2020 NEWSLETTER

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Distinguishing the certain from the merely possible

Matt Steele (Undergraduate Research Assistant) and Brian Leahy (Graduate Student)

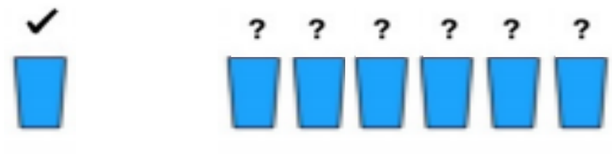
Some states are guaranteed, some are impossible, and some are somewhere in between. We need to recognise when something is possible but not guaranteed in order to make good decisions. Are we born with this ability? Or is it a skill that we must learn? Research suggests that this ability starts to develop around age four. A good example of this evidence is from games where children get to pick a cup and keep whatever is inside. Two stickers are hidden in three cups. Participants know that the green cup holds one sticker (we'll call that the certain cup), and they know that the other sticker is in either the blue cup or the yellow cup (we'll call those the uncertain cups), but they do not know which. The interesting question is, do they go for the safe bet, and choose the certain cup?

Three-year-olds pick the certain cup only half of the time, and otherwise choose at random between the uncertain cups. Older children pick the certain cup much more often. If three-year-olds were performing at chance, they should pick the certain cup only 33% of the time. Why are they so much better than chance, but still so far from perfect? We suspect that 3-year-olds make an assumption about which of the uncertain cups holds a sticker, and don't realize that they are making an assumption. In this way, 3-year-olds think they are being asked to pick arbitrarily between two cups that are both guaranteed to hold a prize.

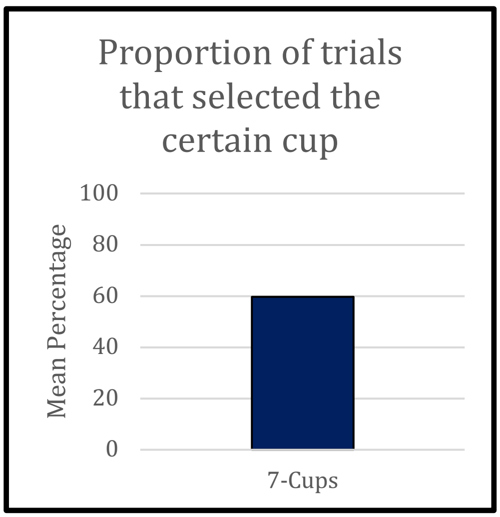
There is some evidence that doesn't fit with this explanation. In a follow up study we made the uncertain cups all the same color, and the certain cup a different color, so that it was easier to distinguish the certain from the uncertain cups. Now 3-year-olds pick the certain cup at a much higher rate.

Why is this 5-cups version of the task easier? We tested two explanations. First, perhaps the higher number of uncertain cups helps 3-year-olds notice the low probability of finding a sticker on the uncertain side. Alternatively, perhaps the changes in colors and numbers make the single cup stand out more (sometimes called a "pop-out effect") and make it an attractive choice even if children are not evaluating the chances of finding a sticker there.

We tested these hypotheses by increasing the number of uncertain cups to 6 (making the difference in probabilities even more dramatic) but making them all the same color to eliminate any pop-out effect.



If number of cups is helping children figure out the probabilities of finding a sticker in each cup, then they should perform very well on this task. But if their success on the 5-cups task was driven by a pop-out effect, performance should return to about 50% choice of the certain cup, as it was on the 3-cups task.



Children's performance was not significantly different from 50% on this task. The unexpected findings from the 5-cups task may have been produced by a pop-out effect. This is compatible with our view that a concept of possibility is learnt, a process that starts to develop around age four.

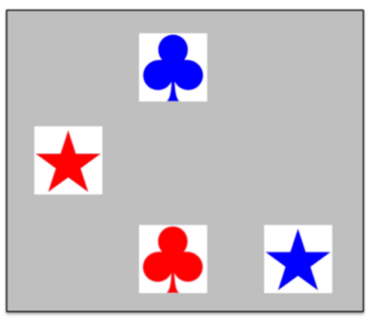
Children's Understanding of Complex Sequences

Stephen Ferrigno (Postdoctoral Research Fellow)

Learning a language is a complicated process for children. Not only do they need to learn what each word means, but they also need to understand how words are put together to form sentences. Human grammar uses many complex sequences. One of the types of sequences used in language is center-embedded sequences or ones that have long-distance dependencies between elements. Sentences with these structures like: "The cat that the dog chased ran away." are especially difficult for children to understand. One possible cause of this difficulty is the underlying sequential abilities needed to understand these sentences.

Here we test children's ability to represent these sequences outside of language. This allows us to isolate one specific component, just the representation of the complex sequences. To test children's sequencing abilities, we had children play a computer game in which they had to touch pictures in a center-embedded order. In this example (below), two items (stars) are embedded inside other items (clovers) much like the types of sentences that are difficult for children to understand. Children were then shown new images to see if they used the same overall center-embedded with new, untrained images.

So far, our results show that children begin to understand these complex center-embedded sequences as early as 3.5 years old. However, this ability continues to develop until much later. We see steady improvements until six-years-old or even later. We also tested children's sequencing abilities on other types of sequences and found that these center-embedded sequences are much harder to learn and master than other types of sequences. Preliminary evidence suggests that the ability to represent these center-embedded sequences may preclude the understanding of these same sequences in language. We have also found some evidence that the ability to represent these sequences may depend on children's working memory ability. Not only do the sequences need to be learned, but the dependency between the first picture pressed (the blue clover) and the last item (the red clover) need to be remembered throughout the trial.



Example of the touch-screen computer sequencing task.

The order children learn to touch the pictures.

Children's Sensitivity to Knowledge and Guesses

Samantha Fung (Undergraduate Research Assistant) and Brian Leahy (Graduate Student)

When young children make a guess, they do not always realize that they are guessing. Rather, we think, they treat their guesses as though they are well-established facts. One paradigm that established this fact is the *knowledge/guess paradigm*, developed by scientists in Austria. In this study, participants face three different tasks.

Figure 1. Total ignorance trials

In the first task, a *total ignorance task*, the experimenter first shows the participant an empty box. Then she raises an occluder between the participant and the box and tells that participant, "I'm hiding one toy in the box now". Finally, she takes the occluder away and asks, "Do you know what toy is inside the box?" In existing studies, this question was easy for children as young as 3: everyone says they do not know what is in the box.

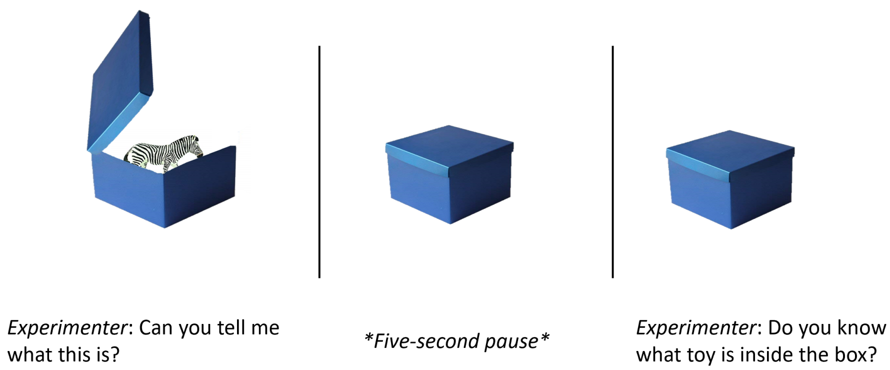


Figure 2. Complete knowledge trials

The second task, a *complete knowledge task*, is also easy. The experimenter shows the participant what is in the box, pauses, and then asks whether they know which toy is inside.

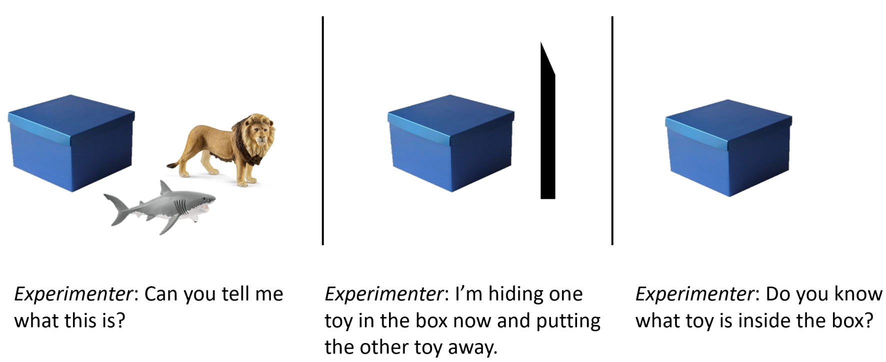


Figure 3. Partial ignorance trials

The final task, the *partial ignorance task*, is difficult. In this task the experimenter shows the participant two toys, then raises an occluder and hides one in the box and puts the other one away, so that the participant does not know which toy is hidden. Then she asks the participant whether they know which toy is inside. Children as old as 5 tend to tell the experimenter which toy is in the box, though they have no way of knowing. Somehow, making two possibilities salient makes it difficult for children to recognize their own ignorance.

We began by trying to replicate existing findings, modifying the procedure to make it simpler in a number of ways and to adapt it from German for an English-speaking audience. We also added three new tasks, versions of the partial ignorance task, to see if performance improved.

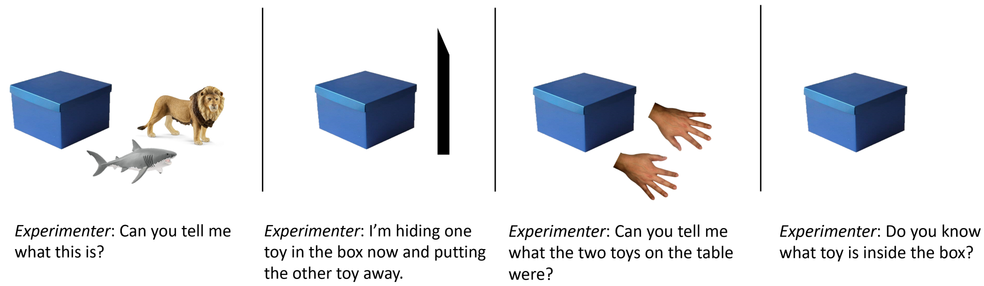


Figure 4. Memory task: memory question and partial ignorance trial

The *memory task* was exactly like the partial ignorance task, except that before asking whether the child knew what was in the box, we asked them to say what the candidate toys were. We thought this might help them to remember that there were two toys that could be in the box.

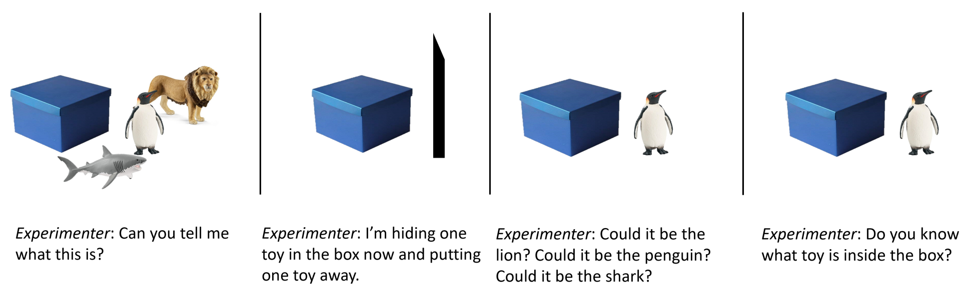


Figure 5. Modal language task: 1/3 toys visible

In the *Modal Language task (1/3 toys visible)*, the experimenter puts 3 toys on the table. Then she raises the occluder, hides one toy in the box, and puts one toy away. Then she takes away the occluder and asks: Could it be the shark? Could it be the penguin? And could it be the lion? This allows us to check whether children understand the questions, and whether there is a relationship between understanding the questions and performance on the task. It also prompts children to think about all of the relevant possibilities.

