Harvard Lab for Developmental Studies

Newsletter 2023

Contents

Welcome to the Bergelson Lab!

Elika Bergelson (Principal Investigator)

Coming to the Laboratory for Developmental Studies this summer is Elika Bergelson, PhD! Dr. Bergelson joins us from Duke University, where she was an Associate Professor in the Department of Psychology and Neuroscience. Her research explores the language development of babies and toddlers, particularly how their environment and the senses impact their learning. Soon, we will have studies for children from six months old to around two years old, focusing on the connections between word learning skills and other developing communication skills like understanding pointing, predicting what's coming next in a sentence, and understanding pitch and rhythm patterns. Other studies will look at how specific your child's knowledge is about what words sounds like and mean—for example, do they hear the difference between "banana" and "bananoona" right away, or only when they are very familiar with a word? Dr. Bergelson also studies how children who are born blind, deaf, or Deafblind learn language. Her studies will use eye tracking, games and videos, and EEG (using a cap made of special sensors to study brainwaves). Stay tuned for opportunities to get involved!

Welcome to the Thomas Lab!

Ashley Thomas (Principal Investigator)

Also joining the Laboratory for Developmental Studies this summer is Ashley J. Thomas, PhD! Her lab will research how humans think about social relationships across development, answering broad questions such as "What is caregiving?" and "How do people think about social change?". The Thomas Lab will have studies for infants and young children, where participants will play games and watch videos examining how they think about social relationships and their social networks. For example, one study will investigate whether children infer that people in close relationships are better able to understand each other's mental states. Another study will test infants' understanding of caregiving relationships and whether they use physical and social cues to predict who will respond to someone in distress. Stay tuned for opportunities to get involved in research at the Thomas Lab!

Perspective Taking in Children

Michael Huemer (Postdoctoral Researcher); Theo Schulz (Research Assistant); Susan Carey (Principal Investigator)

In this study, we looked at how and at what age children can understand the perspective of other people and whether they can tell the difference between true and false beliefs. To see if the children could understand another person's perspective, they were shown different animated stories on the laptop. In one story the person had a false belief, in others the person had true beliefs. In the story where the person has a false belief (see Figure 1, top row), Lisa puts her doll in the blue cupboard and then leaves. Her brother comes, takes the doll out of the blue cupboard and puts it in the green cupboard. Lisa comes back and wants to play with her doll. Children are then asked where Lisa will look for her doll. Children who answer that Lisa will look in the box where she put it in the beginning can already understand Lisa's perspective. In the true belief stories (see Figure 1, middle and bottom row), Lisa watches her brother moving the doll to the other cupboard. So, Lisa knows that the doll is now in the other cupboard. In order to correctly answer where Lisa will look for the doll, children do not need to understand the other person's perspective. This is because the child and Lisa both have the same perspective and therefore children can solve this task correctly even if they only consider their own perspective.

Previous studies have shown that children as young as 3 years old respond correctly to true belief tasks. At about 4 years of age, children begin to master false belief tasks. Interestingly, as children begin to understand false beliefs, they make more errors on true belief tasks. In a prior study, we learned that children from the age of 4 had less difficulty with true belief tasks when it was made clear that Lisa had seen her brother move the doll. If this is not made clear, some children might have thought that Lisa did not see the doll being moved when she just stood there passively and showed no reaction. Therefore, we compared stories in which Lisa goes along with her brother while he moves the doll and stories in which she is only passively present.

We tested children between 3 and 6 years of age. Data collection is still ongoing. Preliminary results show that about half of the children were already able to master the false belief task. Children who failed on the false belief task almost always succeeded on true beliefs task correctly (up to 93% correct). Children who mastered the false belief task made more errors on the true belief tasks. When Lisa only stood passively during the transfer, only 30% of these children solved the task; when Lisa accompanied her brother during when he moved the doll, 53% of the children solved the task. This effect was expected but is not as strong as in other studies.

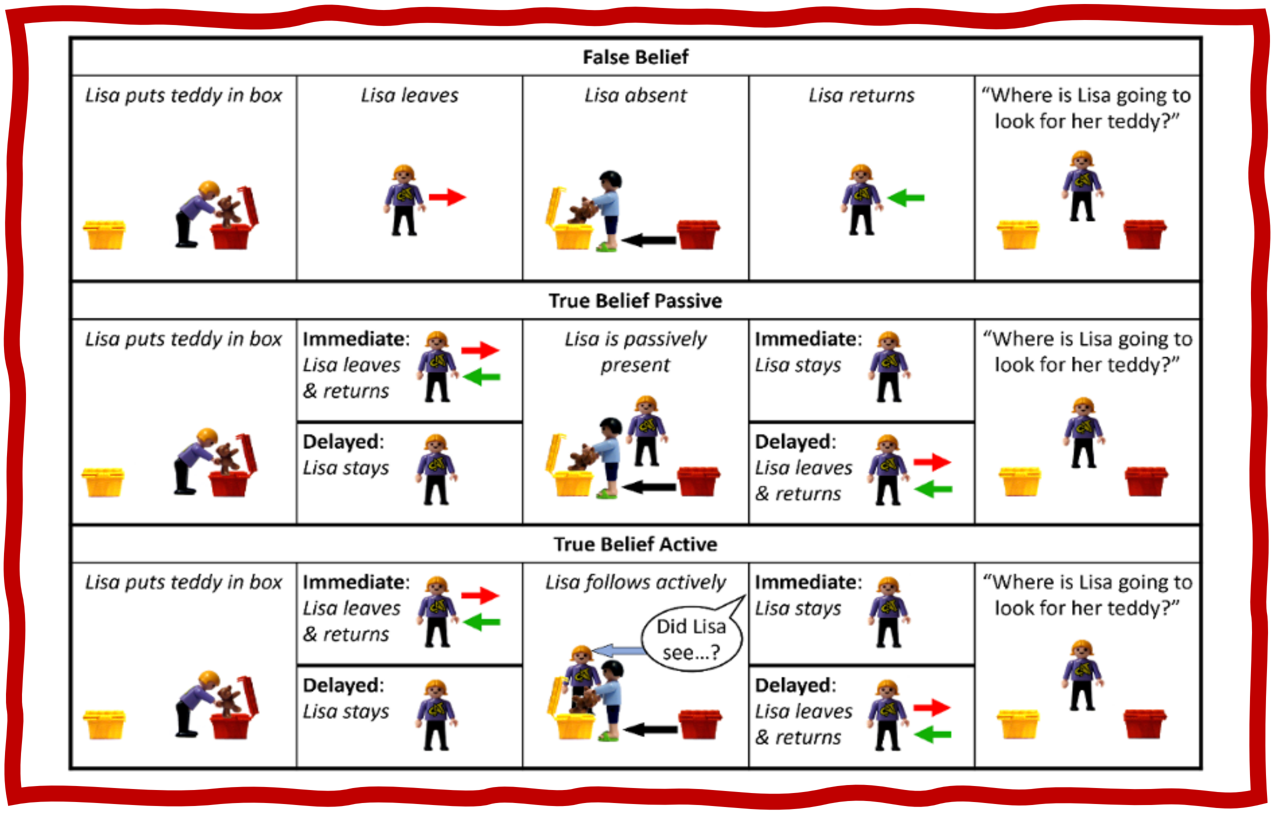


Figure 1. The 3-cup and 7-cup tasks for studying the ability to reason about multiple possibilities.

Seeing Through the Eyes of Others

Laura Lee (Research Assistant); Brandon Woo (Postdoctoral Researcher); Andrea Ventura (Research Assistant); Elizabeth Spelke (Principal Investigator)

Have you ever wondered how young children perceive the world around them? Our study explores the realm of children's perspective-taking abilities, shedding light on their understanding of how objects appear to others. For example, whilst you may easily understand that when I sit across from you, my left is your right, or whilst I see a 6, you see a 9, this is not so straightforward for younger children.

Over the past several decades, researchers have demonstrated that 3-year-old children are unable to take the visual perspective of another person. However newer research has claimed that previous studies may have been exploring a more challenging skill called perspective-confronting, which involves considering multiple perspectives simultaneously. In contrast, the ability to adopt another person's singular perspective, known as perspective-taking, appeared to be a much easier task for young children. Motivated by these findings, the present study aimed to investigate whether 3-year-old children could understand and appreciate someone else's unique viewpoint in both perspective-taking and perspective-confronting tasks. To conduct the study, 40 children participated online through Zoom. The tasks involved stimuli that could elicit different experiences based on their orientation, such as the famous rabbit-duck illusion.

Surprisingly, our findings showed that 3-year-old children did not take the actor's perspective in either the perspective-taking or perspective-confronting condition, with children performing similarly in both conditions. These results suggest that 3-year-old children do not understand another's visual perspective in these kinds of tasks.

Solve a Mystery! Do Children Predict the Form of Upcoming Words?

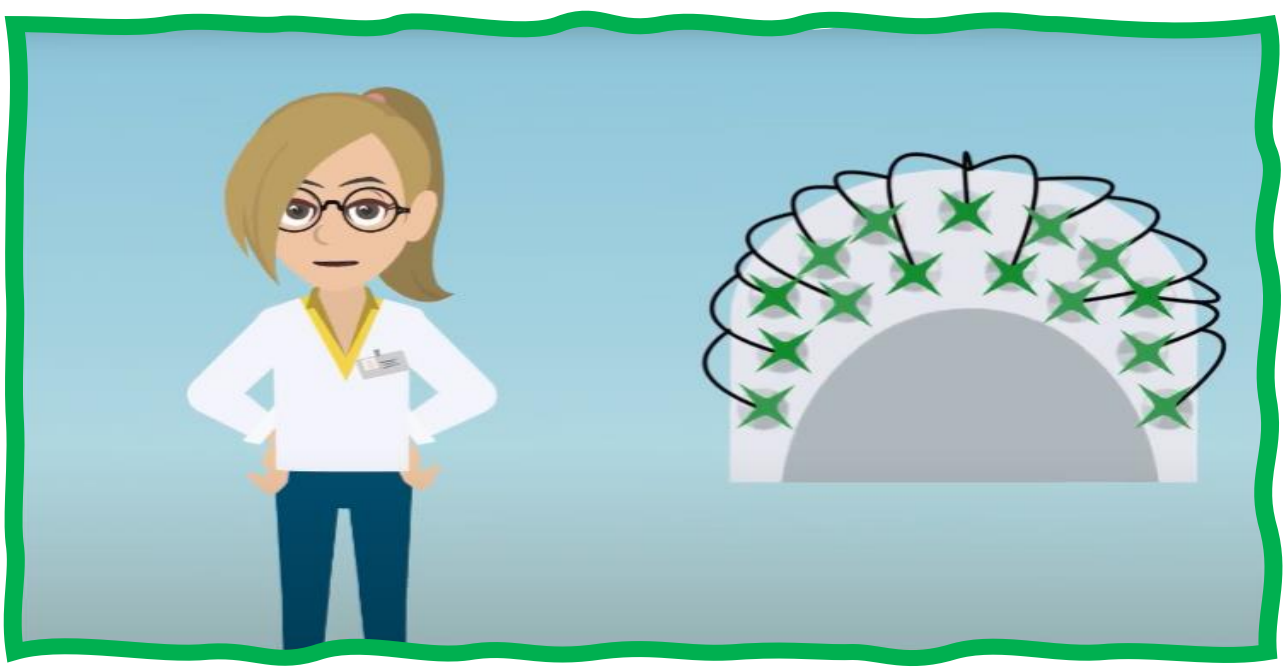
Anthony Yacovone (Graduate Student); Briony Waite (Lab Manager); Jesse Snedeker (Principal Investigator)

In this study, we are investigating how children understand the words that they hear while listening to a story. As listeners, we must quickly turn incoming sounds into words and then use those words to build up meaningful sentences! Prior work has found that, instead of just passively listening to people speak, people also actively predict what someone is about to say. This process of predicting upcoming words seems to help us understand people better and allows us to notice when people make mistakes. However, there are still open questions about linguistic prediction and how this ability develops!

So, to study this phenomenon, we asked your child to watch a cartoon while we recorded their brain waves using electroencephalography (EEG). We looked at lots of children's brain responses to various words spoken throughout the story. Some of these words were perfectly normal (e.g., *cake*) while others were slightly mispronounced (e.g., *ceke* or *vake*). More specifically, the story contained two types of mispronounced words: one type had the same initial sound (*ceke* instead of *cake*), and the other type rhymed with the original word (*vake* instead of *cake*).

