Dear Families,

The Princeton Baby Lab is a research group in the Department of Psychology at Princeton University. 2018 has been an active and successful year with dozens of studies investigating how young children learn and develop. Our talented postdocs, graduate students, undergraduates, and staff spend countless hours designing experiments, interacting with families, and analyzing data in order to understand the minds of children. We have gained new insights into the way children, as young as a few hours old, learn about the world around them. Here are summaries of just some of the exciting research studies we have conducted this year.

None of this would be possible without the participation of families like yours. If you are receiving this newsletter, you probably contributed time and effort to support our science. THANK YOU! We could not do this without you and your Tiny Tigers. We rely on the community in central New Jersey, and we are deeply grateful to families who have visited the Baby Lab and helped spread the word about our work. Your efforts have made significant contributions to our understanding of child development.

We hope you enjoy reading about some of the research you have been part of.

Best wishes,

Lauren Emberson and Casey Lew-Williams
Co-directors
Princeton Baby Lab
Get to know our researchers!

What do we love about working in developmental psychology?

Sagi Jaffe Dax
Postdoc
“Babies are unexpected. One can never fully predict how babies are going to react to a given situation. This is what makes our work so challenging, and yet so rewarding.”

Chris Potter
Postdoc
“What I find most exciting about working in developmental psychology is that we get to figure out new ways to understand what babies think and know, even when they can’t tell us directly.”

Gabriel Xiao
Postdoc
“Babies always give honest feedback for our research!”

Elise Piazza
Postdoc
“I like seeing how the basic elements of cognition (learning, perceiving, communicating) unfold!”
Felicia Zhang
Grad student
“My favorite thing about working in developmental psychology is when kids come in for multiple studies and I see immediately how much they’ve grown!”

Tracy Reuter
Grad student
“My favorite thing about working in developmental psychology is teaching and mentoring undergraduates - helping them to develop their research skills as we study how infants and children develop language and cognitive abilities.”

Sori Baek
Graduate Student
“I get to work with adorable babies and figure out what's happening in our brains as we grow!”

Mira Nancheva
Graduate Student
“I love getting a window into how children begin to learn about such a complex world they know so little about (also, playing with giant slinkies at work!”

Sammy Floyd
Graduate Student
“I love how enthusiastic the participants (children) are! They’re often very excited to play our games and their joy is infectious.”
Claire Robertson  
Research Specialist  
“My favorite part about working in developmental psychology is talking to our fantastic families about our research! I'm always excited about that we're working on in lab, and it’s amazing to share that excitement with our enthusiastic families.”

Evelyn Perez  
Research Specialist  
“The best part of working in developmental psychology, for me, is being able to play with kids all day. I have the best job!”

Juliana Trach  
Lab Manager  
“I feel that studying the developing mind provides insight into how we perceive the world. And I love kids”

Kachina Allen  
Lab Manager  
“I love seeing how excited children are to learn new things, and how quickly they learn them.”
What have we learned from your visits to the Baby Lab?

What does the learning process look like in the infant brain?

Alice Wang, Sagi Jaffe-Dax, Lauren Emberson

What is the importance of getting bored, and how does boredom relate to learning? When babies get bored, does it mean that they’ve simply become tired and disengaged, or that they’ve learned everything possible from a given situation and are thus keen to move on? These are fundamental questions that have been overlooked in the past, mainly because we didn’t have the technology to tell apart the alternative answers. We are now using fNIRS, non-invasive and infant friendly neuroimaging method, to look into what happens in the brain as babies get bored.

Babies are eager little learners and will often pay more attention to events that seem novel or unexpected, thus offering learning opportunities. For example, an infant might look less at a video clip that he or she originally found interesting after it has been played many times consecutively. Though there has been lots of research about how infants’ looking behavior changes in response to learning, we know much less about what the process of learning looks like in the brain.