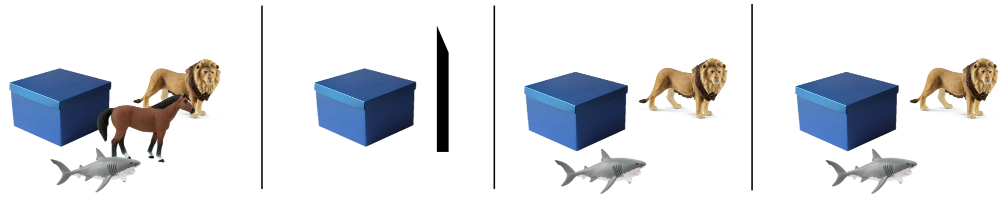


Figure 6. Modal language task: 2/3 toys visible

The final task is exactly like the fifth, except now when the occluder is taken away, two toys remain on the table. Thus children should be able to infer the contents of the box. Again, we ask, Could it be the lion? Could it be the horse? And could it be the shark? This again allows us to test how children understand the language of possibility, and explore how that relates to performance on the task.

Our initial study turned up unexpected results: children said they were guessing in every task, even when they knew what toy was in the box. We expect that this is an artefact: perhaps the word "guess" is harder to learn in English than it is in German; or perhaps English speaking children are subject to different pragmatic effects when they are asked, "Do you really know that, or are you just guessing?". To further explore this, we ran a version that stayed as close as possible to the script of the original Austrian task. We tested 4-year-olds, and again found a pattern quite unlike the one reported by our colleagues in Salzburg: 4-year-olds tended to respond correctly on every task; they did not show the curious lapse observed on the partial ignorance task reported by our colleagues. Our next step in this series of studies will be to test 3-year-olds, and see if they have any struggles with the partial ignorance task.

Infants' inferences about insides

Yiping Li, Debbie Kwan, and Jiayi Hu (Undergraduate Research Assistants), Jonathan Kominsky (Postdoctoral Researcher)

How do babies know when something is alive? When the whole world is new to you, and you see all kinds of things moving around, how do you figure out that the family dog is alive, but your tickle-me-Elmo toy, that makes noise and has fur, is not?

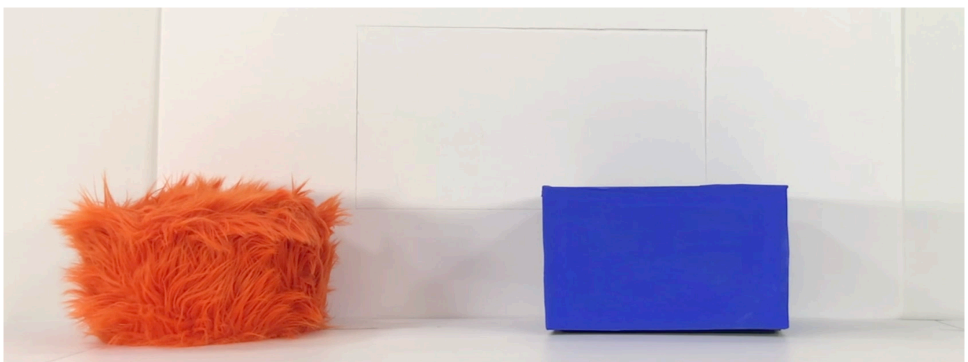
In this thesis project, we were interested in whether infants use information about cause and effect to determine whether something is alive. Previous work in our lab and others has found that 10-month-old babies are surprised if something they think is alive has nothing inside it. We used this surprise to measure when infants think something is alive, and when they don't.

In an award-winning senior thesis last year, we found two important things. First, we found that infants think that a puppet that is covered in fur or feathers and moves around on its own is alive, but a puppet with fur or feathers that is pushed around by a human actor is not. Second, we found that if a fur-covered puppet collides with a feather-covered puppet (or vice versa) and causes it to move, infants are equally surprised, or equally unsurprised, when each one is revealed to be hollow, no matter which one is the cause and which one is the effect.

This led us to another question: when the fur puppet collides with the feather puppet, do infants think that *both* of them are alive, or *neither* of them?

To test this, we replaced the feather-covered puppet with a plain box, like you see in this picture, and showed infants events where the box caused the fur-covered puppet to move, or the fur-covered puppet caused the box to move.

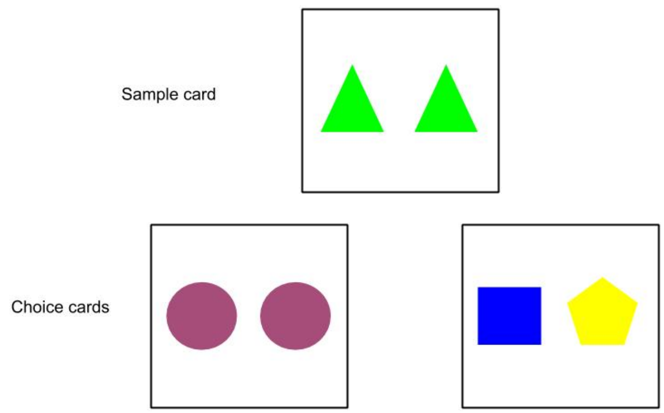
We found that infants think the fur puppet is alive no matter whether it is the cause or the effect. This tells us that in the earlier experiment, infants thought both of the puppets were alive, not just the one that caused the other puppet to move. This suggests that infants don't decide whether something is alive just based on whether it's a cause or an effect. If it has fur or feathers and it moves, they think it's alive, unless they can see a human moving it.



Matching abstract relations: What makes it hard?

Ivan Kroupin (Graduate Student)

Relational reasoning is the ability to compare sets of objects not on the features of the particular objects but on the relations that hold within the sets. For instance, we can compare a solar system to an atom because the *relations* between their constituent parts are similar (a large central body which is orbited by smaller ones) even though the parts themselves do not resemble each other in the slightest (i.e. electrons do not look like planets). Humans are uniquely proficient at this kind of relational comparison - but how does this ability arise, and what determines how and when we use it? Currently we are testing children on a task known as Relational Match to Sample: Children are shown three cards, each of which has two images. These two images are either identical in all respects (e.g. both green triangles) or different in some respects (e.g. a blue square and a yellow pentagon). The sample card (the one that is to be matched *to*) is either a 'same' card or a 'different' card while one choice card is always a 'same' card and the other a 'different' card. The correct choice card on any given trial is the one that has the same relation as the sample card.



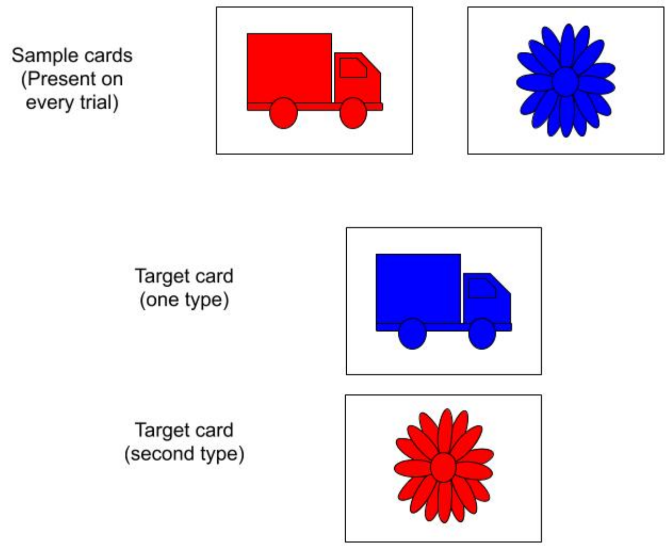
While this task may sound easy to us, it has proven surprisingly difficulty for children below the age of five. We are currently testing the hypothesis that part of this difficulty is children's tendency to focus on shape and color matches to the exclusion of other possible bases of matching, such that in RMTS they'll make approximate matches on shape or color (e.g. 'both cards have an object that is pointy') before considering matching on relations. To mitigate against this tendency we have designed a task in which the objects on the cards vary only on size (i.e. the objects are either the same size or different sizes, but otherwise identical). The hypothesis is that this will prevent children making approximate shape and color matches and focus their attention on relations.

Results have shown that removing shape and color from the stimuli - dimensions which children find very salient - dramatically increased the rates at which they made relational matches (from a statistically negligible number to over one-half of participants. This is important evidence of the conditions under which children tend to reason relationally - or fail to do so. Specifically, this study shows that the degree to which children engage in abstract reasoning depends heavily on what the problem they are faced with looks like. This has important implications in the long run for how we think about teaching abstract relational concepts to young children.

Investigating children's attention regulation abilities

Ivan Kroupin (Graduate Student)

Executive functions (EF) are a group of top-down cognitive control processes critical for day-to-day problem solving, academic performance and, by extension of both, to life in general. EF shows a dramatic increase in the early years of life, and one developmental stage has been measured in previous literature by a task known as Dimensional Change Card Sort (DCCS). DCCS involves matching one target card to one of two sample cards on one of two dimensions, traditionally either by color or by shape. The bases of matching are confounded between the cards - sample cards match the target cards in shape but not color or vice versa. Once the child matches a few cards using one dimension, say shape, we ask them to play a new game and match on the other dimension, say color. Now children must change the rule they use and put the target card with the sample card which it didn't go with in the previous game.



This task has proven difficult for three-year-olds, with around half consistently continuing to use the old rule even though they were instructed to use the new rule. This failure to switch is a reflection of still-developing executive functions.

In our studies we have been investigating reasons why this switch may be so difficult for kids. In one study we modified the instructions during the procedure of switching between tasks to make it feel more like a story for the kids. The idea was that perhaps if we made the switch between games less arbitrary kids would better be able to follow along. This did not turn out to be the case.

A new study examines whether changing the dimensions on which the cards are sorted may make children switch more easily. Support for this idea comes from some findings that individuals are more likely to encode a dimension they are less familiar with (e.g. number of objects per card, in the case of kids) in a more abstract way. Encoding the rules of the game more abstractly has been shown to make switching easier.

Results have shown, however, that making dimensions in DCCS less familiar did not significantly change children's performance on the task. This suggests that the difficulty children experience is related to the processing of the rules themselves - and not simply how they encode them.

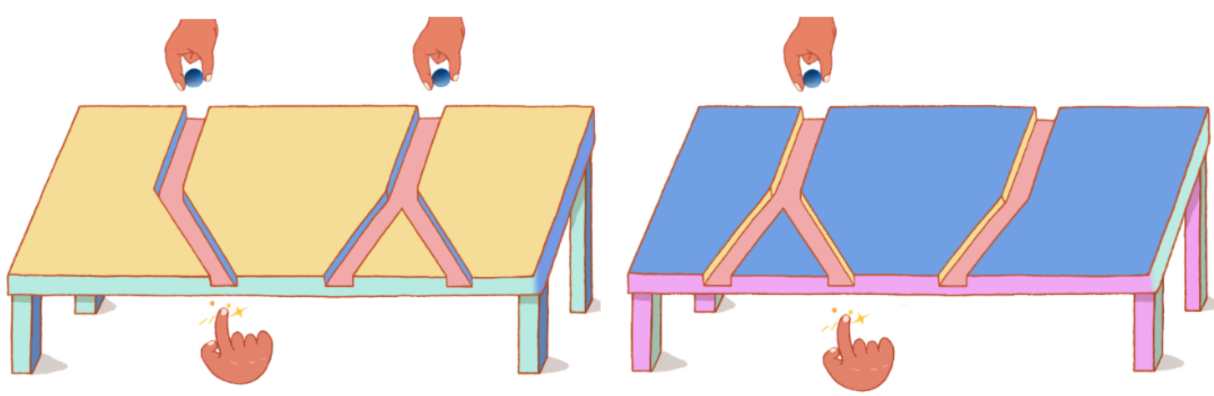
Talking about what can, will, and has to happen.

Eimantas Zalnieriunas (Undergraduate Research Assistant) and Brian Leahy (Graduate Student)

We routinely use words like ‘can’, ‘will’, and ‘must’ to express our thoughts: “I can afford to take leave from work”, “I will make it home in time for ten o’clock”, “I must pass this class in order to graduate”. Children begin to use words like these around their second and third birthdays, as in, “Maybe I have ice cream?”, or “My toy has to go in the box.” But what thoughts are children expressing with such phrases? Do they really understand that they might not get ice-cream, or that their toy cannot go elsewhere? And what is the relationship between their ability to talk about possibilities and their ability to think about possibilities? To investigate, we used a game about marbles rolling down slides.