If children are expecting certain words to come next in the story, then these mispronunciations should be quite surprising to hear, resulting in larger brain waves! The size of these brain waves often reflects how difficult it was to understand the error in the story—so, we are also interested in whether there are different sized responses to errors like *ceke* or *vake* when the original word was supposed to be *cake*. If the error is very similar to the expected word (e.g., *ceke* and *cake*), then the brain responses should be relatively small. We have evidence that this is true for adults, and the remaining question is if this is true in children!

We are just wrapping up data collection for this study, so please stay tuned for updates in our newsletter next year. Thank you for participating!



Early Understanding of Parent-Child and Other Caregiving Relationships

Christina Steele (Graduate Student); Denis Tatone (Postdoctoral Researcher); Ashley Thomas (Principal Investigator)

Every day, we recognize social relationships and use knowledge about social relationships to inform our behavior. We act to maintain our existing relationships, create new ones, and change the ones we have. For example, we recognize that it is acceptable to eat off our spouse's plate, but unacceptable to eat off our employer's plate. We may laugh at our boss's joke to maintain our deferential relationship or do a favor for a coworker to maintain a cooperative one. We might bring a rose to a friend to create a new intimate relationship or advocate to incorporate voting to change our book club into a democracy. While scholars in Anthropology, Sociology, and related fields have long studied the structure and nature of social relationships, relatively little is known about how these behaviors arise from cognitive processes in individual minds, especially in infants and young children. Infants are born into complex social networks made up of many relationships. The most relevant and common relationships in an infant's social network are caregiving relationships.

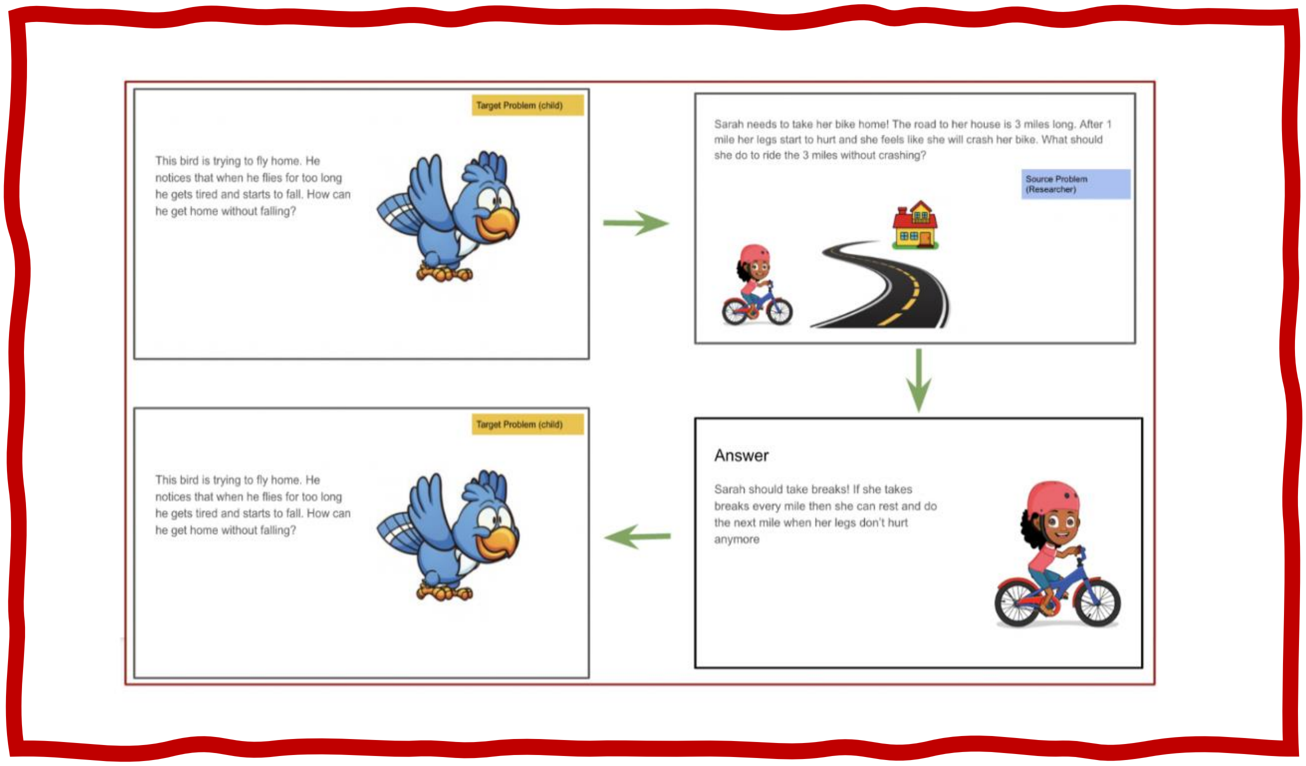
These can be with parents, older siblings, teachers, grandparents, babysitters, nannies, etc. Even when an infant's social network expands, caregiving relationships dominate the social experience of young humans throughout early childhood. Compared to most other species, human infants are more dependent and interact with a greater number of caregivers. Accordingly, the ability to recognize caregiving relationships may be particularly useful for humans. We are currently running a study to investigate how and whether infants represent caregiving relationships, specifically testing whether they use physical (e.g., size) and social cues (e.g., touch) to make predictions about response to distress and food requests.

Positive Transfer and Analogical Problem Recognition in Four-Year-Old's: Mathematical Perspectives

Nicholas Kendall (Research Assistant); Marie Amalric (Postdoctoral Researcher); Elizabeth Spelke (Principal Investigator)

Children are known to use analogies in their daily lives as a way to make sense of the world. They have been shown to recognize and apply analogies in certain settings if there is enough surface similarity between two problems. As children begin formal education, an analogy is a tool used in an attempt to aid them in the development of mathematical skills. Math problems are often accompanied by a story component throughout schooling. We are studying the ability of young children to recognize analogies and utilize them in order to solve a new problem (positive transfer).

Testing took place over Zoom with 4-year-olds. Each child played a 15-minute game with three distinct question sets with two problems per set. Each question set is composed of a target problem and a source problem.



The first question set presents a duration over time problem (Shown above). The second question set requires the children to combine shapes and then count the number of sides. The third question set involves approximating numbers with the commutative principle.

The participant has the chance to solve these target problems before and after they see an analogous source problem and its solution. One problem is concrete (uses numbers/geometry) and the other one is more abstract (story with no numerical component). We also test the effect the order of presentation has when showing either the complex/abstract or simple/concrete math problem as the source problem. Missing the first attempt and correctly answering the second attempt is counted as a successful "Positive Transfer". The child was then presented with a matching task to test analogical recognition.

So far, we are finding that some 4-year-olds have the ability to recognize analogies and use analogies. Most interestingly, those abilities were independent of each other. We have conflicting results regarding the effect the level of concreteness has, where it had no effect in some question sets then the opposite effect for matching and positive transfer in two question sets.

Even Very Young Infants Recognize Close Social Relationships

Ashley Thomas (Principal Investigator)

In all human societies, people form 'thick' relationships, which are characterized by strong and enduring attachments and specific moral obligations. While thick relationships often occur between genetic relatives, not all thick relationships are between genetic relatives and not all genetic relatives form thick relationships. How do young children identify thick relationships in their social environments? One possible cue is the sharing of bodily fluids, which occurs within thick relationships across many cultural settings. In these studies, we found that children, toddlers, and infants infer that individuals who act in ways which suggest saliva-sharing have a different kind of relationship with one another than do other social partners. Children expected saliva sharing to happen within nuclear families, and infants and toddlers expect these behaviors to occur between individuals who respond to one another in states of distress. We're currently running a study to ask whether even 4-month-old infants use the same cues. Our findings so far suggest they do! (For more information about the study and some examples of stimuli there is this video: https://youtu.be/f-nvmiY056g)

Infant's Representation of Objects in Physical Tracking

Yichen Li (Graduate Student); Brandon Woo (Postdoctoral Researcher); Elizabeth Spelke (Co-Principal Investigator); Tomer Ullman (Co-Principal Investigator)

We are interested in how people represent objects differently when they're tracking them physically (say, to grab them) vs. to recognize them visually. This project examines the early development of this difference.

Studies in cognitive development show that babies below 12 months do not use fine-grained form information to track objects (Xu & Carey, 1996; Xu, 2005). That is, when they see a toy elephant go behind a screen and a ball come out, they don't seem to think there are two different objects behind the screen. But infants can certainly tell the difference visually between a ball and an elephant (Wilcox et al., 2010, show infants are certainly able to individuate objects based on shape, pattern, and color). We interpret these findings as showing that infants may be relying on rough approximations for physical tracking: a 'rough blob' surrounding the elephant may be similar to a ball, and that's all you need to keep track of where something is.

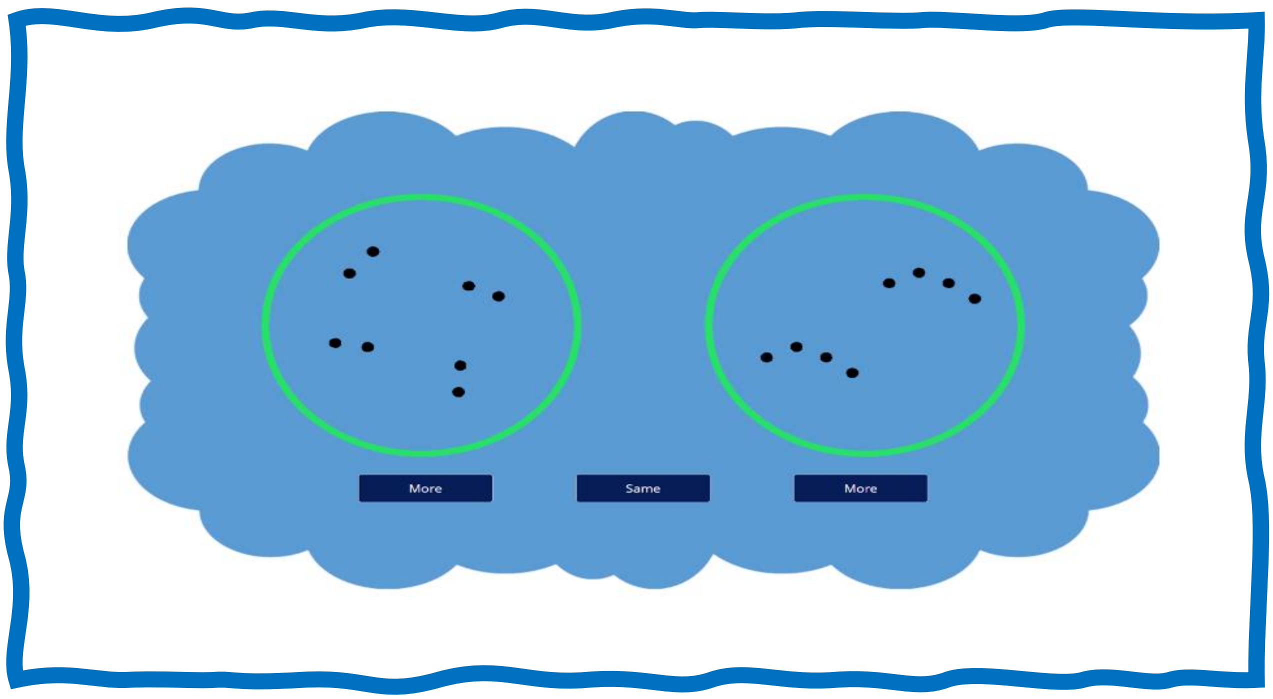
We are designing infant behavioral studies to examine this hypothesis, showing infants objects of different forms going behind screens, and seeing if their tracking and surprise is best predicted by this 'blob-like' representation.

We have used the animation software Blender to create videos of moving objects in 3D to replicate the stimuli used in Xu and Carey (1996). We piloted a few participants and found our experiment pipeline to be working properly. We are currently in the process of formal data collection and designing stimuli for the second study.

Do Elementary School Children Know That 2x4 = 4x2?

Marie Amalric (Postdoctoral Researcher); Elizabeth Spelke (Principal Investigator)

Mathematical symbols are culturally acquired knowledge, typically learnt over many years of schooling. While our symbolic abilities are often built upon our concrete understanding of quantities, formal learning of arithmetic operations also seems to reshape our perception of spatially organized dot arrays. In this study, we tested the influence of school learning about multiplication and its commutative principle on the perception of grouped dot arrays in 2nd and 3rd graders. In a More/Same/More task implemented as a number game, we asked children to compare the arithmetic outcomes of pairs of stimuli, such as 2 groups of 4 dots versus 4 groups of 2 dots, or 2x4 versus 4x2.



