.

In the Picky Prince task, participants saw pictures and heard sentences. For example: (1) No, I don't want the blue mittens. I want the yellow toaster. (2) No, I don't want the BLUE mittens. Choose again! (3) No, I don't want the blue MITTENS. Choose again! Adults use prosody in (2) and (3) to decide which picture to select. That is, when the Picky Prince doesn't want the BLUE mittens, we guess he wants the grey ones.

In the Tannegrams task, participants saw pictures, and told the experimenter to move shapes to create an image. For example, "Put the brown oval on the board." We expect participants to use prosody to help the experimenter find the right picture. For example, they might say, "Put the green triangle on the board. Put the RED triangle on the board."



Bingo was his NAME-O

Tracy Brookhyser, Lab Manager

We are interested in whether two-year-olds implicitly label the objects they see. That is, when they see a chair, they might think silently to themselves: "chair!" Spontaneous naming and pointing to objects is common during this age, but we want to better understand what toddlers are thinking silently. So we use a priming method. We show toddlers one picture (called a prime), followed by two pictures (called a target and a distractor). If they implicitly labeled the first picture, their preferences for looking at the two pictures might be influenced (primed) by this naming process. We expect toddlers to look more at the target picture than the distractor picture when words sound similar.

For example, toddlers would look more at the BIRD in this scenario, because it sounds similar to BUTTERFLY.



"Prime" - Butterfly



"Target" - Bird



"Distractor" - Star

Oh, I know what happened!

Tracy Brookhyser, Lab Manager

We are interested in how adults and children (2-5 years old) understand negated sentences. These are sentences which include words like "no" and "not." People, even young children, use negated sentences frequently, so distinguishing the two is important in communication.

In the study, your child saw pictures on a computer screen, and heard stories about things that Arthur and D.W. did or did not do. After each story, Dora chimed in to say, for example: "Oh, I know what happened! D.W. dressed/didn't dress one of the teddybears! Which one was it?" We recorded your child's responses, as well as which picture they looked at on the screen while they heard Dora's sentence unfold.

Previous researchers have proposed that we understand the meaning of a negated sentence only through its affirmative counterpart. That is, to understand, "I didn't read the book," your thought process would be something like: "I read the book...not." This would mean that processing negated sentences would take longer. However, the results of our study indicates that adults and children as young as 2 process negated sentences incrementally. That is, they are just as fast to understand a negated sentence as they are to understand an affirmative sentence.

Thank you for your generous participation!

Finger Puppets study : Do young children understand exact quantities? Veronique Izard, Visiting Scholar

Young children tend to be fascinated with numbers – they love counting activities and trying to count all kinds of different things. Yet, for a long time, children do not understand what the goal of counting is; to evaluate how many objects there are in a group. They seem to think that counting is just another lullaby. This is particularly striking, given that children around two to three years of age are formidable word learners. They can learn new words after hearing them only a few times, and they can learn several new words per day. So why is it so hard for them to learn the meanings of the number words, and the counting activities they enjoy?

We think this might be because children this age do not have a concept of exact numbers that can be applied to these words. Even infants know some things about numbers and quantities, and this knowledge is present in young children as well, however, this knowledge is really about approximate numbers ("a little", "some more", "a lot"). Infants and young children may not be able to appreciate that if one takes some number of objects away from a group, and then adds only one more object back into the group, this now makes a different total quantity, even if the difference is not perceptible.



In the Finger Puppets experiment series, which we started several years ago, we ask how children understand this notion of exact quantities. We first studied two- year-old children who, for the most part, die not understand the purpose of counting. The children played a game with puppets that live on the branches of a tree – one puppet for each branch. At night, puppets go to sleepin a box, then morning comes, and children need to place the puppets back on the tree. We observe whether children use the branches to know when exactly all puppets are back on the tree. In this first study, we found that 2-year-olds did use the branches, but only when the puppets remained the same throughout the story. If we added one new puppet, or if we subtracted a puppet, or even if we replaced one of the puppets with another, identical puppet, they stopped using the branches. For these young children, the branches indexed a particular set of individuals with unique identities, but not the actual number of individuals present.