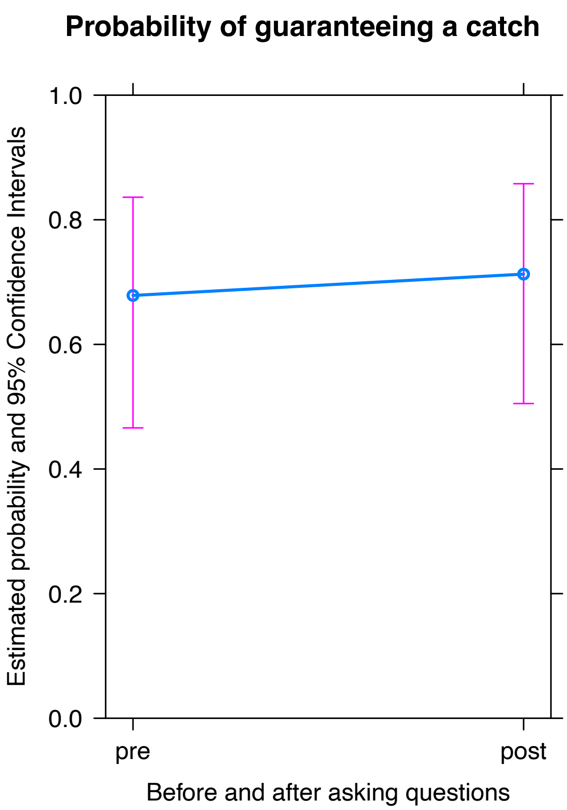
We showed four-year-old children a slanted board with single-slide and a Y-slide. In one part of the study, we held a marble above each slide and asked the children to choose the best place to catch a marble (see yellow board). To solve this problem, children must understand that a marble above the single-slide has only one place to come out, whereas a marble above the Y-slide can come out the left or right exit. The best place to catch a marble is under the single-slide, as illustrated by the pointing finger. Over six turns, children chose to put a container under the single-slide 62.5% of the time, much more than the 33% expected by chance, but still not close to 100%.

After these 6 turns at catching marbles, we asked children several questions. Our goals were to (a) probe their understanding of the words ‘can’, ‘will’, and ‘has to’ and (b) prompt them to think through the possibilities for each marble, to help them solve the problem. We asked children a total of 18 questions. For example, while holding a marble above the Y-slide, we pointed to one of the exits asked, “If I drop a marble in here, can it come out here?” (pointing to one of the outcomes; see blue board). We repeated this question for each combination of the two input locations, three output locations, and three verbs (can, will, and has to). The question was always, “If I drop a marble in here, ___ it come out here?”, with the blank filled in with one of the three verbs.



When we were asking about the single-slide, most children had no problems: they said that the marble can, will, and has to come out the single-slide exit. They also said that it doesn't have to, will not, and cannot come out either of the Y-slide exits. However, when the experimenter held a marble above the Y-slide, children struggled.

Consider the blue board. The marble can come out the left and right – both possibilities are open. More often than expected by chance, 4-year-olds correctly said that the marble could come out the left Y, could come out the right Y, and could not come out the straight side. However, when asked about where the marble has to come out, the problem was harder. In fact, the answer to that question is always 'no': It doesn't have to come out the left Y, it doesn't have to come out the right Y, and it doesn't have to come out the single-slide. Again, more children answered all three questions correctly than was expected by chance, but a substantial proportion of children seemed to confuse what has to happen with what can happen: they correctly said that the marble does not have to come out the single-slide, but it has to come out the left Y, and it has to come out the right Y!



The 'will' questions were hardest of all, with very few children performing correctly. And again, most errors were in treating 'will' like 'can': saying that it will not come out the single-slide, but it will come out the left Y and it will come out the right Y.

In sum, it seems that at this age children are only beginning to understand these verbs; many children seem to confuse all three meanings.

After the question phase, we gave them six more chances to catch marbles, to see if thinking through the problem improved their performance. We found no change in behavior: children chose the single-slide 65% of the time.

Logical reasoning with 'or' and multiple possibilities

Anna Holliday (Undergraduate Research Assistant), Samantha Fung (Undergraduate Research Assistant), Peter Zhu (Undergraduate Research Assistant), and Brian Leahy (Graduate Student)

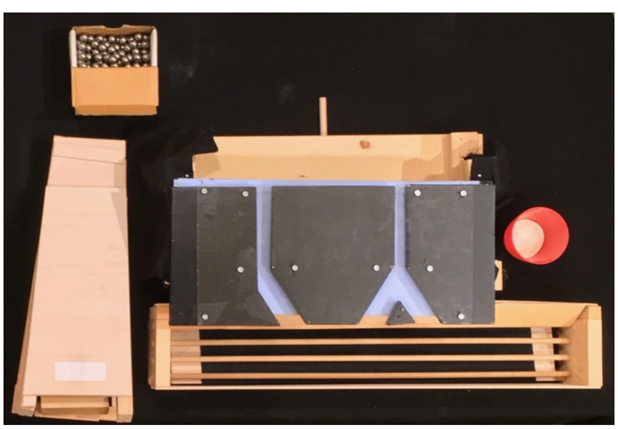
A study from our lab several years ago explored children's ability to reason through the so-called "disjunctive syllogism": If I know that a sticker is hidden in location A or location B, and then I learn that it is not in location A, I can infer that it is in location B. We presented children with 4 cups. Two were occluded, and a sticker was hidden there. Then the other two were occluded, and a sticker was hidden there. So participants knew that there was a sticker in cup one or cup two, and there was a sticker in cup 3 or cup 4. Then they were shown that cup 4 was empty. Do they now choose cup 3, which disjunctive syllogism should tell them contains a sticker?

In a control condition, children saw 3 cups. First cups 1 and 2 were occluded, and a sticker was hidden there. Then cup 3 was occluded, and a sticker was hidden there. This control condition poses many of the same challenges as the test condition: children must realize that there is definitely a sticker in cup 3, and they have to form and execute a plan to get that sticker. The only difference is that they do not need to arrive at certainty by a logical inference of eliminating option 4.

We tested 2.5-, 3-, and 4-year-olds. Almost all age groups performed better than chance on both test and control conditions (figure below, light green bars). But there were two interesting findings: (a) performance on the control (3-cups) version was never easier than the test (4-cups) version; (b) even when performance was better than chance (33%), it was still quite poor, with performance around 50% until age 4.

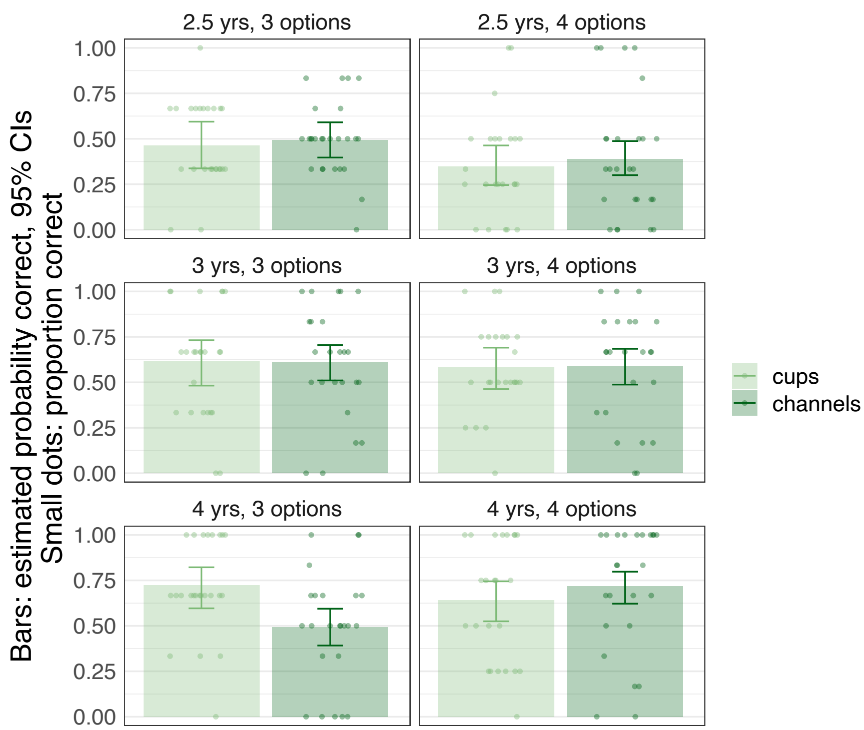
We proposed that many children before their fourth birthdays, and some even after their fourth birthdays, solve this task by making an assumption about which of the uncertain cups holds a sticker; then they only have to choose between two locations that both "certainly" hold a sticker. Thus they pick the certain cup 50% of the time (because they always know there's one there), and they pick the uncertain cups 50% of the time (because they "know" which one of these cups holds the sticker).

An alternative explanation is that this task is too difficult. Children have to track multiple objects in many hiding places through multiple phases of occlusion, which may overwhelm their working memory. Also, the experimenter knows something that the participant does not, which we know makes tasks difficult for children this age. To address these issues, we developed a "channels" version of the task, as in the photo. This is the "3 channels" version: two marbles will be rolled at the same time; the participant will be given one cup to catch a marble. They should put it where they are most likely to catch a marble: under the unforked slide. We also had a "4 channels" version, where there were two forking channels, and we showed participants that one of the



four outcomes would be blocked, so that disjunctive reasoning should allow them to infer with certainty where one of the marbles would come out. This task has all of the inferential features of the cups task, but makes none of the working memory demands: the relevant information is all entirely visible all the time. Moreover, the participant and the experimenter have all the same knowledge (at least as far as the participant can tell; in fact the experimenter secretly controlled where every marble landed). The question is: do these simplifications make the task easier?

The answer is no: as shown in the figure below, performance is nearly identical with cups and channels in every age group. The sole exception is 4-year-olds on the 3-options version, which was significantly more difficult in the channels version! Note, though, that 4-year-olds performed identically on both versions of the 4-options problem, and moreover performed better than they did on 3-options with channels. This makes us suspect that the difficulty of the channels version of the 3-options task is an artefact. Ongoing followups are testing that hypothesis.



Observing imitation

Narges Afshordi (Post-Doctoral Researcher)

Imitation is ubiquitous in human life. By copying those around us, we learn, we bond, and we fit in. We also notice when other people imitate each other. Can preschoolers do this too? In past experiments for this project, we showed three-, four-, and five-year-old children three characters, one of whom copied the actions of another. We then asked children who the copier liked, the options being the person she had copied, or the person she had not copied. Adults have the intuition that if we imitate someone, we probably like them. Our findings suggest that children as young as three years can do this task too, but three-, four-, and five-year-olds all do much better if we give them some hints along the way. This suggests that while they can infer whom the copier likes, it is also not the easiest task for them to accomplish.

In a new follow-up study we are running online with three-year-olds, we are interested in whether children can tell us who is copying whom. In a Zoom session with children and parents, we show animations of two people, in which one of person keeps copying the other one. We then ask children to tell us who was copying whom. Since we can't see where children point over Zoom, we use color words to ask them for their answers. See below for a picture of two of the characters, Yellow Girl and Green Girl. Thank you for your participation and stay tuned for our results!

Children's knowledge of plants

You-jung Choi (Postdoctoral Researcher)

Throughout evolution, humans and animals alike have foraged for food and faced the crucial task of distinguishing edible plants from poisonous ones. Given the high stakes, it is likely that animals, including humans, possess cognitive systems that promote rapid and effective learning to identify, categorize, and reason about plants. Nevertheless, the existence, properties, and development of such systems are not well-studied.

The present research aims to fill these knowledge gaps. We tested whether children's abilities to perceive, categorize, and learn about plants are supported by a system for representing a fundamental property of all living plants: plant forms are organized around a skeleton with a primary vertical axis and roughly symmetrical branching roots and limbs. Plants have a distinctive skeletal structure due to constraints on how plants grow, capture energy from the sun, and distribute water and chemicals throughout their bodies. This research tested whether children are sensitive to this structure and use it in categorizing plants by species.

Specifically, in this study, four- to thirteen-year-old children received two tasks: an internal structure task and a categorization task. The internal structure task examined whether children can infer the correct skeletal structure of trees, leaves, and geometric shapes from their outlined shapes. Children saw a target outline shape and were asked to find the correct “inside” of the target (Fig. 1a & 1b). In the categorization task, children were asked whether they could find a plant from the same species as a target plant based on their properties including shapes, venation patterns, edge pattern, and colors (Fig. 2).