We found that children's symbolic mastering predicts their performance on non-symbolic trials, independently of their age or the grade they are in. While symbolic masters can identify that 2 groups of 4 dots and 4 groups of 2 dots contain the same number of dots, children who do not yet master symbolic multiplication are purely relying on estimation to compare spatially organized dot arrays that can be interpreted as a multiplication, and struggle to recognize commutative situations in non-symbolic contexts.

In a second session, children watched a 5-minute video explaining the commutative principle of multiplication and tested their knowledge via a short quiz including immediate feedback. They were then asked to play the number game again. The second session was conducted online in most cases, but some children watched the video, answered the questions, and played the number game while undergoing a brain imaging exam with MRI. As we are still in the process of collecting brain imaging data, we have not yet started its analysis. At the behavioral level, we found that the pre-intervention level of symbolic mastery again influenced children's learning. While children with the lowest level of symbolic mastery improved on commutative symbolic trials, children with highest level of symbolic mastery improved on commutative non-symbolic trials.

Can Preschoolers Track Exactly Five Objects?

Yiqiao Wang (Graduate Student); Susan Carey (Co-Principal Investigator); Elizabeth Spelke (Co-Principal Investigator)

This project aims to study the development of children's integer concepts. As adults, we know some key properties of integers. For instance, we have an exact representation of each integer that we can distinguish each one from the others. Previous research has shown that there are two preverbal systems that can support our exact representations of small numbers (i.e., numbers up to three or four). However, it's still an open question where the capacity to represent large, exact numbers comes from. We hope to find an answer through a case study investigating young children's representation of the number five. We chose the number five because it's where the two preverbal systems reach their limitations.

In the baseline study, we recruited children aged from 36 to 54 months who speak English as their primary language. Each child played two games with an experimenter in a Zoom session. The first game was to measure whether children can track and represent exact numbers of objects. In this game, children saw certain numbers of stars hidden in an empty box. On half of the trials, they saw all the stars come out of the box, and on the other half of the trials, they saw all but one star come out. At the end of each trial, children were asked whether all the stars had come out. The second game was to measure children's number word knowledge. Children were asked to put certain numbers of objects on a plate upon hearing the number words. This game sorted children into two groups: Children who have understood how counting works and what the number word "five" means (i.e., CP-knowers) and those who haven't (i.e., Subset-knowers). We expected that CP-knowers can rely on the counting procedure to successfully track five stars, but not the subset-knowers. We found that only 30% of the CP-knowers succeeded at tracking exactly five stars and there was one out of 30 subset knowers who succeeded.

We think one possible reason that CP-knowers did not perform well is that they might not spontaneously deploy the resource they have and use counting as a strategy to track the stars. In a follow-up study, we prompted children to count the stars before they go into the box. If counting is one of the resources that are available to children, CP-knowers, but not subset-knowers should perform better than those in the baseline study. We are also conducting a follow-up study in which we chunk a set of five stars into a set of two stars and a set of three stars. This is to explore whether hierarchical set-building capacity supports children's exact representation of five. Data collection for both follow-up studies is ongoing, and we hope to share the findings in the next newsletter!

Fingers as Tallies

Peggy Li (Research Associate); Sarah Chiang, Crystal Gill, Tyler Neri, Peggy Yin (Research Assistants); Susan Carey (Principal Investigator)

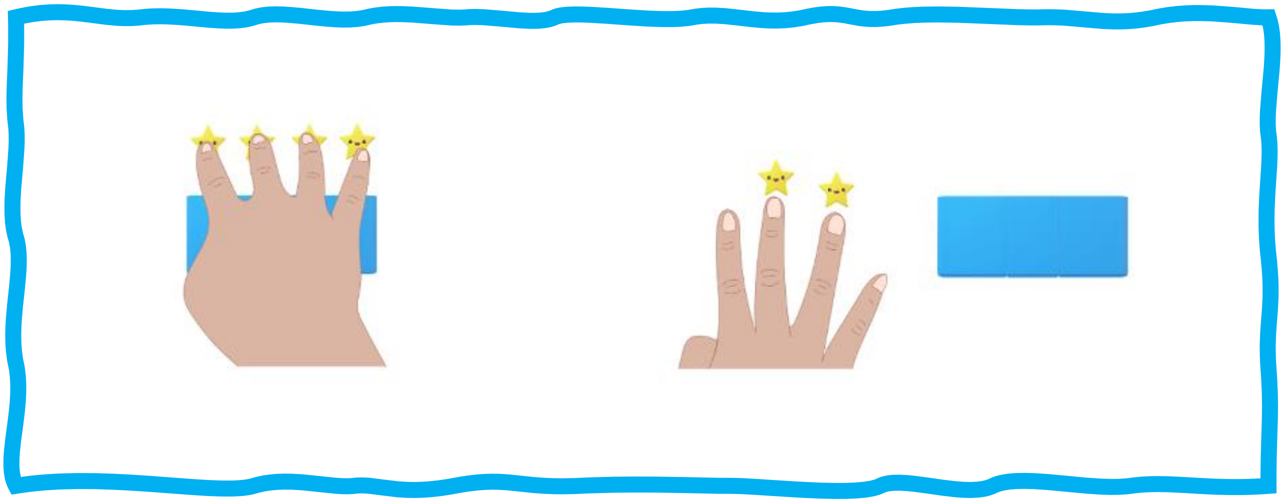
Numbers are so essential to contemporary human activity—data processing, scheduling, trading—that it seems only natural that natural numbers (1, 2, 3, …) are, well, *natural*. But such number concepts may not be innate to humans after all: in cultures without counting systems ("one, two, three, …"), even adults tend to make errors when asked to match sets greater than 4 or to perform arithmetic. Also surprisingly, while most 2-year-old American children can recite numbers 1 through 10, they do not understand the logic of counting. For example, children may count a set correctly but fail to understand that the last word they reach when counting indicates how many items are in the set.

This project explores representations that may have supported the cultural invention of counting systems by testing 3- and 4-year-olds. Specifically, we focus on tallying, which served as a precursor to counting as a way for ancient human cultures to represent exact numbers. These tally systems often made use of fingers as tallies, where one finger represented exactly one object. We asked whether children could use fingers to represent an exact number of objects, even before learning how to count.

In one study, we explained to children that fingers in one-to-one correspondence with objects could help us represent how many there are ("We raise one finger for one donut. The fingers raised can show how many donuts there are."). Children were shown fingers raised and lowered as objects were added to or subtracted from a set. Then, to see whether children understood our explanation, we asked them to use their fingers to show how many objects when objects were added or subtracted from sets, and to show how many there were in pictures. We found that the idea of using finger tallies to represent sets may not initially be intuitive: many children, instead of raising or lowering the number of fingers appropriately, simply pointed to each object with their index finger. However, some children who had not worked out the logic of counting, did appreciate our instructions and tried to match the number of fingers they held up to the number of items presented.

Another study sought to find whether children could use finger tallies to track objects. For this study, children were provided finger tallies in one-to-one correspondence with stars entering and exiting a box. If children intuitively understand how tallies can represent exact large numbers, then we should expect to see improvement on this task compared to results from the same task without finger tallies, regardless of children's counting knowledge. We then asked the children whether all of the objects had come back or whether some remained in the box. We found that even children who did not know how to count could improve their performance on the task when provided with finger tallies.

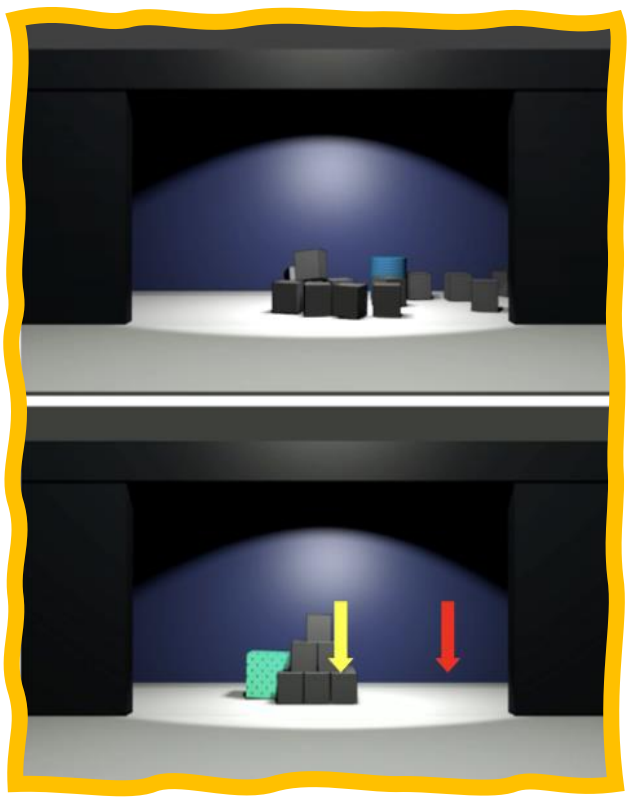
Overall, these studies begin to shed light on children's developmental understanding of tallying and the role tallying could play in the cultural invention of counting systems.



Heavy and Light: Children's Reasoning About Mass

Brandon Woo (Postdoctoral Researcher); Sanghee Song (Research Assistant); Tomer Ullman (Assistant Professor, Harvard University); Elizabeth Spelke (Principal Investigator)

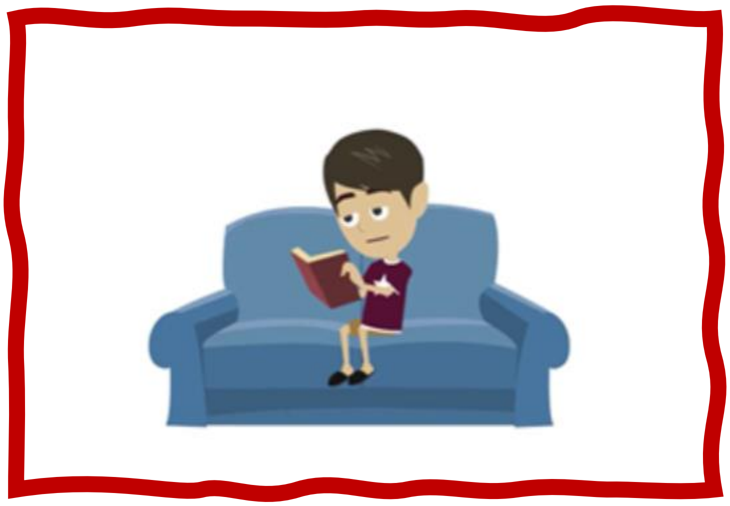
A blue block hits a block tower and knocks all the blocks down. A green block, moving at the same speed, hits the same block tower, and only knocks a few blocks over. Which block is heavier? How will each block act in a new situation (e.g., after being pushed)? This study asks whether 4- to 5-year-old children can (i) reason about the mass of objects based on how they act in different situations and (ii) make predictions about how objects will act in new situations. Some past work has argued that children should find it difficult to form such predictions. This study is ongoing, and we have promising pilot data suggestive that children are able to reason about mass flexibly.



Predicting Words in Stories

Tanya Levari (Postdoctoral Researcher); Briony Waite (Lab Manager); Jesse Snedeker (Principal Investigator)

In this study, your child listened to a story while we recorded their brain activity. We are looking at the brain's response to each word in the story to see which features (e.g., frequency and predictability) help us understand what we are hearing. 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 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!

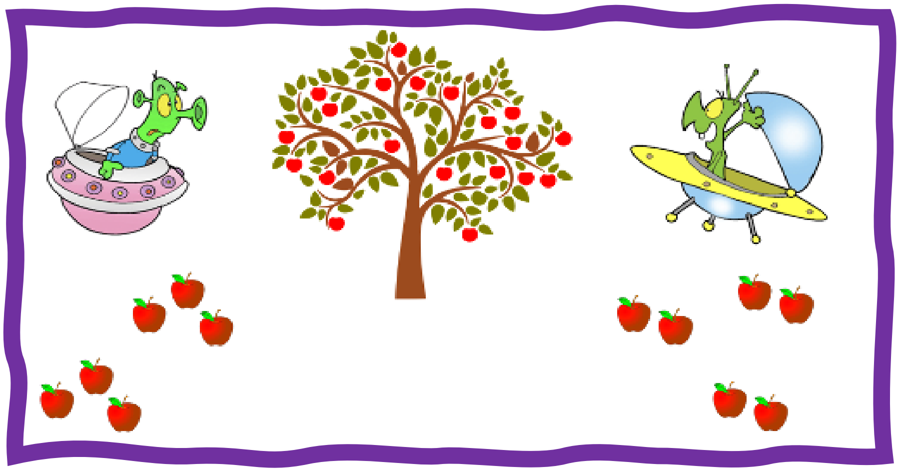


For example, imagine hearing the following: "On a windy day Johnny liked to go fly his..." You wouldn't be very surprised if the next word was "kite", but you would be very surprised if you heard "blimp". The size of the n400 brainwave would show exactly that – the n400 wave would be smaller if you heard "kite" and larger if you heard "blimp". In our study we are interested in seeing when the ability to predict upcoming words develops and how it changes as children age. In addition, your children completed a vocabulary task. This task will allow us to see if the ability to predict words develops with children's age or their language ability. Thank you so much for participating!