We used fNIRS to look at changes in babies’ brains as they learned the associations between specific shapes and sounds. This involved showing infants
video clips of the same shapes and sound effects paired together many times over (with the length of each video dependent on how long they chose to look at the screen). We then tested infants for “learning” by measuring whether they looked longer at mismatched shape and sound pairings. So far, we have found that babies’ brain activity generally appeared to decrease as they “learned” (and began to look less at) associations between specific shapes and sounds.

**Infants use their knowledge to rapidly shape the perception of motion**

Naiqi G. Xiao and Lauren L. Emberson

For adults and children, one of the purposes of learning is to use the learned knowledge to improve the capabilities of understanding this world. By acquiring knowledge, we become a better observer and listener. Given the fact that the remarkable learning abilities emerge in early in infancy, are infants capable of using what they learn to guide the way to interpret their environment? To probe this question, we developed a novel paradigm to examine whether learned knowledge could affect infants’ perception of left vs right motion patterns. To present motion pattern, we displayed 1200 colorful moving dots on a computer screen. A motion pattern can be seen when majority of the dots moving toward one direction (left or right). To examine whether infants can see the directional motion pattern, we measured whether infants’ eyes will consistently move to the motion directions.

Six- to 8-months old infants first learned associations between a sound and a motion direction (Sound A predicts left motion and Sound B predicts right motion). Then we tested whether the learned associations between the sounds and motion directions could guide their perception of directional motion in an Omission condition. In this condition, after hearing the sound (Sound A or B), they would see a display or random motion. All of the dots move in random directions, which do not form any directional motion pattern. Any consistent eye movements have to be induced by the sound preceding the random motion display.

We found that when direction motion presented, infants exhibited eye movements which closely mapped onto the direction of movement. In the Omission condition, when no direction motion is available, infants’ eyes also
moved in the directions indicated by the sounds even no directional motion was presented at all. This finding suggests that infants can actively and rapidly modulate their visual perception in response to specific contexts, which is the first study demonstrating the flexibility of perceptual capabilities in preverbal infants.

Is predicting *cookie* the same thing as hearing *cookie*?

Tracy Reuter, Chandra Greenberg, Casey Lew-Williams & Lauren Emberson

A number of recent theories propose that prediction – the ability to anticipate upcoming words in language – is a useful tool for learning. In a recent study, we investigated whether infants’ ability to predict a word was distinct from simply hearing the word. Is predicting the word *cookie* from related words (e.g., *eat*, *yum*, *mouth*) different from hearing the word *cookie* itself?
During the study, infants looked at some pictures while our eye-tracking computer recorded where they were looking. Infants saw two familiar objects (e.g., a cookie and a shoe, like above) and heard three different kinds of sentences. Some of the sentences included words that would help the infant to predict an upcoming word (prediction trials), some sentences included repeated instances of the same word (repetition trials) and some sentences did not provide any information about the upcoming word (neutral trials).

- **Prediction**: Let’s go eat! Ooh yum yum! Open your mouth! Where’s the cookie? Find the cookie!
- **Repetition**: Look at the cookie! There’s the cookie! Do you see the cookie? Where’s the cookie? Find the cookie!
- **Neutral**: Look at that! There it is! Do you see it? Where’s the cookie? Find the cookie!

Comparing prediction trials and neutral trials, we replicate our prior findings that infants can predict upcoming words during language processing (Reuter, Mazzei, Lew-Williams & Emberson, under revision). Critically, we found that infants’ behaviors during prediction trials are distinct from those of repetition trials. Findings suggest that, during language processing, infants activate distinct word meanings. That is to say, using *eat* to predict *cookie* is different from simply hearing *cookie* repeatedly. In sum, infants’ knowledge of words is detailed – even at 15 months old! – and those details matter as infants interpret they language they hear from caregivers like you.

Thank you for supporting our research!
Do babies remember the languages different people speak?