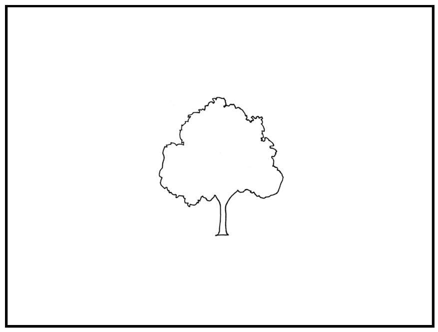


Fig. 1a. An example of a tree trial’s target stimuli

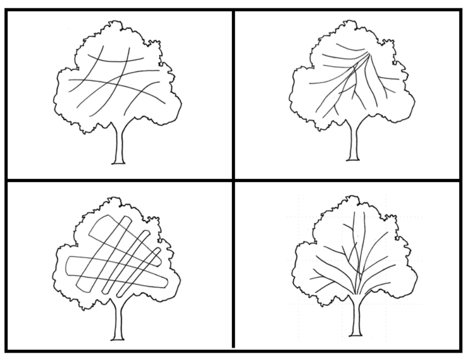


Fig. 1b. An example of a tree trial’s four options: simple distractor, orientation distractor, complex distractor, correct skeleton, from top-left, top-right, bottom-left, to bottom-right)

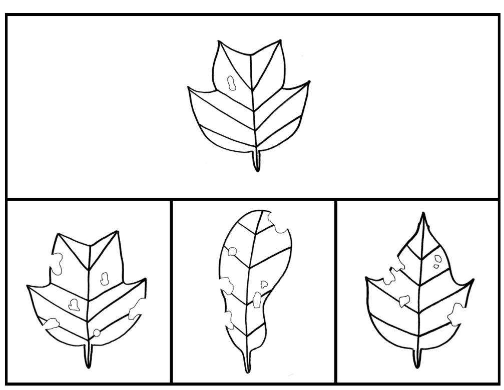


Fig. 2. An example of a shape single-group trial stimuli (a target on the top and three options on the bottom)

Given the evolutionary importance of plants, it is theorized that children will indicate a better understanding of the plants in comparison to geometric shapes. However, if children are equally sensitive to the internal structure of plants and artifacts, then that could mean either 1) experiences or education equalized the distinct systems for this age group, or 2) humans might have one system for both. To examine these alternatives, we might need to examine younger age groups in the future.

In the categorization task, if children understand the essential properties of leaves (such as shapes, venations, and edges), they will categorize leaves based on these properties. Furthermore, if children understand the hierarchy of certain properties in differentiating leaf species, they should treat the property cues differently. Because leaves change color, a color cue is less important than a venation cue in determining a leaf's identity. When these two cues conflict, children should use the venation cue to categorize leaves while ignoring the color cues.

The preliminary results show that children in the internal structure task have no problem finding the correct skeleton of trees. In the categorization task, children show that they rely heavily on shape information when identifying the same species of plant. They also used color and edge pattern information, but not the venation pattern. With more data, we will confirm what kinds of featural information are important for children in identifying the species of plants and how their responses change by age to explore environmental influences on children's understanding of plants.

Thank you again so much for your participation!

Infants' sensitivity to the canonical orientation of plants

You-jung Choi (Postdoctoral Researcher)

Humans interact with a multitude of different kinds of objects, but until the industrial revolution, the most crucial kinds for people to know about were animals and plants. To survive, humans had to distinguish and classify animal species into those that are used for work (hunting, farming), those that provide food or clothing, and those that prey on humans and must be avoided. Previous research reveals that very young infants are sensitive to the canonical orientation of animals' faces and bodies. Similarly, are infants able to recognize the canonical orientation of plants?

The plants that humans forage vary greatly in size and shape, but they are similar in that they all grow upward toward the sun and send roots downward for water, nourishment, and stability. Thus, plants, like animals, have a privileged vertical orientation. In this study, we aim to examine whether infants prefer canonically oriented plants prior to experience with plants. Specifically, we test whether five- to six-month-old infants prefer to look at plants, human body parts, and artifacts in their canonical vertical orientation, relative to inverted or horizontal orientations, as they do for faces.

Five- to six-month-old infants view two pairs of identical plant videos and two pairs of artifact videos (a milk bottle, a toy boat) displayed side by side at orientations of 0°, 90°, or 180°. Each infant is randomly assigned to one of two orientation conditions: 0° vs. 90° (horizontal condition) or 0° vs. 180° (vertical condition, see Fig.1). The procedure of these two conditions is the same except for the orientations of the paired stimuli.

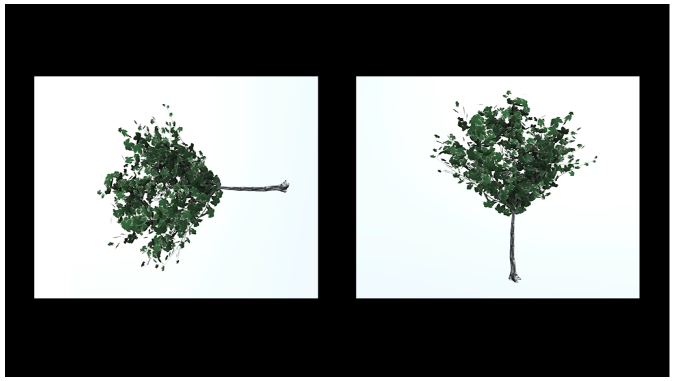


Fig. 1. An example of the tree with leaves trial in the horizontal condition.

Since plants grow vertically, with stems growing upward and roots growing downward, if infants are sensitive to the canonical orientation of plants as they are faces, they will look longer at upright plants and faces but not the body parts or the artifact.

Our data collection was paused due to COVID-19, but we are planning to run the study over Zoom so stay tuned for the results!

Thank you for your participation in this study!

Evaluations of Helpers in Means-End Sequences

Brandon Woo (Graduate Student) and Liz Spelke (Advisor)

A number of studies have found that infants prefer interacting with individuals who help others over individuals who do not. The present studies aim to examine how 15- and 8-month-old infants evaluate actors who help others complete a series of actions towards an ultimate goal.

In two studies, infants saw two transparent boxes, each containing a unique toy. In the first few trials, a protagonist tried but failed to open one box. Two helpers helped the protagonist to open the box, and the protagonist grasped the toy inside. Following these first few trials, infants saw the two toys switch positions, such that the original box that had been opened now contained a new toy, and the other box contained the original toy that the protagonist had grasped. After the switch in toy positions, the protagonist jumped between the boxes, as though calling for attention. One helper opened the original box with the new toy, whereas the other opened the second box with the original toy that the bear had grasped. In each study, we assessed infants' preferences for the two helpers.

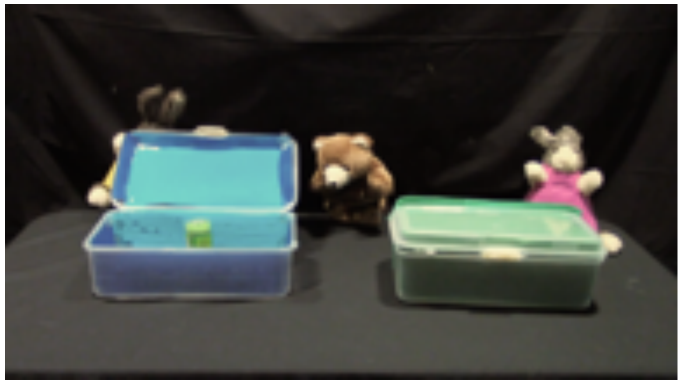
We found that 15- and 8-month-old infants had opposite preferences. Whereas 15-month-old infants preferred reaching for the helper who opened the box with the original toy that the protagonist had grasped, 8-month-old infants preferred reaching for the helper who opened the original box that the protagonist had tried to open. These findings are consistent with a developmental change in how infants understand actions that are taken towards an ultimate goal. We are now in the process of writing these results up for publication.

The Role of Beliefs in Evaluations of Helpers

Brandon Woo (Graduate Student) and Liz Spelke (Advisor)

A number of studies have found that infants prefer interacting with individuals who help others over individuals who do not. The present studies aim to examine whether 15-month-old infants take others' beliefs into account when evaluating helping actions.

In two studies, 15-month-old infants saw two boxes, each containing a unique toy. In the first few trials, a protagonist tried but failed to open one box. Two helpers helped the protagonist to open the box, and the protagonist grasped the toy inside. Following these first few trials, infants saw the two toys switch positions, such that the original box that had been opened now contained a new toy, and the other box contained the original toy that the protagonist had grasped. After the switch in toy positions, the protagonist jumped between the boxes, as though calling for attention. One helper opened the original box with the new toy, whereas the other opened the second box with the original toy that the bear had grasped. In each study, we assessed infants' preferences for the two helpers.



The critical distinction between the studies concerns the helpers' perceptual access to the toys. In Study 1, the boxes are transparent and the helpers are present as the toys switch positions. By contrast, in Study 2, the boxes are opaque and the helpers are absent as the toys switch positions. Thus, although infants know of the switch in toys in both studies, they can only accurately reason that the helpers have knowledge of the switch in Study 1.

We found that infants in the two studies had opposite preferences. In Study 1, 17/22 infants preferentially reached for the helper who opened the box with the original toy that the protagonist had grasped. By contrast, in Study 2, 19/24 infants preferentially reached for the helper who opened the original box that the protagonist had tried to open. These findings suggest that infants are sensitive to others' beliefs in helping contexts.

We are now trying to replicate our findings over Zoom, using preferential looking instead of reaching as our measure of infants' evaluations.

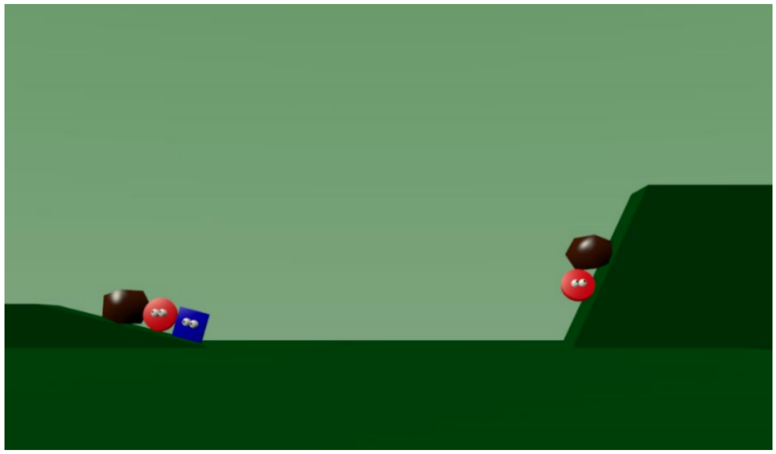
Pupil Dilation in Response to Different Accents

Brandon Woo (Graduate Student) and Liz Spelke (Advisor)

Past work has found that infants (raised in North American, English-speaking homes) are sensitive to accent, preferring to look at and interact with individuals who speak English in a North American accent vs. in a French accent. In this study, we were studying whether infants might prefer interacting with individuals who speak in an accent that is familiar with them because such individuals may be able to communicate with them and may therefore be better potential teachers to them. To start getting at whom infants think could be a good teacher, we looked at how much infants' pupils were dilated when they saw someone speaking in a familiar accent vs. in a foreign accent. There were not clear patterns in pilot data, and so, we stopped data collection.

Evaluations of Effortful Helping

Brandon Woo (Graduate Student), Shari Liu (Post-Doctoral Researcher), Hyowon Gweon (Collaborator), and Liz Spelke (Advisor)



Early in development, infants appear to: (i) prefer interacting with individuals who help others over individuals who are unhelpful; and (ii) understand that steep slopes take more effort to climb than less steep slopes. The present studies aim to examine whether 16-month-old infants think a character should help someone when a task requires more vs. less effort.

In Study 1, infants saw one character try to climb a steep hill while another character tried to climb a less steep hill. A third character helped the character at the steep hill by pushing it up, whereas a fourth character helped the character at the less steep hill by pushing it up. We found that infants preferentially reached to the character who helped at the steep hill. This finding was consistent with the prediction that infants would positively evaluate individuals who help those that are in greater need of help.