Early Understanding of Commutativity in Preschoolers

Marie Amalric (Postdoctoral Researcher); Nick Kendall (Research Assistant); Elizabeth Spelke (Principal Investigator)

Commutativity – the property of an operation that allows one to change the order of the operands without changing the results – is a fundamental principle of mathematics. Young children seem to have early intuitions that addition is a commutative operation, even before knowing formal additions. On the contrary, evidence for early intuitive grasping of the commutativity of multiplication is much less clear. In fact, the commutative principle in additive contexts is intrinsically one-dimensional while it is intrinsically two-dimensional in multiplication, and interpreting multiplication as repeated addition may render perceiving its commutative principle difficult.



Here, we investigate the existence of precursors of the understanding of the commutative principle of multiplication in preschoolers, i.e., before learning symbolic multiplication, and the type of representations that preferentially support them. To do so, 5-year-old children are asked to decide whether two characters got a fair or an unfair share of apples at a tree. The apples that each character got are displayed on each side of the screen. They probe commutative multiplication and addition versus identity (ungrouped arrays) and test the influence of simple grouping, geometrical cues such as rectangular display and 90° rotation, or language on the perception of equal commutative quantities.

Our results so far confirm that additive commutativity is more easily perceived than multiplicative commutativity. With simple grouping, 5-year-old children answer at chance in both multiplicative and ungrouped cases. When added to the layout of the groups of apples, geometric cues strongly improve children performance. However, adding linguistic descriptions of the situations did not help children's number perception. Our results may suggest that with simple grouping, the intrinsic symmetry of commutativity is lost, while a rectangular array that is rotated from horizontal to vertical directions provides a geometrical description of the commutative principle. This has implications to teaching the commutative principle of multiplication at school.

Using Language to Infer Others' Goals

Brandon Woo (Postdoctoral Researcher); Elizabeth Spelke (Principal Investigator)

A person reaches for a red ball. Does he want it because it's red or because it's a ball? People often use language to express the relevant features of objects that may drive their actions (e.g., "I want the ball" or "I want something red"). Here, we ask whether 14- and 15-month-old toddlers use a person's language to form inferences about why the person is acting on an object. Data collection is ongoing.

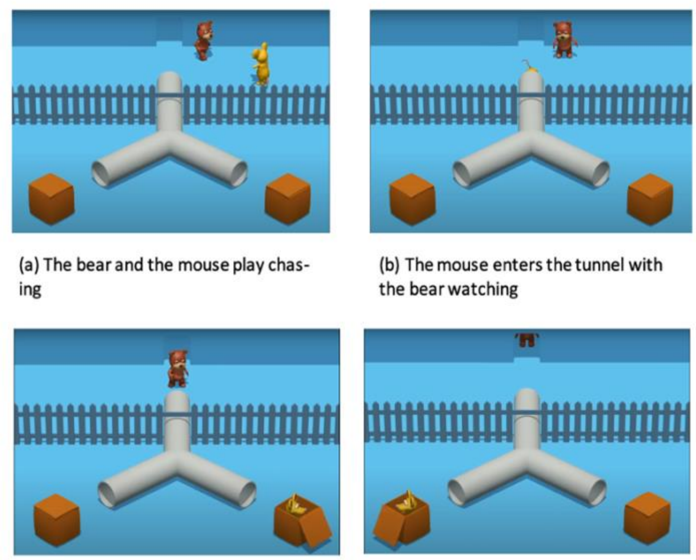
Perspective Taking in Infants

Irene Canudas Grabolosa (Postdoctoral Researcher), Michael Huemer (Postdoctoral Researcher), Caden Li (Research Assistant), Susan Carey (Principal Investigator)

In this project we aim to study the development of theory of mind, or the ability to ascribe mental states like beliefs, knowledge or desires to others and oneself. Previous research has shown that infants from an early age are already sensitive about the intentions of others, and form expectations about what the others will do. In the current study we want to see whether children are taking into account others' knowledge or ignorance about a situation when they predict their actions.

We showed children (between 18 and 27 months of age) and adults some videos in which a bear chases a mouse (see Figure 1). Then the mouse enters a tunnel with two exits and ends up in one of two boxes at one exit of the tunnel. The bear follows the mouse trying to find it. However, we varied whether the bear knew where the mouse went. In some cases, the mouse sneaked out when the bear was not watching. If children anticipate someone else's actions according to what they (the bear) saw, then in the case in which the bear has seen the mouse, children should be able to anticipate the bear will go towards the exit at the mouse's actual location. In the case where the bear didn't see where the mouse went, children should not have that kind of expectation.

We measured children's anticipatory looks with an eye-tracker device, which also allowed us to investigate whether they would look longer when the bear unexpectedly moved towards where the mouse was even if it had not seen the mouse hiding there. Data analysis is still ongoing.



(a) The bear and the mouse play chasing

(b) The mouse enters the tunnel with the bear watching

(c1) Knowledge ending: the bear sees where the mouse hides

(c2) Ignorance ending: The bear doesn't see where the mouse hides

Figure 1. Snapshots of the videos we used to investigate toddlers' perspective taking.

The Super Vision Game

Margaret Kandel (Graduate Student); Jesse Snedeker (Principal Investigator)

Eye-tracking is a very useful method for language research, as we can use it to gain insight into how listeners interpret words and sentences in real-time. In this study, we assessed how well a webcam eye-tracking software called WebGazer (https://webgazer.cs.brown.edu) works to track children's eye-movements. We started experimenting with running studies virtually while our lab was closed during the COVID-19 pandemic. We found that online experiments can be more convenient for parents and children than in-lab studies, as children can complete the studies from the comfort of their own home, and we can reach families who live further away from our lab.

The WebGazer software has the potential to make eye-tracking studies even more convenient for parents and kids, as it can be run in a web browser without an experimenter present, meaning that participants are able to complete studies whenever is most convenient for them.

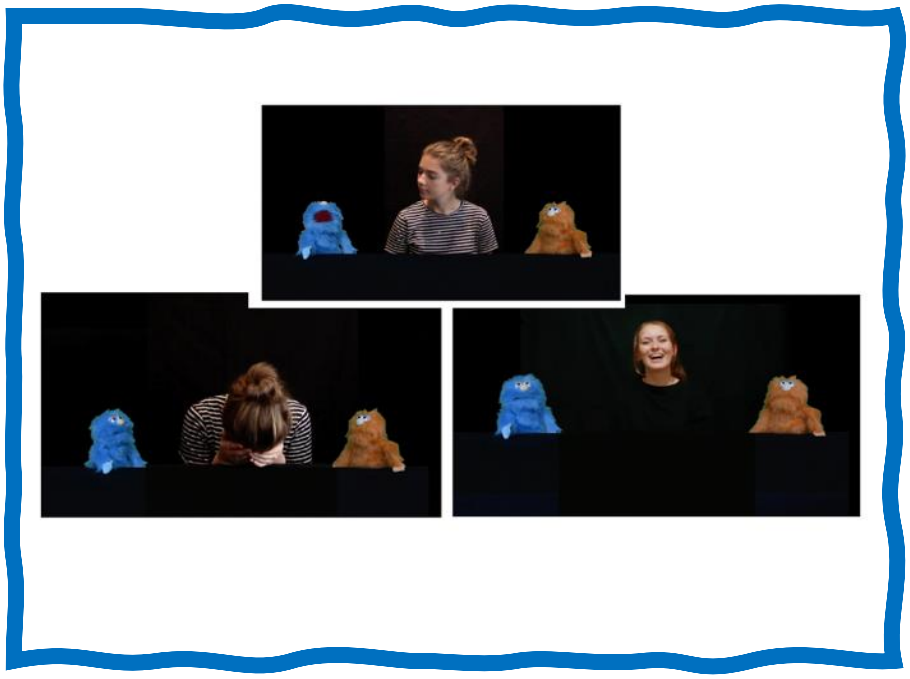
This study was conducted with English-speaking children aged 4–12 years old. Participant families were sent a link to the experiment via email. Participants completed the study from a computer with a webcam using either the Google Chrome or Mozilla Firefox web browser. During the experiment, children saw colorful plus signs (like this: +) that appeared in different parts of the screen. Their job was to look at the plus signs that appeared and to stare at them until they disappeared! We used the data from this study to estimate the difference (i.e., offset) between participant gaze location as estimated by WebGazer and the true stimulus (plus sign) location.

We found that it is possible to use WebGazer to conduct web-based eye-tracking experiments with children. In particular, WebGazer detected sharp increases in looks towards the plus sign stimuli shortly after they appeared, suggesting that it successfully picked up on participant eye-movements. However, we found that WebGazer is less accurate than the infrared eye-tracking devices we use in the lab; the average offset between the stimulus location and estimated gaze location was ~38% of screen size, compared to ~1% for in-lab eye-trackers. This offset tended to be smaller for older children, suggesting that WebGazer is more accurate at estimating gaze location with older participants. This data pattern could result from WebGazer-specific factors or because older children may be less susceptible to distraction and more likely to sit still throughout the duration of the experiment. We used the results from this study to provide other researchers with recommendations on how best to use WebGazer when running web-based eye-tracking studies with children.

Early Reasoning About Relationships Through Imitation Interactions!

Vanessa Kudrnova (Research Assistant); Ashley Thomas (Assistant Professor, Harvard University); Elizabeth Spelke (Principal Investigator)

Earlier work suggests that infants make predictions about future behaviors between two social partners based on imitation. For instance, when four-month-olds watch one character imitate and one not imitate a common target, they only expect the imitator (as opposed to non-imitator) to approach and affiliate with its target. Notably, when 12-month-old infants watch one central character imitate one puppet and not another, they reach more for the not-imitated puppet. Moreover, infants and toddlers appear to think about different types of relationships when watching responses to distress. For example, when a puppet expresses distress 8-10- and 16–18-month-olds expect (look first and longer at) a person who previously shared food (commonly occurring between close others), rather than a person who passed a ball with a puppet (commonly occurring between more distanced others), to react.



However, from this literature it is unclear whether infants and toddlers see imitation and responses to distress as cues of the same underlying type of relationship, and whether infants and toddlers think differently about behaviors depending on whether they are reasoning about the targets or non-targets of imitation compared to those who perform imitation. Hence, across a series of experiments, the current study asks whether 11.5 to 12.5 and 16.5 to 18.5-month-olds see imitation as predictive of who will respond to another individual's distress, and whether these predictions are affected by the direction of imitation. For this, babies watched a set of videos of one puppet imitating a central human character and one not, and another set in which one puppet was imitated by a central human character and one not. After each set of videos, the relevant central character expressed distress and we measured which puppet babies looked at first and for how long, as though they expected that puppet to respond.

Our results showed that infants and toddlers expect the imitator and imitated puppet to respond to their central character in distress. Therefore, we incorporated a control exploring whether these expectations were based on a relationship between the characters, or prosocial traits of the imitator and imitated. Interestingly, when the central characters were replaced by new individuals not involved in the prior imitation interactions, we found that babies were at chance with looks towards puppets, suggesting that infants and toddlers only expect the imitator and imitated to react to the distress of their social partner, and not just anyone. Our last study then explored whether infants' expectations are limited to a response to distress or extended to other behaviors such as laughter. We chose laughter because responses to distress occur more commonly in relationships, whilst responses to laughter are more likely to occur even with strangers. Therefore, babies watched imitation interactions after which the puppets' social partners expressed distress or laughed. Amazingly, we found that infants predictions do not extend to laughter. Together, these results suggest that by 12 months of age, infants do infer relationships between individuals, expecting an imitator and imitated puppet to respond to only their social partner when in distress!

Which Cup Do You Want to Pick?

Michael Huemer (Postdoctoral Researcher); Isobelle Hawkins, Katherine Holmes, Franziska Griessenauer, Caden Li, Simon Born, Samy Almshref (Research Assistants); Brian Leahy (Graduate Student); Irene Canudas Grabolosa (Postdoctoral Researcher); Susan Carey (Principal Investigator)

Previous studies from our lab suggest that young children do not think about alternative possibilities before they turn 4. For example, when children are presented with the task shown in Figure 1 (3-cup task). A coin is hidden in a single occluded cup and another coin is hidden in an occluded pair. If given a chance to choose one cup and receive its contents, choosing the singleton cup is the safe bet, because each member of the pair might be empty. Yet 3-year-olds choose a member of the pair almost half the time.