Christine Potter, Fares Marayati, Casey Lew-Williams

Some babies grow up in families where everyone speaks the same language, but other babies hear different people speak to them in different languages. One question we had is whether babies are able to keep track of who speaks what language. In this study, we let babies listen to people speaking English (a language that they have heard a lot) and Arabic (a language they’d never heard). For example, a baby might listen to a man speaking English and a woman speaking Arabic. We gave babies a chance to listen to these people talking until the babies got bored. Then, the speakers switched languages—that is, the man started speaking Arabic, and the woman started speaking English. We wanted to know if babies were surprised by this change and if hearing people change languages might grab their interest.

So far, we’re seeing that this is pretty hard for babies who are growing up in homes where they only hear English. Next, we want to know if babies who live in bilingual homes (where they are used to hearing different people speak different languages) have an easier time remembering how different people talk. We also want to know if it’s easier for babies to keep track of the languages that different people use when they can see their faces, instead of just listening to their voices. We’re hoping that the results of this study will help us understand how babies pay attention to the people around them, and how they might be able to learn most effectively from them.
The Goldilocks effect, with respect to a child’s development, refers to research showing that infants prefer an intermediate level of surprise over completely predictable and unpredictable events. This preference help infants avoid wasting time on events that are too simple or too hard. In this current study, we are interested in measuring how the Goldilocks effect will manifest itself in terms of eye movements and pupil size. We created an eye-tracking study where we presented 8-month-old infants with a sequence of location alternating (L-R-L-R etc.) pictures. On one side of the screen, we showed them a predictable sequence of pictures where the same picture appeared every single time. On the opposite side of the screen, we showed them a semi-predictable sequence where they saw one image 66% of the time, and another image 33% of the time. This semi-predictable sequence should generate an intermediate level of surprise and we hypothesize that infants will prefer the semi-predictable sequence over the predictable sequence. This preference will be measured via eye movements and pupils size. Specifically, we hypothesize that infants will look faster to the semi-predictable sequence, look longer at the semi-predictable sequence and have larger pupil size for the semi-predictable sequence. We are still in the data collection stage so stay tuned for the results! Thank you to the families who have participated in our study so far!
Research has shown that young infants can form predictions based on their experiences and learn new information when their predictions are wrong (i.e. experience a prediction error). However, these two lines of research have often been studied separately. In the current study, we are interested in studying the relationship between prediction and prediction error. Specifically, we are interested in how pupil size (or prediction error) is related to prediction, in the form of anticipated eye movements.

Based on very early studies, we know that infants form predictions about where images will show up next, when it follows a simple pattern. For example, if a baby learned that a picture appears on the screen following the pattern L-R-L-R, then when the baby sees a picture on the left disappear, she might quickly shift her eyes over to the right side. This shift to the right side, before the image has even appeared, is called an anticipatory eye movement. With respect to pupil size, previous research suggests pupil size is correlated with prediction error, such that the larger the prediction error the larger the pupil size.

To study the relationship between prediction error and prediction, we had 14 months old infants watch a shape appear on one side of the screen eight times in a row (i.e. trials 1 – 8), and then switched the shape to the opposite side of the screen for the next eight times (i.e. trials 9 – 16). This design allows us to track pupil size and eye movements before the switch, as infants are first learning where the shape appears and forming predictions, to after the switch, as infants experience prediction error and form new predictions.

We are close to finishing data collection for this study! We have also completed this same study with 6 months old which will allow us to draw comparisons between how 6 months old learn compared to 14 months old. Thank you to all the families who have participated in this study. We can’t wait to share our results with you!
Happy sounds make happy faces easier to see and angry sounds make angry faces easier to see

Naiqi G. Xiao and Lauren L. Emberson

Studies in our lab already showed that learning can rapidly shape infants’ visual perception. Last year, we continued to probe this early emerged cognitive capacity by examining whether infants can flexibly use their knowledge to sharpen their eyes in novel scenarios.

We designed a study to investigate whether infants can use their knowledge of emotion in voices and facial expressions to help them see emotional faces better in a situation that they have never experienced prior to their participation. Specifically, we let infants to hear a short audio clip of happy vocal sound while maintaining their attention to the center of the screen. After hearing the happy sound, infants were presented two faces: a face with happy (or angry) expression and a face with neutral expression. We deliberately displayed these two face images in small size at the edges of the screen. This makes them hard to see when infants’ eyes are oriented to the screen center.