Of course, an alternative interpretation was that infants might have preferred the character who helped at the steeper hill because it did something that was more difficult, and might appear more competent. We are now testing this alternative interpretation of our original results in additional studies.

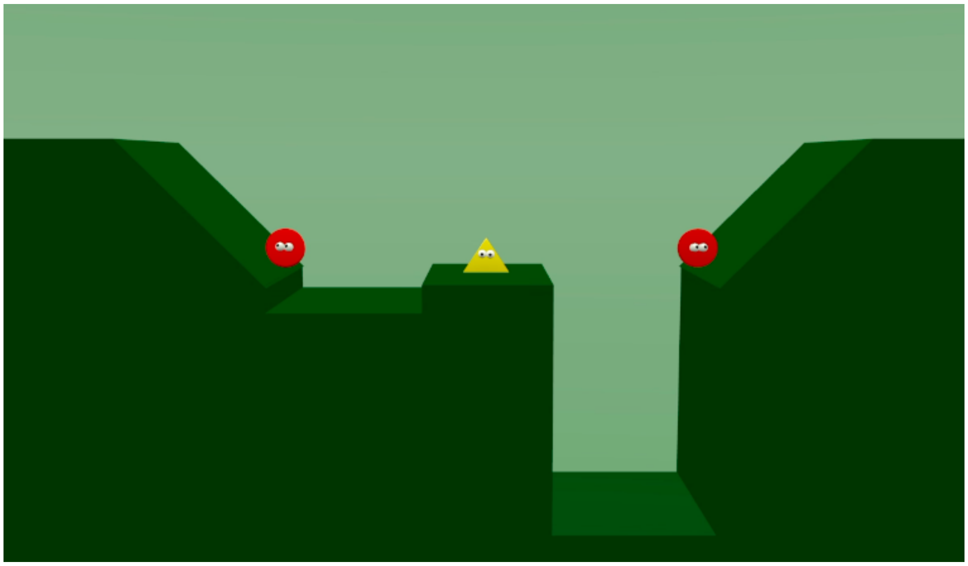
Understanding the Intentions of Social Group Members

Brandon Woo (Graduate Student) and Liz Spelke (Advisor)

Past work has found that infants and young children are sensitive to: (i) the distinction between intentional and accidental actions; and (ii) whether someone speaks in the same language as their family. We wanted to see whether 3-year-old children might be more sensitive to others' intentions when someone is in their social group (e.g., speaking in the same language as their family). There were not clear patterns in pilot data, and so, we stopped data collection.

Evaluations of Risky Helping

Brandon Woo (Graduate Student) and Liz Spelke (Advisor)



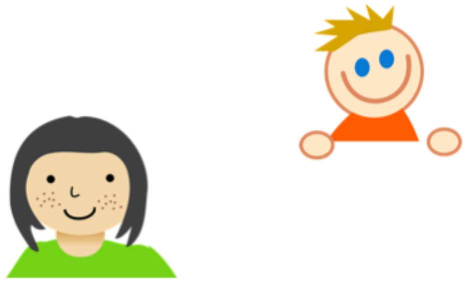
Early in development, infants appear to: (i) prefer interacting with individuals who help others over individuals who are unhelpful; and (ii) understand that deeper cliffs are riskier to jump over than are less deep cliffs. The present study aimed to examine whether 13-month-old infants think a character should help someone when a task is more vs. less dangerous.

In Study 1, infants saw two characters try to climb hills. One character was climbing next to a deep hole, whereas the other was climbing next to a more shallow hole. A third character helped the character climbing near the deep hole by pushing it up, whereas a fourth character helped the character at the less deep hole by pushing it up. We found that infants preferentially reached to the character who helped at the hill that is next to the deeper hole. We are now in the process of trying to replicate these findings over Zoom.

You Had to Ask?

Brandon Woo (Graduate Student) and Liz Spelke (Advisor)

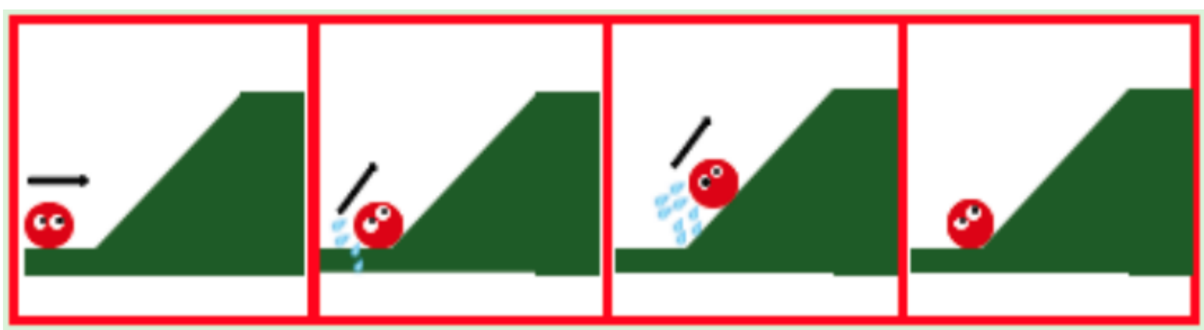
A person asks two friends for help. One friend immediately agrees. The second friend agrees only after first asking, "How much time will it take?" Which of the friends is closer to the person in need of help? Work on adults has found that adults would find the former friend to be closer to the person in need of help. That is, adults are sensitive to not just whether someone agrees to help, but also the process that led them to make that decision. In the present study, we are looking at what 3- to 7-year-old children think of individuals who have to ask questions before agreeing or refusing to help, or before accepting or rejecting information. Everything for the present study is in the piloting phase, and so, we are unable to comment on trends in data.



Kate asked: "Is it an easy puzzle? How many pieces are there? How much time will it take?"

Training Social and Moral Reasoning

Brandon Woo (Graduate Student) and Liz Spelke (Advisor)



Past work in this lab has developed games to improve children's ability to reason about number. In the present study, we are examining whether a game focused on social evaluation may improve 6- to 7-year-olds' ability to reason about social and moral problems. In the game, children see social scenarios and are asked to determine who's nicer.

We are currently developing these games on social evaluation and are developing assessments involving social and moral problems (e.g., evaluation, distribution of resources, emotion recognition, emotion prediction, etc.). Everything for the present study is in the piloting phase, and so, we are unable to comment on trends in data.

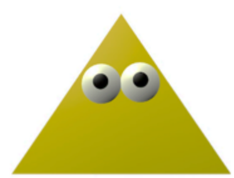
Perspective Taking in Infants and Children

Brandon Woo (Graduate Student) and Liz Spelke (Advisor)

A person repeatedly reaches for a picture in an upright orientation over the same picture in an upside-down orientation. If the person moves to the other side of the room, such that what was upright to her is now upside down and vice versa, what will the person reach for? The present studies aim to examine whether infants and 3- to 7-year-old children are sensitive to whether a person's perspective is different from their own. Everything for the present study is in the piloting phase, and so, we are unable to comment on trends in data.

Whom to Learn From

Brandon Woo (Graduate Student) and Liz Spelke (Advisor)



A person takes a really inefficient route to get to a goal as two individuals observe. One observer takes the exact same route, whereas the second observer takes a much more direct route. What do children think of the two observers? Which one might be better at tasks that are relevant to culture (e.g., dance, music, cooking, etc.)? Which one might be better at tasks that are not as relevant to culture (e.g., making a puzzle, navigating a maze, etc.)? The present study aims to examine 3- to 7-year-old children's inferences about someone's potential to teach tasks that are either culturally relevant or not culturally relevant. Everything for the present study is in the piloting phase, and so, we are unable to comment on trends in data.

Five-Month-Old Infants Preferences for Responsive Caregivers

Rhea Howard (Graduate Student), Annie Spokes (PhD), and Elizabeth Spelke (Advisor)

In these studies, 4.5 to 5.5-month-old infant participants watched short video animations of caregiver-baby interactions. In the videos two large shapes represented "adults" and a small shape represented a "baby." Each shape had eyes and was a bright color to make them easily distinguishable. Infant participants saw the "baby" shape cry and one of the two adult shapes approached and comforted the baby, while the other adult shape moved away from the baby. Participants watched this interaction four times. Afterwards, the two adult shapes came onto the screen for 45 seconds. We were interested in whether infants would look longer at the adult shape that had comforted the crying baby. At this age, infants tend to look longer at things that they prefer. If infants looked longer at the responsive caregiver, this would be evidence that they are able to track the relationships between these characters and that they have a preference for the more helpful character. In previous studies, we have found that 5-month-old infants do look longer at the more responsive caregiver. However, in this most recent study we did not replicate this preference.

We are currently following up on this work to investigate more fully whether 5-month-old infants do have a preference for more responsive caregivers, and if so what specific cues about the characters infants are using to distinguish between these characters.

Inferences about Caregiver Gender at Fourteen Months

Rhea Howard (Graduate Student), Annie Spokes (PhD), and Elizabeth Spelke (Advisor)

In these studies, 13.5 to 14.5-month-old infant participants watched short video animations of caregiver-baby interactions. In the videos two large shapes represented "adults" and a small shape represented a "baby." Each shape had eyes and was a bright color. One of the adult shapes had a male voice, and the other adult shape had a female voice. At the start of the video, each of the adult shapes introduced themselves to the infant participants. After the characters introduced themselves, the "baby" shape cried and one of the two adult shapes approached and comforted the baby. In the next clip, the baby cried again, but this time the other adult comforted the baby. Infant participants saw the male-voiced adult shape and the female-voiced adult shape each comfort the crying infant twice. At this age, infants tend to look longer at events that they find surprising. We wanted to know whether infants would find it more surprising if a baby was comforted by a male character over a female character.

These studies are currently ongoing, however we do have preliminary data that 14 month olds who are themselves primarily cared for by female caregivers find it more surprising when a character with a stern male voice comforts the crying infant instead of a character with a cheerful female voice. Interestingly, babies are equally unsurprised when a cheerful male character or a stern female character comfort an infant. These results suggest that when a male character is friendly, infants do not have an expectation that the female character is more likely to comfort. However, if the male character is stern, infants do have an expectation that the female character is more likely to care for an infant. Currently we do not have enough data from infants who are co-parented or who are primarily cared for by male caregivers to be able to draw conclusions about their expectations about caregiver gender or how temperament might play into their inferences. We are looking forward to continuing to collect data to untangle what expectations babies may or may not have about who is likely to care for an infant.

Training children's understanding of the base-10 structure of the number system

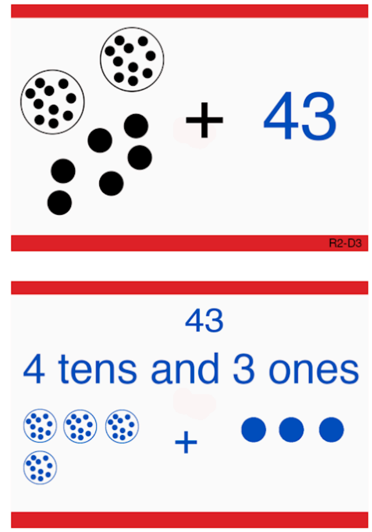
Akshita Srinivasan (Graduate Student)

In school, one of the most important mathematical skills taught to children is arithmetic. However, arithmetic can be really hard for them to learn unless they master the base-10 compositional structure of the number system. Number words in English are not that transparent in revealing this structure. For example, the number 'twenty-five' is actually made up of two tens and five, but the number word 'twenty' does not automatically signal that it is made up of two tens.

In order to facilitate this understanding among 6-7-year-old children (who are on the threshold of arithmetic instruction in school), we are developing a game for them to take home and play with an adult or an older sibling. In this game, children will play with a board and some cards for a period of two weeks. Based on the numbers on the cards, they need to move a token on the board in order to perform addition. For example, in the cards shown below, they will first find the number in black (26) on the board by counting by tens. Then, they will add the number in blue (43) to it, by leveraging its compositional structure (43= four tens and 3 ones). With a battery of assessments before and after this training, we will measure if our games promote school relevant arithmetic learning.

Data collection is ongoing for this study. We hope that our game will help children encode numbers in a manner that makes school-based learning easier for them. Stay tuned for the findings from this study!