When chimpanzees are presented with the 3-cups task, they take the singleton cup about as often as 3-year-olds. However, when chimpanzees are presented with versions of this task in which they have a choice between a singleton cup and a cup from a set of three or more cups, they take the singleton cup much more often. This increases with the number of cups on the set side, e.g., in the 7-cups version (see Figure 1, 7-cup task) they take the singleton cup in 84% of the trials.

Increasing the number of cups on the set side makes it less likely that a particular cup contains a prize. Children may now find it easier to recognize that the singleton cup must contain a coin while each of the other cups merely possibly contains a coin when there are more cups that might be empty. We showed 3-year-olds an online version of both the 3- and 7-cup tasks and compared three different hiding procedures.

We tested 170 3-year-olds with an online version of the cup task. Their response in the 3-cup-task is the same as in previous studies. In the 7-cup task (regardless of the procedure), children picked the singleton cup about 10% more often than in the 3-cup task. We are currently analysing the data in more detail, to find out whether children's improved performance is due to an understanding of possibility or based on some other reasoning strategy.

In an ongoing study, we are testing 3-year-olds with 3- and 7-cup tasks in-person. Six children have participated in the study so far.

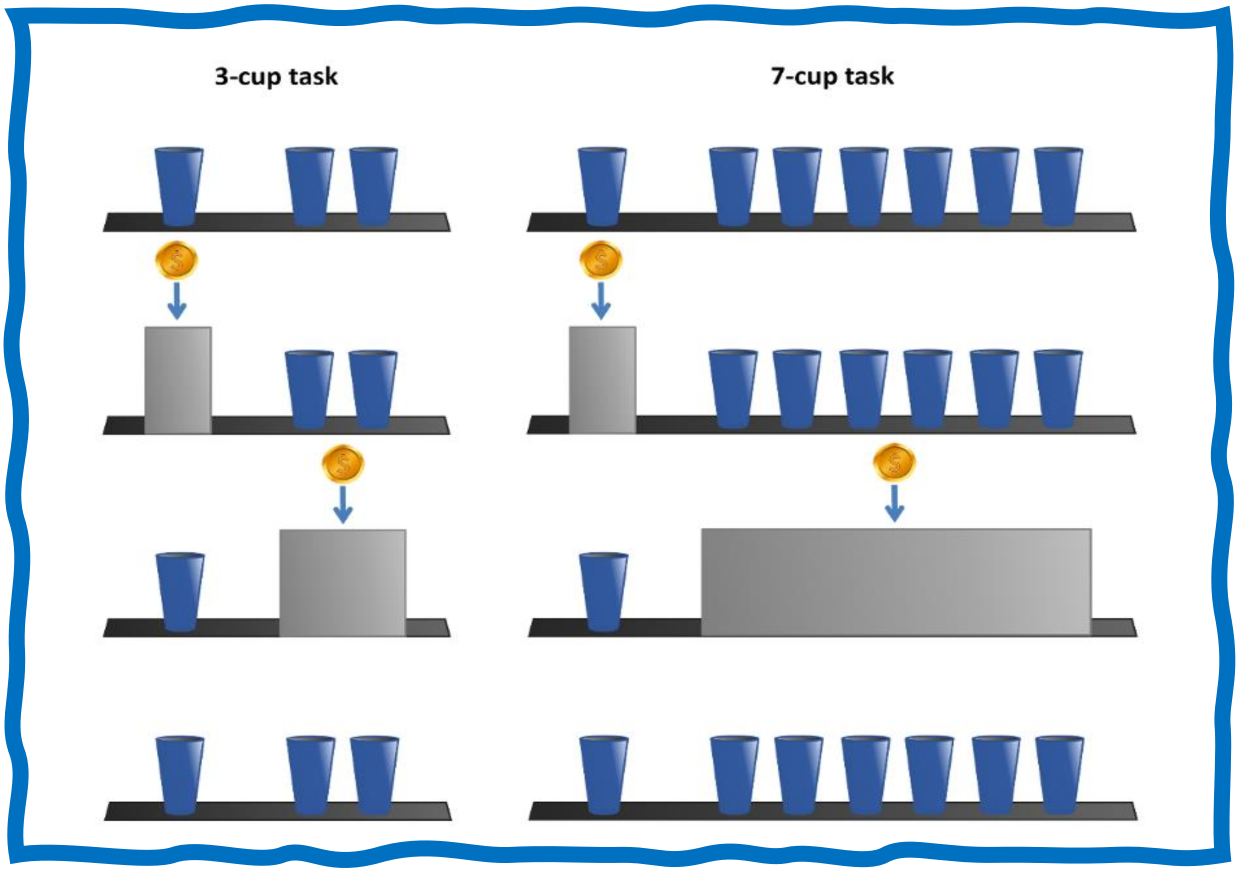
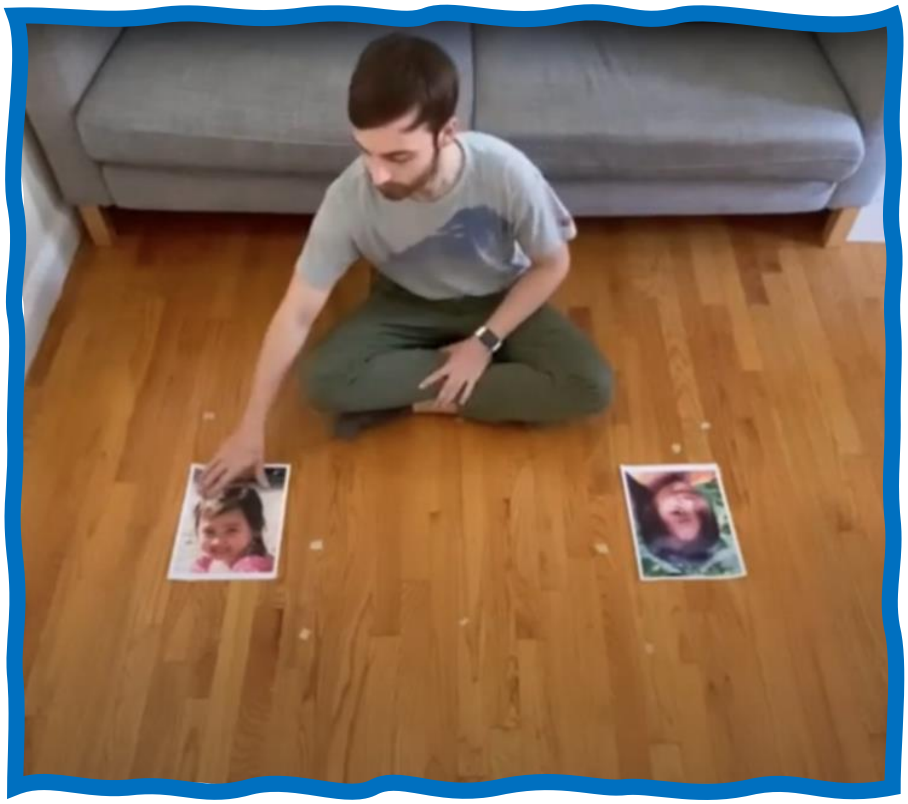


Figure 1. The 3-cup and 7-cup tasks for studying the ability to reason about multiple possibilities.

Representing Others' Experiences in Toddlers

Brandon Woo (Postdoctoral Researcher); Gabriel Chisholm (Research Assistant); Elizabeth Spelke (Principal Investigator)

The ability to appreciate others' experiences is important for communication, learning, and cooperation. Do toddlers appreciate that other people can look at the same object, and experience it differently depending on their perspectives (e.g., as upright versus upside-down)? In several experiments conducted over Zoom video calls, we have now found that toddlers struggle to appreciate that pictures that are upright and upside-down to themselves may be in other orientations to other people. Instead, toddlers appear egocentric. We have since replicated this finding in person. (For a recent working paper, see https://psyarxiv.com/3gbj6). In ongoing work, we are exploring whether toddlers may be more sensitive to others' experiences when these experiences are conveyed by language.



What Information Do Kids Use to Identify Words?

Margaret Kandel (Graduate Student); Nan Li (Postdoctoral Researcher); Jesse Snedeker (Principal Investigator)

When you are listening to someone speak, there are multiple potential sources of information that could be used to help you identify the words that you are hearing. One obvious source of information is the sounds contained in the word. Another potential source of information is the sentence context in which the word appears. In this study, we are interested in whether children are able to use contextual information in addition to sound information as they identify the words they hear in a sentence.

We are currently conducting this study with American English-speaking children aged 4–5 years old. In this study, participants are seated in front of an eye-tracker. In each trial of the experiment, they see four pictures and hear a sentence that includes the name of one of the pictures. Their job is to select the picture whose name they hear in the sentence. In each sentence, there is a critical word that appears before the participant hears the name of the picture they will select. We manipulate how predictable the critical word is and whether there is another picture on the screen whose name starts with the same sound (a cohort competitor). For example, participants may hear the critical word "bed" when there is a picture of a belt on the screen. We will test whether participants look more at the cohort competitor image (e.g., belt) than at an unrelated picture (e.g., stream) as they begin to hear the critical word (e.g., bed); this will let us know whether they consider the cohort competitor image as a potential match to the sounds they were hearing. If participants are able to use sentence context to constrain word identification, we expect fewer looks to the cohort competitor image when the critical word is predictable than when it is not. Data collection for this study is still ongoing, so stay tuned for results!

Can Infants Use Labels to Categorize Objects in Overhead Settings?

Cristina Sarmiento (Lab Manager) and Elizabeth Spelke (Principal Investigator)

It's not uncommon to experience a time when a child said a bad word out of the blue. It is very likely that the child overheard an adult say that particular word. How much of what is not directly spoken to children are they picking up on? Past research has focused on investigating infants' abilities when being directly spoken to. However, direct speech is not the only type of speech that children hear. In this study, we sought to investigate whether infants can use labels to categorize objects when not being spoken to directly.

We ran a series of pilots with infants and toddlers ages 8.5 months through 18 months. We showed videos of a conversation of an adult finding and labeling two objects inside a box and showing them to another adult. Objects labels were novel words that children have not heard before. In some videos, the object labels matched the objects and in other videos, the object labels did not match the objects. An example of a label matching is if two identical objects were given the same label, or two different objects were given different labels. An example of a label not matching is if two identical objects were given different labels, or two different objects were given the same label. If infants and toddlers are using the labels to categorize the objects, we would expect infants and toddlers to look longer at the more surprising events – the videos where the labels did not match the objects.

So far in most of our pilots, we are seeing a slightly longer looking time towards the unexpected events. We're brainstorming next steps and hope to run more versions of this study!

A snapshot of videos shown in earlier pilots with 2 identical objects.

A snapshot of videos shown in later pilots with 2 different objects.

Children's Understanding of Close Relationships

Brandon Woo (Postdoctoral Researcher); Kaitlyn Tsai, Lauren Kaplan (Research Assistants); Ashley Thomas (Principal Investigator)

Imagine being on a roller coaster. Are you more scared or excited? Now ask: Who in your life might be best able to predict your emotional state: your best friend, your coworker, etc.? The present study asks whether 7-year-old children understand that people within close relationships may be more accurate at representing each other's emotional states. Data collection is getting started this fall!