Thus we wondered when children would start using the branches to reason about number, not only about specific individuals. Additionally, we wanted to know what enables them to do so? Following these questions, we ran a similar study with children just one year older. At this age, children's understanding of counting varies a lot, depending on the individual interests of each child. We wondered whether the children who understood number words better would use the branches more.

So far we have found that 3-year-olds are able to use the branches, independent of their understanding of counting. In a new version of the study to be run next summer, we will ask whether children of this age also use the branches to perform addition and subtraction.

Math and Social Games for Preschoolers Moira Dillon, Graduate Student, Brian Reilly, Assistant Professor, Ellyn Schmidt, Lab Manager, & Conisha Cooper, Lab Manager

A group of researchers from our lab has been collaborating with an Economics lab at MIT on a schoreadiness intervention project. Here at the Lab for Developmental Studies, we've been working to create training games based on previous laboratory studies investigating children's numerical, geometric, and social abilities. Over the last year, we've piloted various versions of these games with 4- and 5-year-old children in the lab. Some games engage number skills such as numerical esti-



mation, approximate numerical addition, and one-to-one correspondence. Other games engage geometric reasoning, including identifying shared geometric properties among a set of shapes, navigating in differently shaped environments, and using information in maps to find locations in an environmental array. Still other games engage skills essential to social and pedagogical learning, including determining the object of another person's attention, and discriminating between a person's different emotional expressions.

Some children have come to the lab to play a game individually with a researcher and some children have come to the lab to play a game with another child. Based on this piloting, we have been making adjustments to the games to ensure that preschoolers can easily learn the rules of each game, engage with the materials and with each other, and remain interested in gameplay. We've also been creating different levels of each game so that children can progress through increasingly challenging versions of the games.



The goal of this project is to develop a curriculum of math and social games to be introduced in preschool classrooms so as to increase children's motivation for learning and belief that they can improve their abilities with practice. Additionally, we hope that the math games will improve children's early arising numerical and geometric skills and that the social games will improve children's social reasoning. Under the leadership of our collaborators at MIT, an intervention study has begun in impoverished preschools in New Delhi, India. Although primary school attendance in India has increased in the past couple of years, school performance is still decreasing. Our hope is that preschoolers who participate in this intervention will be better prepared, both cognitively and motivationally, for primary school. At the end of the intervention in India, children will complete a battery of assessments that measure number skills, geometry skills, social reasoning, and motivation. In the future, we hope to conduct similar intervention studies in preschools in the United States. We also plan to conduct further lab-based studies on the effects that each game has on school-relevant assessment measures taken in a laboratory setting.



Executive Function Depletion Lindsey Powell, Post-Doctoral Fellow & Meg Barrow, Honors Thesis Student

In every day life, people often follow habits or routines that allow them to get things done with little effortful planning or thinking. Other times, though, we find ourselves in unfamiliar circumstances or with unfamiliar goals, and we have to remember new information and construct new plans to reach those goals. Similarly, we sometimes allow ourselves to give in to desires, like watching a trivial TV program or eating an unhealthy snack, whereas other times we opt to focus on long-term goals, like finishing a novel or losing weight, effortfully resisting those short-term temptations. In each case, the harder of these two routes relies on what psychologists call our executive functions. Executive functions include the capacities like self-control, working memory, and hierarchical planning that let us act flexibly in the world, instead of simply following routines or indulging in every desire we experience.

Unfortunately, ample research with adults shows that most of us are vulnerable to a phenomenon that could be called "executive function depletion." When we use our executive function abilities by engaging in a task that require us to inhibit our impulses or make novel decisions, then our performance on the next executive function task we're asked to do suffers. It seems that we don't have an unlimited capacity to keep controlling our behavior and, at least in the short term, the more we use our executive functions the weaker they become. Though the research documenting this depletion effect is relatively new, the phenomenon has an intuitive appeal, as many of us have experienced the feeling of mental exhaustion at the end of a long day full of multitasking and difficult choices.