90	91	92	93	94	95	96	97	98	99
80	81	82	83	84	85	86	87	88	89
70	71	72	73	74	75	76	77	78	79
60	61	62	63	64	65	66	67	68	69
50	51	52	53	54	55	56	57	58	59
40	41	42	43	44	45	46	47	48	49
30	31	32	33	34	35	36	37	38	39
20	21	22	23	24	25	26	27	28	29
10	11	12	13	14	15	16	17	18	19
	1	2	3	4	5	6	7	8	9



Compositionality and Enumeration

Yelina Yiyi Chen (Graduate Student)

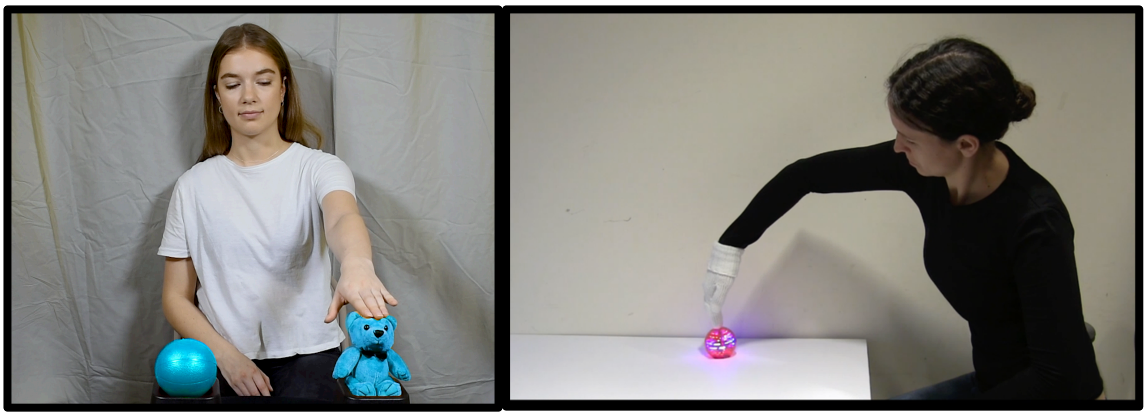
Studies have shown that first-grade children, older children, and adults are able to utilize visual grouping cues to aid counting, compared to when the same number of items to be counted are not grouped. For example, participants are faster and make fewer errors when counting three groups of three dots than a cluster of nine dots. In addition, it has been shown that mastering the counting sequence (“one, two, three…”) does not necessarily indicate that children understand the exact meaning of those number words. In this study, we hope to find out whether young children can take advantage of engaging visual grouping cues and language that highlights the compositional structure of the pictures to reproduce an exact quantity from memory.

This study involves a math game, in which we invite children to use different strategies to reproduce a given quantity and gauge their sense of exactness of numbers. During the study, children are presented with pictures of cartoon figures, which are then covered up and children are asked to distribute tokens to each of the characters they previously saw. We piloted with a wide age range while the study was conducted in the lab (2.5 years old to 5.5 years old); since quarantine, we have started piloting again remotely through zoom with modified procedures and have narrowed down the age range (around 3.5 to 5.5 years old).

From the pilot data we gathered in lab before quarantine, a preliminary analysis shows that grouping the pictures visually accompanied by child-friendly language that highlights compositionality makes it easier for children to reproduce a given quantity. Furthermore, there is a trend that children show comparable performance for a set of objects depicted compositionally as the set size increases, while they tend to make more errors when the set size increases in the absence of compositionality cues. Since we recently started piloting online versions of the study, we do not have enough data to see a pattern yet.

What do prereaching babies know about reaching?

Shari Liu (Graduate Student)



Humans engage in a lot of goal-directed actions: cooking, dancing, acting, reading, buying, throwing, pulling, climbing, and more. Mechanisms that help us understand the structure of these actions is essential for understanding and learning from others. Previous research from our and other labs suggests that giving babies action experience boosts their action understanding. This series of studies asks whether infants really need to experience a particular action themselves in order to understand it in other people.

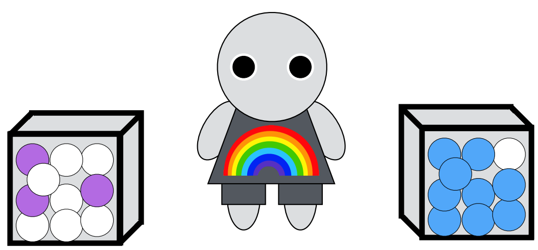
In particular, we were interested in whether 3-month-old infants, who are about 1-2 months away from reaching for, grasping, and manipulating objects on their own, understand that reaching is an intentional action. **This past academic year, we published a paper showing that 3-month-old infants understand how physical obstacles impose costs on other people's reaches**: When someone reaches over or around a barrier for an object, infants appreciate that the person curves their arm because of the barrier, and if the barrier were removed, they would reach directly for the object. This project took us 5 years to complete, and we could not have done it without all the families and babies who volunteered their time! For a copy of this paper, follow this link: **https://tinyurl.com/harvarlds3mo**

More recently, we tested another aspect of 3-month-olds' understanding of reaching: specifically, whether infants see reaches as directed towards a particular goal object. We presented 3-month-olds with an actress to reached for one object over another (e.g. a bear, over a ball). Then, the objects switched locations. Where will she reach: For the same object she did before in the new location (the bear, where the ball used to be), or for the new object in the old location (the ball, where the bear used to be)? Past work shows that infants 5 months and older look longer at when the person reaches for the new object. If 3-month-olds interpret reaching as directed towards a specific goal object, then they, like older infants, will look longer when the person reaches for the new object. However, this is not what we found – instead, infants looked equally at these two outcomes. Right now, we are following up on this finding. Do 3-month-old babies have no expectations about where people will reach? Or are they unsure of whether the reaching action was directed towards an object (the bear, wherever it is), or a location (on the left, no matter what's there)?

These findings are important for several reasons. First, they show that infants do not need any motor experience reaching for objects (which babies do not reliably start doing until ~5 months of age) around a barrier (which babies do not master on their own until 8-10 months) in order to expect that people plan their reaches to be as efficient as possible. Furthermore, our findings show that infants have a lot to learn: for instance, that reaching actions tend to be directed towards objects, rather than places. Thank you for your help with these experiments, and we look forward to doing more science with you in the future!

Children's understanding of probability and reward

Kexin Que (Undergraduate Research Assistant) and Shari Liu (Graduate Student)

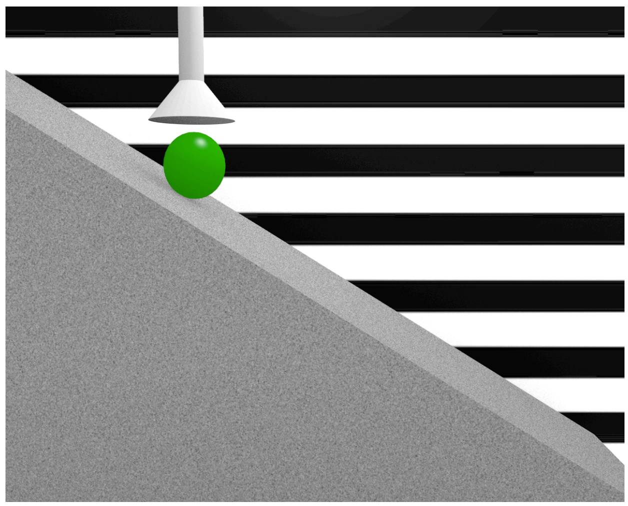


Imagine a person is choosing between two lotteries. Lottery A has a 1% chance of winning a red ball, and Lottery B has a 99% chance of winning a blue ball. The person chooses the 1% lottery, thereby giving up an almost certain chance of drawing a blue ball, in order to pursue an almost impossible outcome of drawing a red ball. Intuitively, you might get the impression that this person strongly prefers the red ball to the blue ball. But reverse the choice (this person chooses the 99% blue box over the 1% red box), and her preference becomes less clear: she could be motivated by the high probability of winning something, or she really prefers the blue ball to red.

In this study, we show 6- to 8-year-old children and adults a character's choices between two boxes, and the chance of winning a colorful ball from each box, and ask them which colorful ball the character prefers and how much more she prefers that ball compared to the colorful ball in the other box. Across trials, we vary the color of these balls, the probability of winning a colorful ball from each box, and the character's choices. The results from pilot studies tell us that both children and adults think the character likes what she chooses. However, only adults infer the character's preferences from both the agent's choices and the probabilistic information. Stay tuned, we will come back with more results!

Infants' understanding of inclined plane mechanics

Shari Liu (Graduate Student)



As adults, we understand that if a ball is dropped in the middle of a slanted plane, it will speed up as it travels down the plane, and we'd be surprised to see it slow down as it's rolling down, or speed up as it rolls up the plane. Past research shows that it takes infants until about 7 months of age to arrive at this intuition: When 5-month-olds see a ball accelerate up vs accelerate down a tilted plane, they look equally to these two events, but 7-month-olds look longer at the event that violates physics (the ball that speeds up as it travels up the plane). This past year, we have been re-running these studies in 7-month-old infants using new, animated events, and our new eye-tracker.

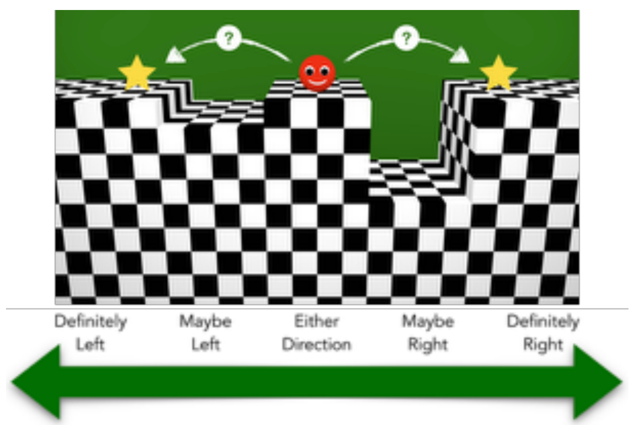
You might be curious about why we're running a study that has already been run before. This practice is called replication, and it is vitally important for scientific progress. In order to discover new things about the world, scientists often have to think outside the box and be open to findings they don't initially expect. The point of replication is to see whether new and exciting findings are reliable and robust (e.g. showing up under a wide variety of circumstances, including the circumstances of the original experiment), fragile (e.g. only appearing under very specific conditions), or the result of random chance. The balance between confirmatory research (where we have strong predictions about the results) and exploratory research (where we have no idea what will happen!) is the foundation for scientific progress, allowing us to push forward from what we know, while still leaving room to discover completely new things.

In this replication study, we found that 7-month-old infants were more interested in the ball accelerating up the plane than down the plane, but only when the ball was dropped in the middle of the ramp, and not when it was placed at the bottom of the ramp (and then accelerated up) vs placed at the top of the ramp (and then accelerated down). One reason for this is that babies are more interested in the movies where the ball could go either way.

There are many reasons why our findings may differ from the original study (e.g. animations vs videotaped movies, using the new eyetracker vs older methods). We are currently planning a new experiment replicating our new finding, and considering testing babies online during the COVID-19 pandemic. Thank you so much for participating and we'll look forward to reporting new results next year!

Children's Understanding of Danger and Reward

Nensi Gjata (Undergraduate Thesis Student) and Shari Liu (Graduate Student)



We recognize that some actions are more dangerous than others; we'd rather skip through a meadow than near the edge of a cliff. Infants are also tuned into dangerous acts and can reason about how much a character might like an object based on how much danger it overcame to get to that goal. We were curious about how robust that ability really is, so we tested whether kids and adults could use fine-grained cues about danger—how badly things could go if an action fails—in order to reason about what others like and what they might do next.

In this study, we show 6- to 8-year-old children and adults (online) a bunch of situations in which a character is able to jump trenches of different depths to get to a prize on the other side. We found that both kids and adults expected the agent to feel worse when jumping deeper trenches and to prefer taking safer actions. Moreover, both kids and adults could infer how deep a cliff the character would jump to get to an object based on how much it liked that object, but only adults could do the opposite: infer how much the character likes an object based on how deep a cliff it was willing to jump to get to it. Taken altogether, these findings support that adults and children appreciate that some actions can end more badly than others. This understanding allows them to use information about reward and danger to explain and predict others' actions. Thank you so much for participating in this game with us!