Children's Understanding of Close Relationships

Brandon Woo (Postdoctoral Researcher); Ashley Thomas (Principal Investigator)

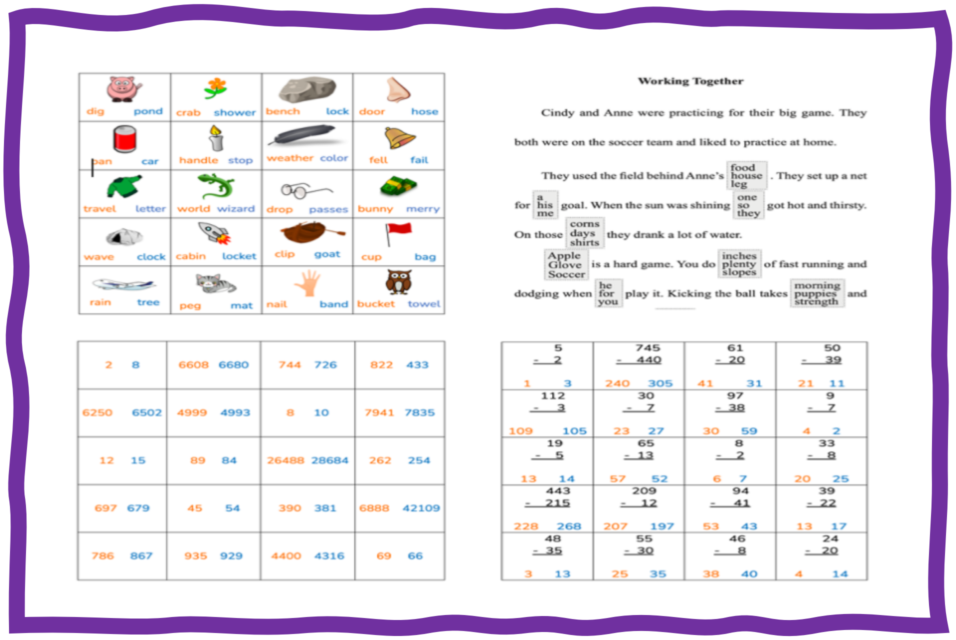
Past research has examined what babies understand of other people's actions but has mostly presented babies with people who are strangers. Yet, the people whose minds may be most relevant for learning, cooperation, and social life are the people within a child's social network: especially the child's own caregiver. The present study asks whether 9-month-old babies may be more sensitive to the goals of their caregivers vs. strangers. Data collection is getting started this summer!

Does Feedback Affect Girls' and Boys' Interest in Math or Reading?

Sam Gregory (Research Assistant); Sara Valencia Botto (Postdoctoral Researcher); Elizabeth Spelke (Principal Investigator)

Achievement in math is crucial to success at school and the pursuit of many STEM careers. However, from the early years of schooling, girls underperform in math relative to boys. A recent study reported that this gender gap does not exist in kindergarten, before formal mathematical instruction is given. This finding raises a critical question: might gender differences in the feedback teachers offer shape girls' and boys' subsequent motivation to learn math? We know that children's behavior is greatly affected by the feedback and evaluations of adults. For example, 3-5-year-old children who are praised for being smart are more likely to cheat, presumably to uphold a reputation for being smart. More recent studies indicate that 3-5-year-old children will strategically engage in one activity over another to obtain a positive evaluation from an adult. Importantly, research indicates that the effect of praise and feedback vary by gender. For example, person praise (e.g., "you're really good at this!") diminishes girls' motivation to pursue a challenging task but has little impact on boys.

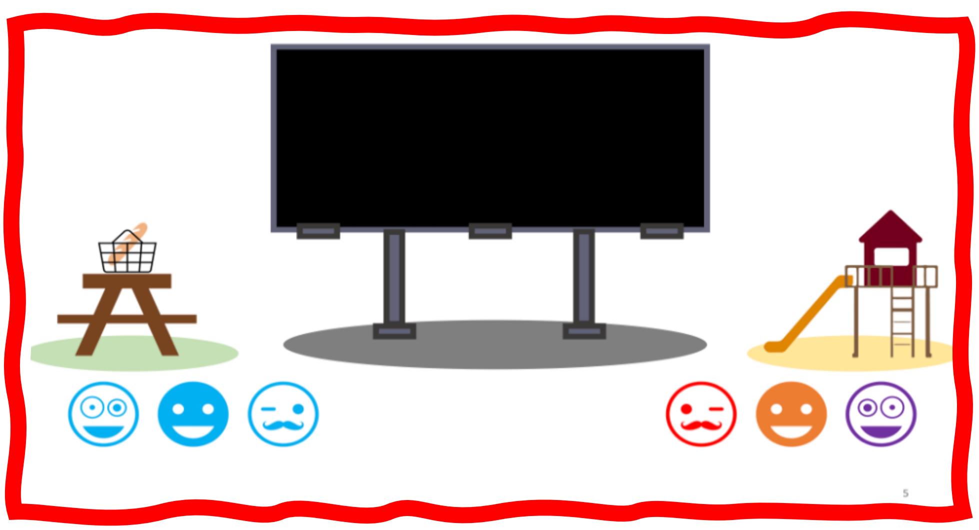
This study investigates whether positive feedback regarding performance in reading or math activities influences 5- and 7- year-olds' subsequent performance and decisions to pursue either 'easy' or 'hard' activities in these two domains. Using a behavioral experiment, children will complete a timed activity in both reading and math before receiving positive feedback on only one of these domains. To see the *potential* effect of this feedback, children will be asked to choose an 'easy' or 'hard' activity in reading and math. Similar to previous findings, preliminary data with 15 participants indicate that 7-year-old boys perform better than girls in math, but 5-year-olds show no gender differences in math. In reading, gender differences were not found in either age group. Importantly, there is a trend where boys are more willing to choose hard math activities, whereas girls seem to choose easy math activities. More data will be needed to examine the effect of feedback on these choices.



Learning from Others

Brandon Woo (Postdoctoral Researcher); Andrea Ventura, Jacob Wilson, (Research Assistants); Sunae Kim (Senior Lecturer, Oxford Brookes University); Elizabeth Spelke (Principal Investigator)

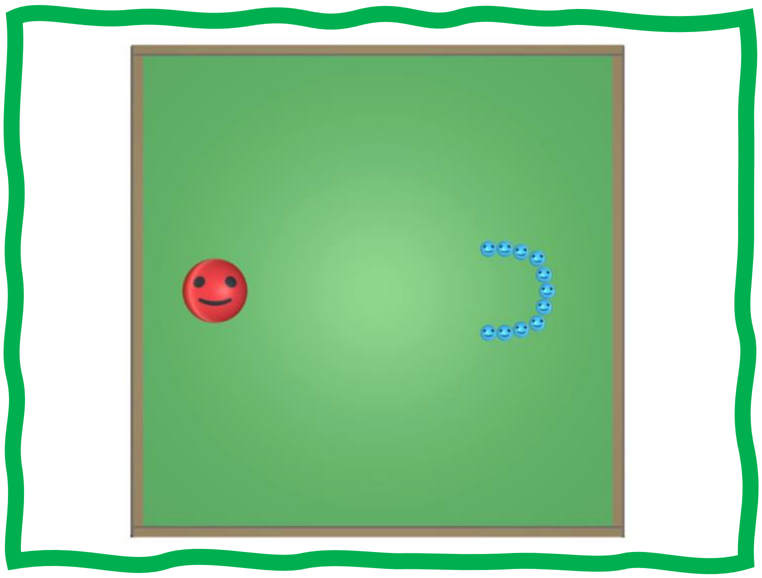
Children often depend on others to learn new information. But how can children determine whether someone is likely to be teaching them something true? This study examines whether children more strongly value information from socially connected people (friends) or from independent people (strangers). This study is ongoing.



“Some” and “All” in Infancy

Irene Canudas Grabolosa (Postdoctoral Researcher); Lal Kablan, Kayla Drazan, Samy Almshref (Research Assistants); Gennaro Chierchia, Susan Carey (Principal Investigators)

The broad aim of our study was to investigate whether young children can understand logical concepts before they can verbally express them. Specifically, we sought to determine if they could differentiate between the concepts of "some" and "all". To achieve this goal, we recruited 33 participants who were 11-13 months old and showed them a series of videos where a large ball collided with a group of small balls, causing some of them to explode. We continued to show these videos until the child lost interest, at which point we presented a new video with all the small balls exploding, instead of just some of them. If the child could differentiate between "some" and "all", they would have found the new video more interesting and shown renewed attention. If not, the child would have perceived the video as being the same as before, and their interest would not have been piqued.



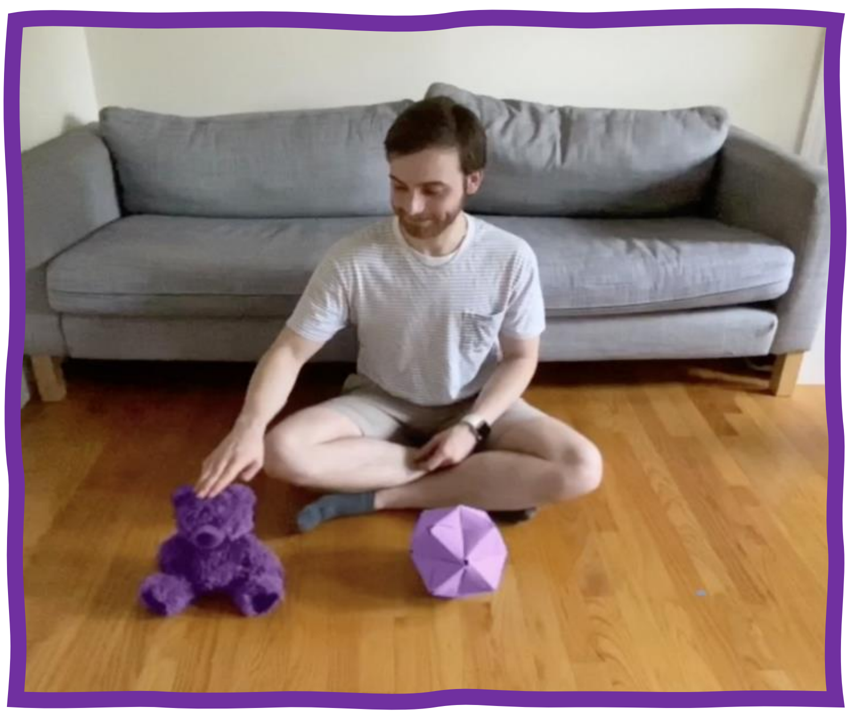
We used an eye-tracking machine to record where and for how long the child looked during the presentation of the videos. The data collected was analyzed to determine if there was a difference in the child's attention and gaze patterns when presented with the new video.

Although the actual data collected did not provide a clear answer to the research question, some trends were identified that indicated it was worth exploring further. We are currently exploring them with a modified paradigm with a new group of 11- to 13-month-olds, a group of 18- to 20-month-olds and a group of three-year-olds. Stay tuned for the results!

Goal Understanding in 3-Month-Old Infants

Brandon Woo (Postdoctoral Researcher); Shari Liu (Assistant Professor, Johns Hopkins University); Elizabeth Spelke (Principal Investigator)

A person sits in front of two objects, a ball on the left and a bear on the right. The person repeatedly reaches for one of the objects (e.g., the ball), always in the same location. Later, the two objects switch positions. Which object will the person reach for now: the same object, or for a different object in the original location that he had reached for? Previous work has found that whereas 6-month-old infants expect the person to continue reaching for the same object, 3-month-old infants do not. The present studies ask: What do 3-month-old infants understand about others' goals? Why have they failed, in past research, to appreciate the goals of others' reaches? We explored one possibility: that 3-month-old infants may not yet appreciate that an object's identity matters more than its location. In a series of experiments, we provide evidence that 3-month-old infants can learn that someone's reaching is guided by a goal to act on a particular object or on a particular location, depending on the evidence that infants observe. Moreover, infants are sensitive to whether actions are intentional vs. accidental. These findings suggest that infants rationally learn about others' actions. We have now submitted this paper for publication (see working paper: https://psyarxiv.com/dx2er/).



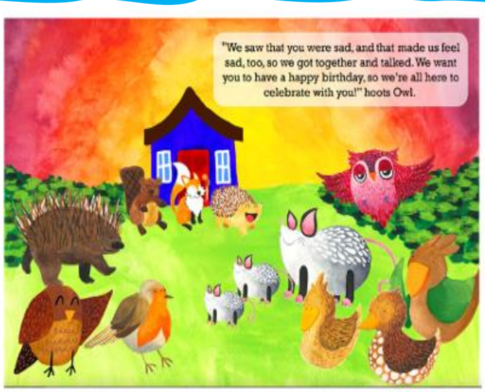
Using Storybooks to Improve Number and Social Emotional Understanding in Toddlers

Cristina Sarmiento (Lab Manager); Sanghee Song (Research Assistant); Caitlin Conolly (Research Fellow); Elizabeth Spelke (Principal Investigator)

Once children enter formal schooling, they need to learn numerous things such as learning about their teachers and peers, learning about their environment, and learning about concepts such as numbers and reading. A foundation of pre-academic skills like number and social-emotional understanding can help children with this transition to formal schooling. To help children build their number and social-emotional skills in a fun and engaging way, we have two developed storybooks (number and emotion) that touch upon these skills. We predict that children who receive the number book will improve in their number skills, and children who receive the emotion book will improve in their social-emotional skills.

In the first book, the number book, two friends 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 make other numbers, and whether those numbers may be exactly enough, or not quite enough for a game of tag. In the second book, the emotion 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. 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.