Our current research asks whether 3- to 5-year-old children also show evidence of executive function depletion. This is an age group where skills like self-control and planning are developing rapidly, and it might seem obvious that these early executive function abilities would be particularly vulnerable to depletion. However, there are some reasons to question whether children, especially at the younger end of the age range, might not be appreciable worse at a second executive function task that comes right after an initial, depleting one.

One reason is that one of the hypotheses about the source of depletion in adults is that it reflects a strategic shift in how we're employing our executive functions. Perhaps, as we start to notice them fatiguing, we employ them more sparingly to avoid full shut down, just as you might slow down when you start to feel tired while exercising. Or maybe the shift reflects an assessment that the initial self-control effort wasn't worth the benefit that it provided, and that in the next task we shouldn't try so hard. Either way, 3-year-old children tend to be very bad at this sort of strategic control of their behavior. For example, they don't slow down on hard tasks to allow themselves to be more accurate, and they also don't anticipate the ways in which they're going to need to control their behavior in the short term. Five-year-olds are much better at these sorts of things. And sure enough, across several studies, we're finding that 5-year-olds show evidence of executive function depletion just like adults, but we have yet to find any evidence of depletion with our 3-year-old participants. Of course, 5-year-olds have better executive function skills even post-depletion, but a silver lining for the 3-year-olds may be that they're better than older children and adults in persisting at using the skills they do have.

Preferences for Imitators Lindsey Powell, Post-Doctoral Fellow

Imitation is a big part of social life for both kids and adults. Children learn many things from imitating others, from words and conventions to how things work. As adults we continue to imitate, though more subtly and often for specifically social purposes. Imagine having an interesting conversation with an acquaintance; you might find yourself mimicking their posture and gestures, or using the same tone of voice or verbal and facial expressions they're producing. This sort of social mimicry tends to make interactions between adults go more smoothly and to make us like one another more.

The goal of our current experiments is to understand the early development of this sort of social information. We aren't asking about infants' own imitation skills – it can be difficult to elicit imitation from shy, uncoordinated, young babies – but instead how they react to witnessing imitation amongst others. In all of these studies, we show infants, from 4 months all the way up to 13 months, movies featuring three individuals. One of the individuals (let's call him the center character) interacts with each of the other two separately. Some infants see the center character start off the interactions, doing a particular action or making a particular sound, which is imitated by one of the other two characters but not the other. Other infants see the side characters start off the interactions, performing different actions or making different sounds, and see the center character imitate one of them but not the other.

After this introduction to the characters' behaviors, different studies ask different questions. Some studies ask whether infants have any expectations about which of the characters like one another. We do this by showing infants events where the characters are approaching one another. Sometimes it's the targets of the imitation who are doing the approaching; for example, the center character might take turns approaching the side character who had imitated him and the side character that had not. Other times infants see the responders doing the approaching; for example, two side characters, one of whom had imitated the center character and one of whom had not, would take turns approaching that center character. The idea here is that if infants have made any inferences about who likes who on the basis of which characters engaged in imitation together then they should respond differently to approaches between characters who did engage in imitation and ones who didn't. So far, we have found an interesting asymmetry in 4-month-olds – they respond differently when imitators approach their targets than when one character approaches another character it hasn't imitated, suggesting that they infer that imitators like the individuals they imitate. In contrast, they don't differentiate cases where characters approach those who have imitated them versus those who haven't, suggesting they don't necessarily expect the targets of imitation to like the imitators back.

Other studies ask whether infants consider imitation to be objectively positive by assessing whether infants themselves like imitators more than non-imitators. Following the demonstration of who imitates who, we give infants a preference test; for young infants, we hold up physical copies of the imitator and non-imitator and measure how long they look at each, while for older infants we hold the characters out and let them reach for one or the other. These studies have revealed a preference for imitators in both 4-month-olds and 1-year-olds, suggesting that this basic social practice of attending to and copying others' movements is something infants develop a taste for from strikingly early on!