Using Storybooks to Improve Number and Social Understanding in Toddlers

Caitlin Connolly (Research Assistant)

As young children near preschool age, pre-academic skills like number sense and social and emotional understanding take on new importance by preparing kids to learn how to learn. It may seem like preschool and kindergarten are simple, but kids have to work really hard to do things like adapt to a brand-new environment, learn about peers and teachers and how to cooperate with them, and learn about new and sometimes challenging concepts like numbers, phonics and early reading, and more.

By encouraging kids to practice some of these skills before they begin school, we can build a solid foundation for kids to draw upon once they start school so that their learning experiences can be more effective. We want to explore fun and accessible materials to see how they might be able to nurture these skills in young children, especially in interactive ways that can bring rich educational experiences into the home environment!

For this study, we are trying to see whether storybooks that revolve around number and social understanding can help encourage these skills in preschool aged kids. We have written two colorful, engaging storybooks to test this idea.

In the number book, children find a story of two friends who are searching for at least two more players for a fun game of tag. As they encounter groups of friends varying in number, they have to think about how these numbers combine to equal other numbers, and whether those numbers may be exactly enough, or not quite enough.

In the social book, the same two friends are trying to find guests for a fun birthday party, but soon discover that everyone has different feelings and moods—and not all of them feel very happy about the idea of going to a birthday party that day. The friends have to think about how they should talk to or act with different friends depending on how they feel, and how they can help in different emotional situations.

Given the constraints on in-person lab visits because of COVID-19, we are preparing to run our study sessions over Zoom! This study will involve two sessions. In the first session, kids will play some games that will look at number and social cognition skills. Then, their parent or guardian will read their assigned book with them. We'll ask parents to read the book with their child as much as they like over the course of the 2-3 weeks between visits. Then, we'll have a second session where kids will play different versions of the previous games, and will read the book with their parent or guardian one last time.

Right now, we think that at the end of the study, kids who received the math book will perform better on the number games, while kids who received the social book will perform better on the social games. We are very excited to learn more about how these books may help prepare kids to have positive school experiences--we hope we can continue to improve on these materials and develop accessible materials to help kids in a wide variety of environments learn better in school!

Do infants like who their caregivers like?

Ashley J Thomas (Post-doctoral Researcher)

In this study we're interested in finding out whether infants pay attention to how their caregivers interact with new people. Across cultures, people imitate those who they like. And in fact, when infants see someone imitate one person but not another, they expect that the person doing the imitating will approach the person they imitated. So in our study, we show infants a video where their caregiver imitates one puppet and doesn't imitate another puppet. To show the infants that their caregiver 'likes' one of the puppets more. When we were doing this in the lab, we then asked the infants to choose between the two puppets. Now, over zoom, we measure which puppet the infants look toward.

We are currently running this experiment over Zoom. Parents make a video using their webcams at home. Infants who are between the age of 11.5 and 12.5 months are eligible.

In the lab we found that infants reached more for a puppet their caregiver imitated over one that their caregiver had not imitated and that this was not true when they observed another infant's caregiver doing the imitating.

Improving school readiness using game-based interventions

Chrissie Carvalho (Postdoctoral Researcher), Akshita Srinivasan (Graduate Student),

Laura Müllertz, Sara Dablouk, Caitlin Connolly , Elisa Campello de Mello, and William Adams, (Research Assistants)

Preschool is a crucial time during which children learn about mathematical concepts (like numbers) and social concepts (like understanding others' mental states). While the importance of learning about numbers to succeed in school easily comes to mind, it might be hard to imagine the school-relevant benefits of understanding mental state concepts. However, a lot of previous research has argued that understanding others' mental states is an essential part of learning to learn. Preschool interventions focused on such domains may help to notably increase school readiness.

With the goal of improving school readiness, we designed two board-and-card games called Number Chase and Mind Hunter (figures 1-2) for preschool-aged children to play at home with their parents. We have also conducted similar large-scale studies in preschools in New Delhi, India. Those studies focused only on mathematical abilities and showed promising results! Children showed short-term gains in their school-relevant mathematical abilities. We are now excited about expanding into the social domain!

In this home-based intervention study, 5-6-year-old children were invited to visit the lab twice, both visits separated by a maximum of three weeks. In between the two lab visits, children played either the number or the social game with their parents at home. We measured children's numerical and socio-cognitive abilities during both the lab visits, that is, before and after they played their assigned game at home.

We have now finished data collection and are very excited to report our preliminary findings! We found that children who were trained on the number game showed greater gains in their numerical abilities, relative to the children trained on the social game. However, children who were trained on the social game showed no specific improvement in their socio-cognitive abilities relative to the children trained on the number game. We are intrigued by these findings and plan to look further into the social game to see why it led to no specific benefit. We plan to use these insights to inform our future work aimed at creating more effective socio-cognitive games. We hope that such games, that can be played at home, will be relevant for children's learning and education, especially during times like these when children and parents are isolating in their homes due to the COVID-19 pandemic.

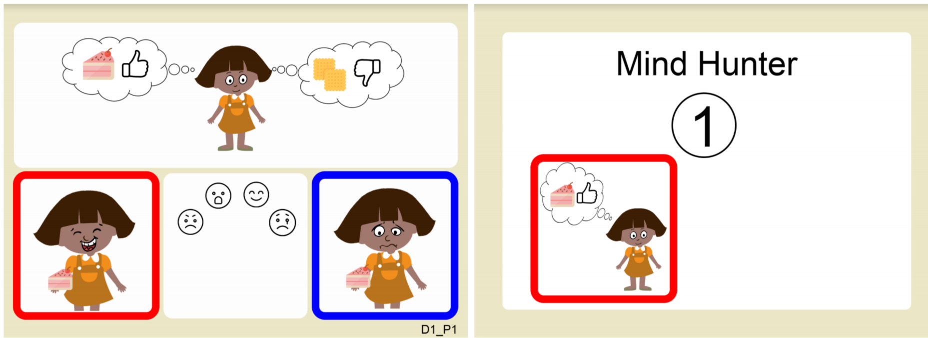


Figure 1 - Mind Hunter is the social game. It challenges children to perform and interpret mental states, perceptions, desires, beliefs, and intentional actions. The top of each two-sided card depicts a character who has a belief or a desire, which the child must reason about using either perceptual information or emotion, or interpreting symbols. On the bottom of the card, the character stands between two goal states, one depicted in red and the other in blue; children sort the card by the color of the image that depicts the character's likely goal or action. The back of the cards indicate the correct answer with a red or blue circle.

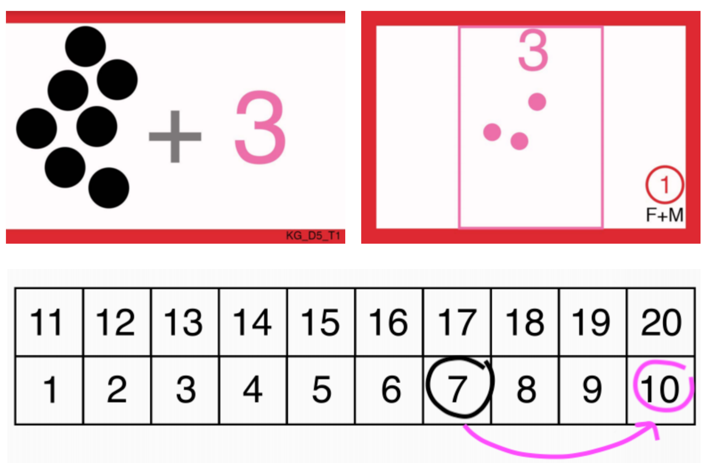


Figure 2 - *Number Chase* is the number game. It is an untimed board game exercising counting, exact addition, and operations using the base-ten structure of the number system. Children locate the first number represented using black dots (7 in this case) on the board and then move forward by the number in pink (3 in this case). The back of the card has a dot representation of the number in pink that indicates how many moves must be made on the board.

Can infants tell the difference between lullabies and other types of songs?

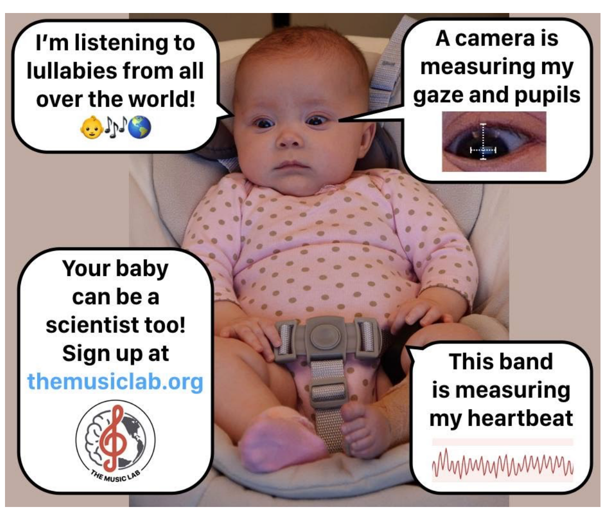
Constance Bainbridge, Julie Youngers, Lidya Yurdum, Jan Simson, Kelsie Lopez, Dylan Xing (Undergraduate Research Assistants), Mila Bertolo (Lab Manager), Stats Atwood (Lab Manager), Alia Martin (Collaborator), Sam Mehr (PI)

In previous work, we found that when adult listeners hear a song from another culture, they make accurate guesses as to what that song is used for in that culture (e.g., to soothe a fussy baby, to express love to another person, etc.). In this study, we ask whether babies share similar intuitions about music: When infants hear a song from a foreign culture, can they tell whether or not it's a lullaby?

Babies in our study watched animated characters sing lullabies and other songs from all over the world. While they watched the characters, we tracked where they were looking, their pupil dilation, their heart rate, and their electrodermal activity (a measure of excitement level that can be detected on the skin). We were curious to see if babies would look longer at characters that sing lullabies than those that sing other songs, and also if they showed differences in physiological activity depending on what kind of song they are hearing. We found that babies relaxed in response to the lullabies, despite the fact that all the songs were from unfamiliar cultures; their heart rate and electrodermal activity were lower during the lullabies, and their pupils were less dilated. This raises the possibility that there may be some features of lullabies that are universally produced by adults, and that infants are universally relaxed by.

We found that the infants did not look at one character for longer than the other. This suggests that even if infants find lullabies relaxing, they don't necessarily have a preference for singers of lullabies. We are running a follow-up study to see what infants understand about the social context of song-singing. We're curious to see if infants have intuitions that adults sing lullabies in order to soothe infants.

Thanks to all the families who have helped with this study so far! We can't wait to listen to tunes with you again soon.



A 4-month old watches animated characters singing

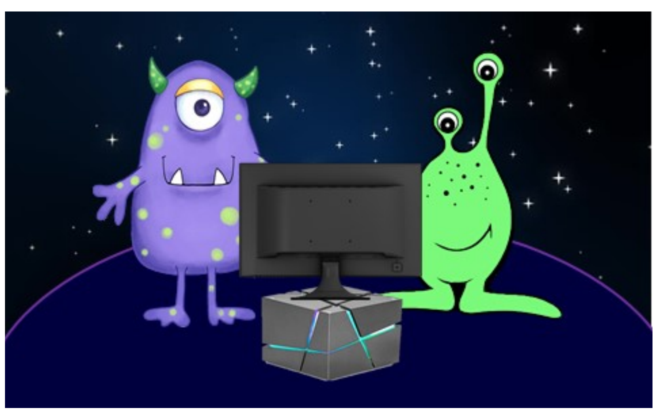
What can our brain waves tell us about how we understand negation?

Tanya Levari (Graduate Student)

One of the incredible things about human use of language is how efficient it is. After each sentence, people do not stop and take time to slowly piece together everything that was uttered – people have conversations. We do this by building up the meanings of sentences right as we are hearing them. One of the key questions that we investigate in our lab is how people are able to do this – what kinds of information do we use when understanding a sentence? What might be the mechanisms involved? And, critically, how does this ability develop?