To make sure we can assess the effects of our storybooks, we created games on numbers, emotions, and vocabulary. We piloted these games with 3-year-olds to make sure our games were fun and the right difficulty level.



Excerpt from the emotion book

Excerpt from the number book

We then piloted these games and storybooks together with 3-year-olds. Participants were mailed one of the storybooks to their homes. They met with researchers on Zoom to play a version of our games and were instructed to the read book at least 4 times at home throughout the next few weeks. After at least 2 weeks, participants met with the researchers again on Zoom to play a different version of our games and to read their favorite excerpt from the storybook.

Pilot results have shown that our emotion book seems to improve emotion skills, but the number book does not seem to improve number skills. We are working on improving our number games to better reflect the number skills touched upon in the storybook. Based on participant feedback, we have also edited the storybook. We hope to pilot our games and storybooks again soon!

Prediction in Children with and Without Autism

Tanya Levari (Postdoctoral Researcher); Briony Waite (Lab Manager); Jesse Snedeker (Principal Investigator)

In this study, your child played many games, both in-person and on Zoom. For example, we asked your child to find smiley faces among pictures of real faces, tap along to a beat, and listen to a story! For some of the games, they were set up for an electroencephalogram (EEG) recording, and we recorded their brain responses while they completed different tasks.

These games might not have seemed connected, but we think they will help us understand different aspects of prediction; how do our brains find patterns in the world and how do we use those patterns to anticipate what we might experience next! In this study we are interested in seeing if there are differences in how children with and without autism make predictions.

For example, in one game, your child was asked to first listen and then tap along to sequences of sounds. This sequence of sounds had a predictable pattern but occasionally a sound was either omitted or delayed - breaking the pattern. By seeing your child's brain responses to these different errors, we can get an understanding of the kind of information being used to make predictions and how such predictions are updated when something new happens.

Your child also listened to a story while we recorded their brain activity. 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. This helps us understand linguistic prediction. 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 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 hearing the following; “On a windy day Johnny liked to go fly his...” You wouldn’t be very surprised if the next word was “kite”, but you would be very surprised if 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”.

Our data so far has shown both similarities and differences in the way that children with and without autism predict information, however, we are still in the process of collecting data for this study and it is too soon to know what we will find. Stay tuned for more results next year!
We loved seeing families in person for this study. Thank you so much for participating!

Find Sound: A Game-Based Intervention to Improve Children’s Reading Skills

Gianna Zades (Honors Thesis Student); Akshita Srinivasan (Graduate Student); Lucia Vilches (Research Fellow); Simran Sanjay, Gabriel Chisholm (Research Assistants); Elizabeth Spelke (Principal Investigator)

Reading is an essential skill that helps children grow intellectually and better understand the world around them as they learn to decipher both sound and meaning in written language from a young age. Reading broadens a child’s horizons, as readers of both fiction and factual texts discover and explore physical, cultural, and social worlds beyond their immediate experience. Learning to read is a process that formally starts in kindergarten and continues through early elementary school. Previous research has shown that early reading skill is a predictor of children’s success in the rest of their education. In order to help support children’s reading acquisition at home, we developed a fun game that focuses on teaching the different sound properties of words including rhyme, alliteration, and syllables.

Our study tested the effectiveness of this reading game by comparing it to a similar game in the domain of geometry. We evaluated the extent to which these games improved kindergarten age (5-6.5 years) children’s school-relevant reading and geometry skills in the short term. The geometry game, “Find Shape,” and the reading game, “Find Sound,” are played as a game of war, where children are asked to find which shape or word belongs in a group based on its geometric or sound properties. Each participant was sent one of the games to their home. The study involved two remote zoom sessions that were about 45-60 minutes long and at-home gameplay for about 2-3 weeks in between the two sessions. In the first session, we asked children questions on the computer about reading and geometry and then another researcher taught the child and parent how to play the game. Then, parents were asked to engage in at-home gameplay with their child on 8 separate occasions. Finally, in the second zoom session the child and parent played one more round of the game and then a researcher asked the child more questions related to geometry and reading.

Preliminary results indicated that children who played Find Sound did not show significant improvements in their reading scores compared to children who played Find Shape, though the results were trending in the direction that favored children who played Find Sound. The data also indicated that, in comparison to those who played Find Sound, children who played Find Shape showed significant improvements in one set of geometry skills that we directly trained in the game and tested in the assessments. We also received qualitative data from participating children and their families regarding the duration and difficulty of the games in addition to their feedback on how the games might be adapted and improved based on their experiences playing them at home.

This research evaluated the effectiveness of two home-based educational interventions with the aim of improving children's school-relevant skills in the short term and the hope of fostering their subsequent learning in school. The outcomes of this work are extremely useful as we continue to develop and test educational interventions that can support the success of young children.

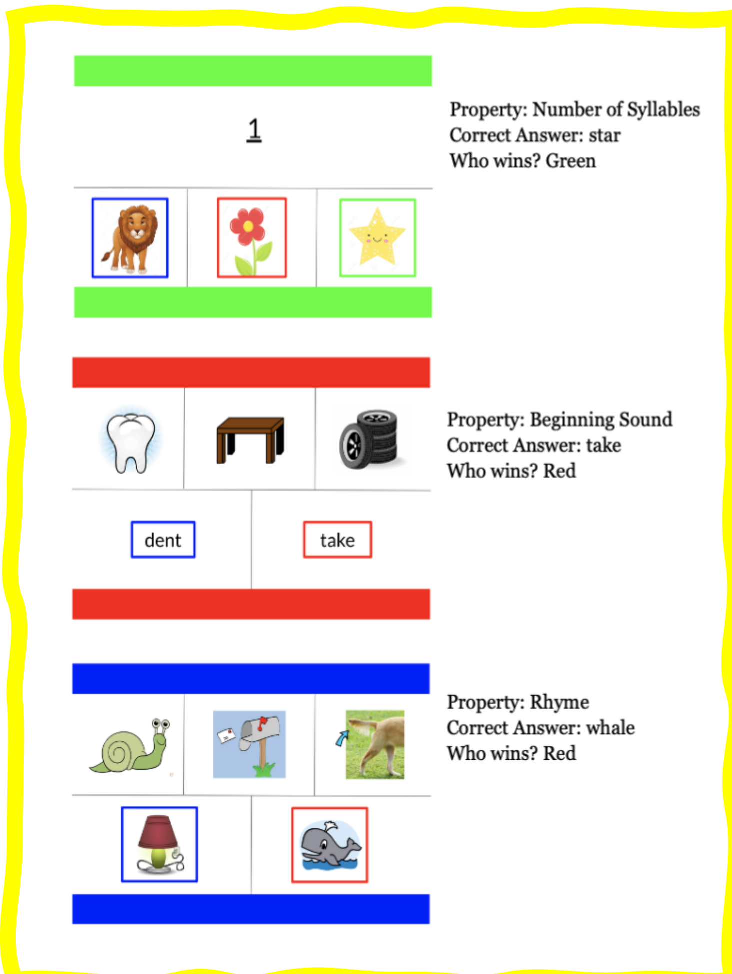


Figure 1: Find Sound is played with two players. Each player has their own deck. For each card, the child must find the answer on the bottom (blue, red, or green) that matches the symbol or word represented by an image on top. Once the players have determined the correct answer, the player whose card has borders that are the same color of the correct answer gets to keep both player's cards in their 'winning pile.' After repeating for each card in a deck, the player with the most cards in their winning pile wins.

Which Chest Do You Want to Pick?

Irene Canudas Grabolosa, Michael Huemer (Postdoctoral Researchers); Samy Almshref, Kayla Drazan (Research Assistants); Susan Carey (Principal Investigator)

Previous studies from our lab suggest that young children do not think about alternative possibilities before they turn 4. For example, when children are presented with the task shown in Figure 1. A coin is hidden in a single occluded chest and another coin is hidden in an occluded pair. If given a chance to choose one chest and receive its contents, choosing the singleton chest is the safe bet, because each member of the pair might be empty. Yet 3-year-olds choose a member of the pair almost half the time. Why don't they choose the singleton chest? This is expected if 3-year-olds do not think about the coin in the pair might be in either chest. Rather, they make an assumption about which chest of the pair the coin is in. Then they make a 50/50 choice between the two chests (the single chest and one member of the pair) that they "know" has a coin in it.

Studies conducted by other labs suggest that even young infants have at least some awareness of possibility. In these studies, children's sensitivity to possibility is measured with pupillometry. This allows to measure pupil dilation, which allows to draw conclusions about cognitive processes.

In our current, ongoing study, we present 3- to 4-year-old children with the 3-chest task (as in Figure 1), and in addition to children's verbal responses what chest they want to pick, we measure also their pupil dilation. We compare the pupil dilations of situations where they find a coin to situations where they do not find a coin. If children have some awareness of possibility, the pupil dilation should show greater dilation (indicating greater surprise) when they find the singleton chest empty than when they find one chest from the pair side empty, and this pattern should be reversed when they find a full chest. In contrast, if children are unaware of the alternative possibilities, their pupil dilation should not differ between events on the singleton and the pair side.

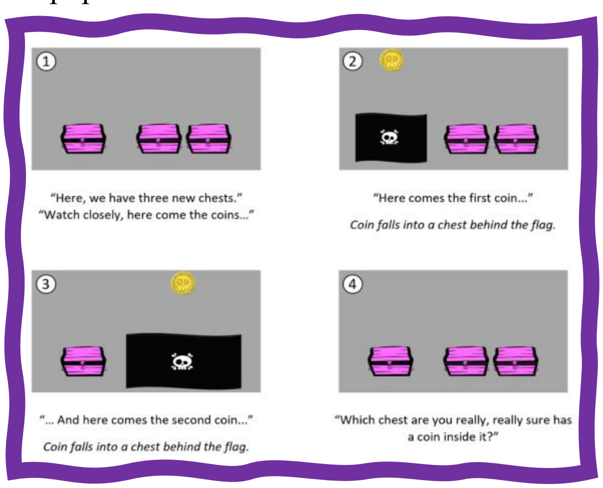
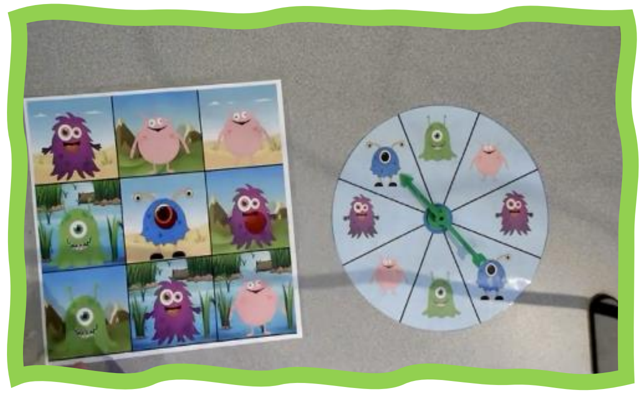


Figure 1. The 3-chest task for studying the ability to reason about multiple possibilities

Can Older Siblings Teach Younger Siblings New Words?

Joseph Coffey (Graduate Student); Jesse Snedeker (Principal Investigator)

Throughout the world, children play an important role in the care and instruction of their younger siblings. In many societies, children spend more time in conversation with their peers than they do with their adult caregivers. Even in societies where children have fewer siblings and spend less time with them on average, older siblings have been found to proactively teach language and literacy concepts to their younger charges. These findings suggest that having older siblings can positively impact children's early language development.



Surprisingly, the literature on language development has little to say about the effects of older siblings. Almost no studies of word learning have recorded children's conversations with their siblings. Of those that have, few have found sibling speech to predict children's vocabulary growth. One possibility for this is that older siblings are not as proficient teachers as parents are. Children may be unable to learn as effectively from older siblings' speech, which tends to be less pedagogical than parents' speech. They may also not believe older siblings are reliable sources of information and prefer to learn from adults.