We examined whether the happy sound can help infants see consistent happy face better as compared to inconsistent angry face. We used infants’ eye movements to measure their face perception capacity by examining how long infants needed to move their eyes from screen center to the emotional face. A faster eye movement indicates a better visual perception of the emotional face. We found that infants moved their eyes faster when they saw happy faces than when they saw angry faces. Moreover, we found similar effect when infants heard angry vocal sounds, which led them to look at angry face faster than happy face. These findings suggest that infants can use the knowledge that they obtain in everyday life to effectively modulate their visual perception in a novel situation.

We observed this ability in 9-months, but not in 6-months old infants, suggesting a developmental change in infants’ ability to adapt their perceptual capacities in the variable environment.
Can bilingual toddlers understand people who mix their languages?
Christine Potter, Fares Marayati, Casey Lew-Williams

In most bilingual homes, parents sometimes mix their two languages in the same sentence and say things like *Do you like perro?* or *¿Te gusta el doggy?* We wanted to know if these sentences are harder for young children to understand than sentences that are all in one language (like *Do you like the doggy?*), and if children can understand sentences in their two languages equally well.

In this study, bilingual children saw pairs of pictures and heard sentences talking about one of the pictures in English, Spanish, or both. We found that overall, children were really good at looking at the correct picture, especially if they heard it labeled in the language that they hear more often at home. So, for example, children who hear English more than Spanish could understand sentences like *Do you like the doggy?* and *¿Te gusta el doggy?* with no trouble, and it didn’t seem to be any harder when they heard two languages together. Toddlers could also understand words in their other language sometimes, but had a little more trouble when those words were in mixed sentences (for example, *Do you like the perro?* was harder than *¿Te gusta el perro?*). This study tells us that bilingual children are learning both of their languages together, but when they get more practice with one language, they probably know words in that language a little better. It also tells us that children aren’t getting overly confused by hearing their languages mixed, which is important information for parents, educators, and clinicians trying to help bilingual children learn both their languages.
How do kids learn words from new people?
Christine Potter, Fares Marayati, Casey Lew-Williams

A lot of our studies focus on how babies first learn new information, but kids of all ages are learning new words all the time. In a study that we’ve been doing with preschoolers, we were interested in how kids might learn from different people. For example, kids hear new words spoken by their teacher, or by their friends, and even by strangers. Are they more likely to learn from some people than from others?

In this study, children watched short videos where they met different actors and heard them talk about some new objects. We wanted to know if they learned the names for the objects, and if they learned some of the names better than others.

That’s a blicket! This is a tursey!

Can you find the blicket?

So far, we’re seeing that children seem to be paying attention to the people that talked about the different objects, and they seem to be able to learn from more than one person. We’re still interested in understanding who kids think is an important person to pay attention to, and how that affects what they learn. Special thanks to the families and staff at UNOW preschool for their help with this study, as well as all the other children who participated and are helping us think about how kids decide who they should listen to!
How does brain-to-brain coupling help children learn?
Elise Piazza, Liat Hasenfratz, Ariella Cohen, Juliana Trach,
Uri Hasson & Casey Lew-Williams

Research using functional MRI has shown that when you listen to someone tell a story, parts of your brain actually become synchronized with or “coupled” to the speaker’s brain. Even more interestingly, the stronger this coupling, the better you’ll understand and remember the story. This is a fascinating and important finding, but the study required adults to lie flat in a brain scanner without directly seeing each other or interacting in any way.

We have been exploring how neural coupling between children and caregivers might help kids begin to learn language. To do this, we use a dual-brain fNIRS system that measures which brain regions are active at different times. The participants wear comfortable caps and can interact as naturally as they would during daily life.

In our first completed study (with 9-to-15-month-olds), we found that an infant’s brain is better synchronized with an adult’s brain when the adult is directly interacting with the child (e.g., singing, reading, playing) than when the adult is distracted. We also found that the infant’s brain is more active when the adult’s speech is more dynamic and “sing-songy”, and that the adult’s brain is more active when the infant is smiling.