Infants Learning about Groups Lindsey Powell, Post-Doctoral Fellow

One of the critical tools that humans, and many other animals, have for thinking about the world is the use of categories. We group things – objects, animals, people, events – into kinds, and this allows us to apply the things we learn about one individual or instance of a kind to a new one. This is the sort of thought that allows us to drive a car we've never been in or use a new computer without learning how they work all over again – we assume that the unfamiliar car or computer will work a lot like other ones we have used. In the social realm, categories can also be useful. It's helpful, for example, to treat an infant or child you've just met differently from a new adult acquaintance. Of course, there are also cases where the categorical generalizations made about people are unfair or inaccurate, but this only makes it all the more important to understand how such categorical thinking works and how it develops in infancy and childhood.

In order to understand the development of categorical thinking, we've been asking whether infants will form categories and apply things they learn about some members of a category to new ones. We are also trying to understand whether infants have different expectations about different kinds of categories. As adults, we think that certain properties are more likely to generalize across some categories than others. For example, if you learned that a new animal only ate plants, you might expect that to be true of all other individuals of that species. In contrast, if I told you that a person from a city you'd never been to only ate plants, you wouldn't necessarily assume everyone from that city was also vegetarian. Our experiments ask whether infants' generalize different kinds of properties across all categories equally or whether, like adults, they already expect that particular properties will generalize across particular types of categories.

In our initial studies, we were interested in whether infants would expect members of social groups to act alike. Children and even older infants are prolific imitators of those around them, and though some of this imitation seems aimed at learning how the world works, much of it seems more social in nature, including imitation of words, gesture, and expressions. We thought this imitation might reflect an underlying assumption by infants that social group members act alike, and that they should thus act like those they want to be affiliated with. In these studies we introduced infants to two groups each composed of three animated characters, and showed them that two members of one group did one thing (e.g. jumped up and down on a platform) while two members of the other group did something different (e.g. slid back and forth on the platform). Finally, we showed infants the last member of each group both doing the action associated with one of the two groups (e.g. both jumping), and found that infants looked longer at the individual that acted like the other group rather than his own, suggesting infants had expected the group members to all act alike. Intriguingly, infants did not have the same expectation about groups of nonsocial or inanimate groups. These findings have recently been published in a paper in the Proceedings of the National Academy of Sciences (titled "Preverbal infants expect social group members to act alike"), which can be found on our website.

We have been following up this research in several ways. In the realm of social groups, we have been asking how much evidence infants need before they will expect all members of a group to act alike. We find that simply showing them that one member of a group engages in an action isn't enough to get them to expect that other members of that group will act alike, perhaps because the action may just reflect the individual's goal or preference, rather than a shared behavior of the

groups. We've also been asking whether infants will generalize different types of actions across social groups equally. In our original studies, we always used actions that could be compared in some way to simple gestures or preferences – the characters jumped up and down, or chose to land on one box instead of another – rather than actions that actually changed the environment in any way. This latter type of action could be referred to as "causal" actions, that is actions that cause some sort of change in the world. We thought that infants might be less likely to generalize causal actions across social groups because they might have an alternative explanation as to why group members would be engaging in the same action; rather than thinking that two individuals were engaging in the same action, like jumping, because that behavior was typical of the social group, they might think the both individuals engaged in the same action because they wanted to produce the same change in the environments and may not necessarily expect additional group members to share this goal. This study is still ongoing, but so far the data support this hypothesis; infants are not showing the same sort of surprise when the third member of a group fails to produce the same causal action as his group members.

Finally, we've been investigating whether there might be other properties, aside from voluntary behavior, that infants do generalize across other sorts of categories, like inanimate objects or nonsocial characters. Most recently, we have been asking whether infants will expect three characters who look alike to share the same ability (e.g. the ability to push a box and make it move), even when the characters don't interact with each other socially. So far, we've failed to find any evidence of generalization across nonsocial groups. This may suggest that social groups are especially salient targets for category-based generalization, or it may just mean that we haven't found the right way to convey either the categories or the properties we're interested in to babies – it's pretty tough to know exactly what they're thinking!



Thank you to all the families who have participated! None of our research is possible without your support. If you have any questions, want to refer a friend, or would like to participate in more research, please get in touch with us!

> babylab@wjh.harvard.edu https://software.rc.fas.harvard.edu/lds/ 617-384-7777