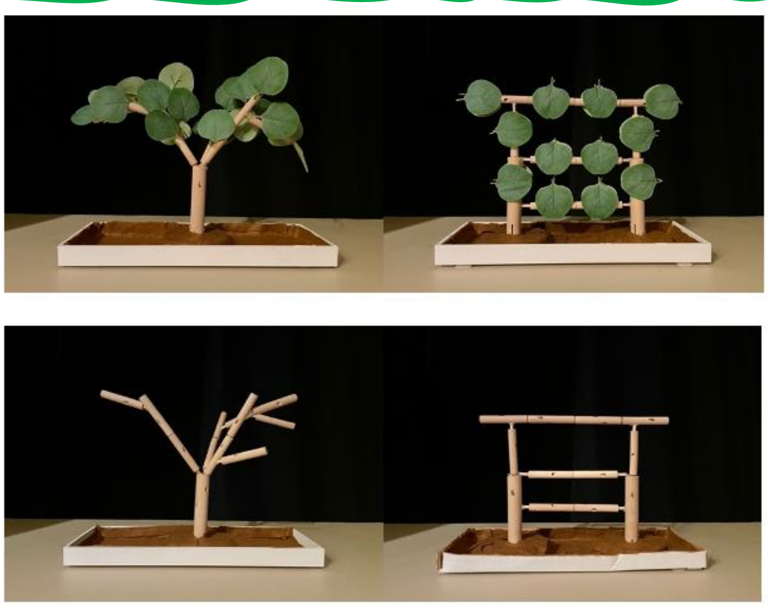
Our study tested these competing theories by examining whether children learn new words through naturalistic instruction by their older siblings. We recruited families with two school-aged children to take part in this study. During the session, both parents and older siblings were taught how to play a version of Bingo that required they learn the names of four monsters, each with a made-up name. Afterwards, parents and older siblings were asked to teach the younger siblings how to play the game, including the names of each of the monsters. Parents and siblings were given slightly different games with some unique monsters, which also allowed us to compare the effectiveness of parent and sibling teaching. All participants were then assessed on how well they were able to recall the names of the monsters.

In our initial pilot of 10 families, we found that younger siblings were able to remember the names of the monsters taught by their older siblings. We also found that they tended to remember words taught by parents better than words taught by siblings, although this may have been because parents were better at learning the words themselves compared to older siblings. We also found some suggestive evidence that words taught by both parents and siblings are easiest to learn but given our small sample this finding is still inconclusive. We look forward to updating you all on our discoveries as we continue to run participants over the next year!

Infant Sensitivity to Plant Structure

Cristina Sarmiento (Lab Manager); Qianqian Chen, Abigail Charlamb, Jacob Wilson (Research Assistants); Elizabeth Spelke (Principal Investigator)

When we look back in time evolutionarily, plants and trees have always been a part of our environment. Before the ease of shopping for food at grocery stores, we had to learn to forage for food and figure out from more knowledgeable others which plants were toxic and which ones were safe to eat. Past research has shown that infants and toddlers are hesitant to touch plants, which may be an evolutionary adaption from when we foraged for food. How are infants and toddlers distinguishing plants from other living and nonliving things? What characteristics of plants are they using? We hypothesize that infants are using the hierarchical branching structure and/or leaves of plants to make this distinction. To explore this, we developed objects that had at a natural growing structure or an unnatural growing structure (looping structure), and that had leaves or no leaves. We also developed a questionnaire for parents to answer to see what infants' previous experiences with plants were. We predict that children will take longer to touch the natural growing structures and the structures with leaves. Pilot data collection is still underway, but preliminary results appear to show that children take more time to initially touch the objects that have a natural growing structure and the objects with leaves.



Infants' Preference for the Way Things Grow

Cristina Sarmiento (Lab Manager); Lola de Hevia (Visiting Scholar); Elizabeth Spelke (Principal Investigator)

In a short study, we wanted to see if infants have preferences for the direction in which things grow. This study grew from interests on our study looking at infant sensitivity to plant structure. We presented infants ages 5 months – 9 months with lines growing in different directions (up, down, left, and right) one at a time. We measured how long infants looked at each video to see what they preferred to look at it. We found a trend that infants prefer the lines that grow upright which is consistent with the way plants and trees grow. We are hoping to bridge this study with our study looking at infant sensitivity to plant structure and in the future, show infants videos of trees growing naturally or unnaturally.

Do 3-Year-Olds Reason More Readily About Their Caregiver's Beliefs Than a Stranger's?

Gabriel Chisholm (Research Assistant); Brandon Woo (Postdoctoral Researcher); Ashley Thomas (Assistant Professor, Harvard University); Elizabeth Spelke (Principal Investigator)

Although adults reason intuitively about others' beliefs, a large body of research has demonstrated that children struggle. For example, when shown a container such as a crayon box which is revealed to contain something surprising e.g., a rock, 3-year-old children struggle to understand that someone else would predict there to be crayons inside. One possible explanation for why children struggle is that the experimenter asking the question is knowledgeable about the container's true contents. Thus, children may be answering based on the experimenter's perspective rather than the target of the question, a stranger. In this early version of the study, experimenters alternated asking about a doll, Sally's, beliefs with one experimenter knowledgeable about the container's contents, and one unaware. Pilot results revealed no difference in children responses based on who was asking the question. Therefore, we decided to focus on a different variable, the target of the belief question, rather than the asker of the question.

In previous studies, children have been asked to reason about the beliefs of a stranger, or someone who is not intimately connected to them. However, a growing body of research has demonstrated the uniquely intimate relationships children have with their caregivers. Children are sensitive to their caregivers interactions with others and infer who is socially connected to themselves based on these interactions. Thus, children may be more motivated to reason about a caregiver's belief than a strangers. In this online study, we show 3-year-olds a series of containers with unexpected-contents and ask what a stranger, or a caregiver who is not present, would think is inside.

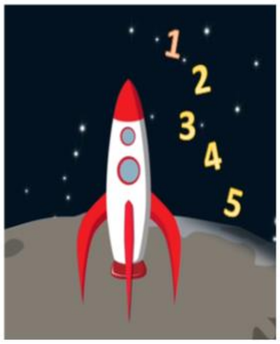
Numbers Across Languages

Akshita Srinivasan, Simge Topaloglu (Graduate Students); Jesse Snedeker (Co-Principal Investigator); Elizabeth Spelke (Co-Principal Investigator)

Learning numbers and math operations like arithmetic are important milestones in school for young kids. But can the language that a child is acquiring make it harder (or conversely, easier) for them to learn numbers?

In most cultures, numbers are organized around a base-10 system, which uses 10 and its powers to represent numbers. This structural logic is also reflected in the number terms that languages use, but not all languages encode their numbers in the same way. For example, a language like Mandarin has very 'regular' number words that transparently reflect the base-10 structure; since 11 is called 'ten-one' and 20 is called 'two-ten.' Compared to the simplicity of Mandarin, English has more opaque number words, since 'eleven' does not reveal that this number is made up of 'ten' and 'one', and 'twenty' also does not reveal that this number is related to 'two' and 'ten'. In this study, we test kids acquiring a diverse set of languages (such as English, Mandarin, Turkish, Hindi, Tamil) that all differ in their numbers' relative degree of transparency; and we seek to find out what the implications of number word transparency/ opaqueness might be for young kids' developing math abilities.

We play number-related games with kids to see how high they can count, whether they understand what operations change the number of a set and what operations conserve it, or whether they understand the base-10 logic.



We are still in the process of collecting data for this project so stay tuned for our findings! This research would not be possible without the help of the children who took part in the study and their parents. Thank you so much for your participation, and we are hoping to see you in our lab for our future studies!

Games to Enhance Children's Reading and Numerical Skills

Akshita Srinivasan (Graduate Student); Elizabeth Spelke (Principal Investigator)

Learning how to read and learning about numbers are two important aspects of early schooling. However, they can be hard for children to learn. While learning how to read, children need to figure out what letters and their combinations sound like. In English, this is especially hard as the same letters can take on different sounds. For example, the letter "u" sounds different in "nut" and "put". Similarly, learning about numbers can be hard, as the symbols and words that represent them do not transparently convey their meanings. For example, a number word like "eleven" doesn't convey to children that it is made up of ten and one. The meaning of written symbols like "23" depends upon understanding place value codes, where the value of a digit varies based upon the position it occupies in a number, making "23" and "32" different quantities. Given the importance and difficulty of learning reading and about numbers, we designed two board games for 6-7-year-old-children. The reading game, called Bingo, focuses on the compositionality of the English alphabet and the number game, called Find and Move, focuses on the compositionality of numbers. We hope that these fun games will help children become better prepared for learning in school.

In this study, children and their caregiver(s) participated in two Zoom sessions, 2-3 weeks apart, from their own homes. In between the Zoom sessions, children played either the reading game or the number game at home with their caregiver or sibling. During both the Zoom sessions, we asked children some questions about numbers and words. We are just a few participants away from finishing data collection so stay tuned for our findings in the next newsletter. We hope that these games will improve children's school-relevant reading and numerical skills.

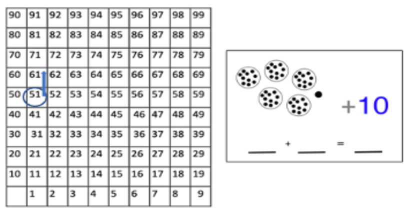


Figure 1: Number game. In this game, children first locate the number of black dots (51) on the board (left) and then add the number in blue (10). They are taught to jump up the line to add 10, that is move from 51 to 61 to find the final answer.

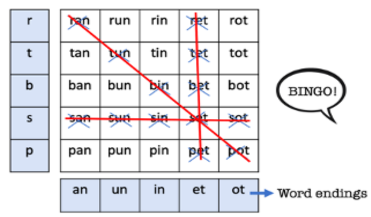


Figure 2. Reading game. In this game, children try to find words, like "pun", on the board by using the word beginnings like "p" on the left and word endings like "un" at the bottom. Once they find 5 consecutive words in a row, column, or along the diagonal, they say "bingo" and move to the next level.

Can Compositional Language Help 2.5- 4-Year-Old Children Learn New Number Words?

Lucia Vilches (Research Fellow); Akshita Srinivasan (Graduate Student); Elizabeth Spelke (Principal Investigator)

Prior to formal education, children have capacities for representing small numbers exactly (e.g., the difference between "two" and "three"), and large numbers approximately (e.g., the difference between "twenty" and "forty"). However, the question of how we come to create exact representations of large numbers (e.g., the difference between "twenty" and "twenty-one") remains open. In this study, we aim to get closer to answering this question by testing one proposal, which posits that compositional language (language that shows how large numbers are made up of smaller numbers) may allow children to create exact representations of large numbers.

For this study, we are recruiting children ages 2.5-4 years of age who are monolingual English-speakers. Each child completes a short (15-25 minute) series of activities. First, they demonstrate their number-knowledge by picking out sets of a variety of sizes (e.g., "which of these plates has exactly five pieces of candy?"). Then, they watch and interact with a demonstration in which they will be exposed to sets of either “five” or “six” objects. In this demonstration, half of the children in our sample will be shown how the set of “five” or “six” can be broken down into smaller subsets (a set of “three” and a set of “two”, in the case of “five”; and a set of “three” and another set of “three”, in the case of “six). The other half of the children will be shown how sets of “five” or “six” are made up of individual objects. After these demonstrations, children will interact with sets of objects of varying sizes, to show what they have learned from the demonstrations. We expect children who are shown how the larger set can be broken into smaller subsets to learn more about numbers.

A better understanding of how children acquire number concepts can help us develop effective interventions to aid their learning. The implications of this research are not limited to number learning. Compositional concepts allow for flexible and generalizable learning. We hope that by using number learning as a case study, we can contribute to the broader literature on children’s understanding and learning of compositional concepts.

Data collection for this project is ongoing. We are grateful to the families who have participated so far, and we look forward to sharing what we find in a future newsletter! We are excited to see what the results of this study tell us about how children learn about numbers!

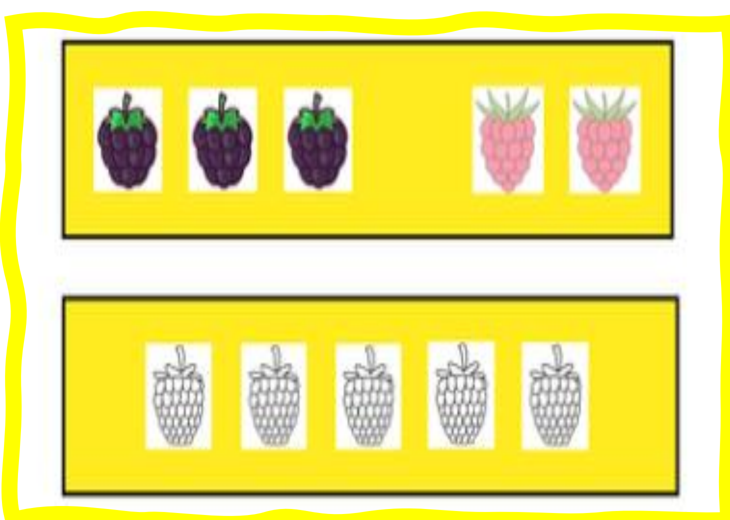


Figure 1. Image from the experiment showing how a set of 5 berries can be composed of two subsets (3 blackberries and 2 raspberries).