A key challenge for studying how we build up meanings to sentences we hear, is studying this process without interrupting it. However, we have an incredibly useful tool at our disposal called electroencephalography, or EEG. An EEG recording records electrical activity in the brain in response to different events, such as hearing a word! Studies using EEG with adults have discovered that there is a specific brain wave that happens when a person hears a word, called the N400 wave. The size of this brain wave changes depending on how easy a word is to understand and incorporate into a sentence! For example, when we hear "*people swim in the…"* we see a small N400 wave if the next word is *pool* and a large N400 response if the next word is *street.*

In our study we use this wave to see how children and adults understand negation, or the word *no*. Specifically, we want to know whether listeners can use a word like *no* or *don't* to make predictions about upcoming words in the sentence. In order to do this, we asked English speaking adults and 5-7 year old children to listen to a conversation between two aliens. One alien asks a 'yes or no' question about planet earth (e.g. *Do people swim here?*) and another alien answers (e.g. *Yes, people swim in the pool/street* or *No, people don't swim in the pool/street)*. Some answers are correct while others are false. We are most interested in how children understand the answers that are negated and false (e.g. *No, people don't swim in the pool)*. If children are able to use negation to predict upcoming words they should be surprised when they hear *pool,* eliciting a large N400 response. Our results suggest that this type of sentence is hard to understand for both children and adults!



What can our brain waves tell us about how we understand words in a story?

Tanya Levari (Graduate Student)

Studies using EEG with adults have discovered that there is a specific brain wave that happens when a person hears a word, called the N400 wave. The size of this brain wave changes depending on how easy a word is to understand within a sentence. For example, when a word is very frequent, like “dog”, the n400 wave is smaller than when a word is less frequent, like “axolotl”. In addition, the wave is smaller when a word is very predictable and larger to words that are surprising! For example, imagine heading the following; “On a windy day Johnny liked to go fly his…” You wouldn’t be very surprised if the next word happened to be “kite”, but you would be very surprised if suddenly you heard “blimp”. The size of the n400 brainwave would show exactly that – the N400 wave would be smaller if you heard “kite” and larger if you heard “blimp”. While studying the N400 response has taught us a lot about what features of words make them easier to understand for adults, we know far less about what information children use when listening to a sentence.

In order to study this, we record children’s brainwaves as they listen to a story. This is a fun and easy task for children and one that they do often in everyday life. We are looking at the brain’s response to each word in the story to see whether children’s brain waves, like those of adults, are sensitive to various word features, such as frequency and predictability. We will be comparing the response patterns across development, from children as young as 5 through adulthood.

The Name Game

Margaret Kandel (Graduate Student), Parker Robbins (Undergraduate Research Assistant), Benazir Neree (Undergraduate Research Assistant), and Jesse Snedeker (Advisor)

The Name Game investigated how adults and 5-year-old children produce words. In the experiment, participants were shown pictures and were asked to name them as quickly as possible. We varied the codability and name frequency of the pictures in the scenes. Codability is a measure of the number of alternative names that can describe a picture, and name frequency measures how often the name of a picture is used in natural speech. Our experiment showed that both adults and children were faster to name images with fewer name alternatives (e.g. *apple* vs. *sofa/couch*) and more frequent names (e.g. *dog* vs. *cactus*). These results replicate the findings of other labs.

In our experiment analysis, we additionally observed a previously unreported interaction between the codability and frequency effects. We observed this interaction in both the adult and child data. We found that the effect of word frequency was smaller when there were more name alternatives for the participant to consider. Image codability is typically assumed to influence the word selection process;

when there are more alternatives, this decision process is slower. This word selection process operates over abstract representations of word meaning. Word frequency is generally assumed to influence how easy it is for speakers to access a word's form representation (i.e. the sounds used to say it); words that speakers hear and produce more frequently are faster to access and thus to say.

We ran simulations that show that an interaction between codability and frequency can arise if speakers activate the forms of candidate word representations as they are still deciding which one to say. For example, while a speaker is deciding whether to say *sofa* or *couch*, the sounds for each possibility will start to become activated, instead of waiting until after the speaker has decided which one to say. The fact that we find this interaction in both the adult and child data suggests that adults and 5-year-old children use similar internal mechanisms to prepare the words they say.

The What-Where Game

Margaret Kandel (Graduate Student), Benazir Neree (Undergraduate Research Assistant), Judy Pendergast (Undergraduate Research Assistant), and Jesse Snedeker (Advisor)

The What-Where Game investigates how speakers of a language plan the sentences they utter and whether this process changes over development. More specifically, this study investigates how far in advance speakers plan words before they start to say them, comparing adults and 5 year-old children.

In this study, participants see simple scenes of two pictures, with one positioned above the other. Participants are instructed to describe these scenes in the form The A is above the B as we record their descriptions and eye-movements. We vary the codability and name frequency of the pictures in the scenes. Codability is a measure of the number of alternative names that can describe a picture, and name frequency measures how often the name of a picture is used in natural speech. We showed in The Name Game experiment that these factors influence how quickly speakers name our pictures: adults and 5 year-old children are faster to name the pictures with fewer name alternatives and more frequent names. In this experiment, we are interested in how these factors influence speech onset time. If we find that how quickly children and adults start to speak is influenced by the frequency and/or codability of A or B in the sentence The A is above the B, that suggests that they have already planned that word before beginning to speak. We may also see frequency and codability effects reflected in the amount of time speakers look at pictures before they say their names.

We are still collecting data for this experiment, but we hope that the results will give us a better understanding of how sentences are planned and whether the amount of words that speakers plan in advance changes across development.

How do we understand slips of the tongue?

Anthony Yacovone (Graduate Student), Paulina Piwowarczyk (Undergraduate Research Assistant)

In this study, we are investigating how adults and children understand people when they make tiny speech errors. As listeners, we must quickly turn incoming sounds into words and then use those words to build meaningful sentences! Previous research has shown that instead of just passively listening to people speak, we also actively predict what people are trying to tell us. This process of predicting upcoming words actually helps us understand people better and allows us to notice when people make mistakes (e.g. saying *ceke* instead of *cake*). Specifically, this study looks at whether or not we predict the actual sounds of words that we are about to hear. If we are able to anticipate the sounds that we are about to hear, perhaps tiny speech errors may not be as difficult to understand!

This study played a short story to adults and children while we recorded their brain activity using electroencephalography (EEG). Some of the sentences in the story were manipulated to have speech errors like "Javier took a deep **brith**." We then looked at how participants' brains responded to these slips of the tongue. Previous research has found that adults and children may not be able to predict upcoming sounds, making the processing of these speech errors a bit more challenging. We are still in the process of collecting data, so stay tuned to find out whether children and adults differ in their abilities to predict and recognize speech errors. Thank you for your interest in this study. If you have any questions, please contact Anthony Yacovone (anthony_yacovone@g.harvard.edu).

Can you find the frog with the paperclip slowly?

Anthony Yacovone (Graduate Student), Karen Andres (Undergraduate Research Assistant)

This study is part of a larger project that investigates the type of information that adults and children use to help them better understand language. In a typical conversation, there are many instances of ambiguous sentences like "Oh, look at the man with the telescope!" This sentence has two interpretations: 1) use the telescope to look at the man or 2) look at the man that has a telescope. Since both interpretations are perfectly fine options, it is impossible to tell which interpretation was intended without more information! Consider another example: "Find the frog with the paperclip!" This sentence still has two interpretations: 1) find the toy frog that has the paperclip or 2) use the paperclip to find the toy frog! In this example, the second interpretation seems very unlikely (e.g. why would someone use a paper clip to find things?!). Using our knowledge of what is likely or plausible in the world, we can reason that the speaker meant to instruct us to find the toy frog that has a paperclip.

We have found previously that children struggle to use information about what makes more sense (e.g. using a paperclip to find things vs. having a paperclip) to help them decide between ambiguous interpretations. Intuitively, it seems like it takes a few extra seconds to understand both interpretations and then decide which one makes more sense. We know that children are slower thinkers than adults, so maybe children just need more time to understand things before they can use this information. In this study, we played ambiguous sentences like the ones above to children at a much slower rate (two times slower than the original). If children simply need more time to think, then this slower rate should allow them to use information about likely events to better understand the sentence. This study is ongoing, so stay tuned for more information. Thank you for your interest in this study. If you have any questions, please contact Anthony Yacovone (anthony_yacovone@g.harvard.edu).

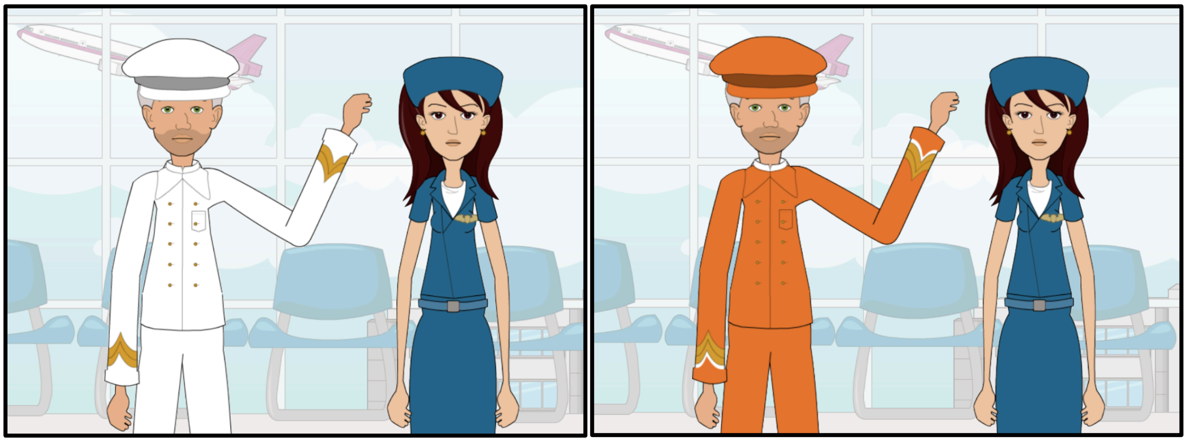
How do children remember events?

Briony Waite (Lab Manager), Emma Van Beveren (Research Assistant), Anthony Yacovone (Graduate Student) and Annemarie Kocab (Post-Doctoral Researcher)

Events in the world typically involve one or more participants each taking on a different role. For example, *eating* involves an eater and a thing being eaten, while *breaking* involves a breaker and a thing being broken. Languages group these roles into broad categories: for example, both the eater and the breaker are commonly called **Agents**, the doer of events. In contrast, the eaten and the broken things are **Patients**, the entities affected by the action.

Interestingly, not all roles are equal. Previous studies looked at one kind of role pairing: Goal-Source. Adults and children were shown different motion events with someone moving from one object (the **Source**) to another object (the **Goal**), for example, a baby crawling from a chair to a desk. These movies were presented a second time, and some of the movies were changed (e.g., the color of the desk changed from red to green). Children and adults better remembered changes to Goals compared to Sources, and were more likely to mention Goals over Sources when describing what happened (e.g., "the baby crawled to the desk" vs. "the baby crawled from the chair"). This finding suggests that Goals are privileged over Sources in language and cognition.

In this study, we want to see whether a similar asymmetry in memory arises with other kinds of roles, such as Agents and Patients. We created new events that depicted different role pairings (e.g., a pilot tapping a flight attendant (Agent-Patient), a king giving a queen a jewel (Donor-Recipient), a child knocking over a box with a teddy bear (Instrument-Theme). We showed 4- and 5-year-old children these videos on a screen with an eye tracker. The videos were then shown a second time, with some of the videos changed in some way (e.g., the pilot's uniform was changed from white to orange). Children were asked to say whether or not each video was the same or different as before. We are interested in whether changes to some roles are harder to remember than others. For example, is it easier or harder to remember a change to the pilot's clothes compared to a change to the flight attendant's clothes?



We are still collecting data for this study. We look forward to sharing our results next year!

Thanks for playing with us!

Listen to a story

Briony Waite (Lab Manager), Anthony Yacovone (Graduate Student), and Tanya Levari (Post-Doctoral Researcher)

In this study, 4- and 5-year-old children listened to a 25-minute long story. During the story, they looked at pictures related to the story, and at the end, we asked them several comprehension questions as well as a few questions about whether they enjoyed the story. We use children's stories in many of the EEG studies in our lab. Listening to a story is a task that children generally enjoy, and one that they are already familiar with. This task design lets us run EEG studies with younger children, something that can be challenging with traditional EEG task design, which are generally very long and can be boring.

We wanted to make sure kids enjoyed listening to and understood our story before using it in EEG studies, so this study was all about testing the story. We used the children's comments to make changes to our design and to improve the way we run our EEG studies. Thanks for listening to a story with us!

Thank you for your participation and interest in our labs, and we hope to see you again soon!