In an ongoing study with 4-yr-olds (below), we are testing how coupling during story reading might lead directly to learning new words and other story content (e.g., character goals). Thanks for participating in these studies, and stay tuned for more results in our next newsletter!
Do toddlers know words with multiple meanings?
Sammy Floyd and Casey Lew-Williams

We often do not realize that most words have multiple meanings (water runs, but not in the same way a child runs, and not in the same way a motor runs). Though these distinct, but related, meanings do not confuse adults, they may be a challenge for children. In this study, we tested 2 to 3 year-olds on words with meanings like this. Toddlers sat on a parent’s lap while an eyetracker recorded where on the screen the child was looking as they heard audio such as “Look! Look at the cap!”.

So far, we have found that toddlers do know multiple meanings for words such as cap, collar, horn, sheet, glasses, and balloon, and that they are equally familiar with both meanings! Thank you for learning about our research!
Rule based learning in children
Alexia Hernandez and Adele Goldberg

In this study, we exposed children to novel linguistic patterns, and tested when they would extend these linguistic patterns to new situations.

The linguistic patterns they were exposed to were plural markings and classifiers (plural ex: lion, lion-po; classifier ex: yellow-dax, green-fep, pink-fep).

In one condition, we exposed children to three rule-following examples, and tested whether they extended the rule they learned to two new examples. When there were nine pairs of either animals or crayons, children were only exposed to three rule-following objects with no exceptions, and were asked to extend the pattern to two new singles in the box. In this condition, children overwhelmingly were able to extend the rule.

In a second condition, we exposed kids to five rule-following examples and four exceptional ones. We were curious to see whether kids would generalize the dominant pattern to new situations, or whether they would have a harder time choosing between the exceptional and the dominant rule. When there were nine singles of either animals or crayons, children were exposed to five rule-following pairs and four exceptional pairs. After exposure, children were asked to re-produce the pattern on two novel animal or crayon pairs. We found that in this second condition, children had a harder time applying the dominant rule to two new examples, and in fact the rate at which they did so matched more or less the ratio of dominant:exceptional cases witnessed.
While these results may seem intuitive, they are at odds with theories that predict that kids need more than three examples to learn a rule (if there are nine total cases that a rule can apply to), and that having witnessed five rule-following examples, kids should be able to recognize a dominant pattern, even if there are exceptions (if those exceptions don't exceed four instances when there are nine total possible instances in which a rule could apply).

How does intonation affect attention and learning?
Mira Nancheva, Elise Piazza, Casey Lew-Williams

When parents talk to babies and young children they sound quite different from how they talk to adults. One of the big changes is in their intonation – their overall pitch is higher and they vary their pitch over the course of words and sentences much more compared to when they are addressing their fellow adults. In this study we were interested in how these changes in pitch affect how much children pay attention during a story and how their attention to pitch affects how they learn novel words.

To measure how much young children are paying attention at any given moment, we used a curious property of our pupils – when different people are attentively listening to the same story, their pupil sizes synchronize. Importantly, this happens in the absence of changes in light and only when they are paying attention. When people’s minds wander off, their pupils are no longer synchronized with each other. Knowing this, we used pupil size synchrony as a measure of attention in the moment.

![Mind-wandering (not synchronized) vs. Paying attention (synchronized)](image)
We found that the intonation changes that parents make when they are talking to their little ones help 2-year-olds pay more attention to a story (compared to when they are listening to the kinds of intonation we use when talking to adults). Furthermore, they showed higher synchrony to intonation commonly used to emphasize words, compared to more unusual intonation.

But does paying more attention when a child hears a novel word help learn it? Indeed, we found that when a child was more attentive during a novel word (and thus more synchronized with their peers), they learned this word better.

Taken together, this study suggests that out naturally variable and exaggerated intonation when we talk to young children might help make our speech more engaging and help them learn better. Thank you for participating in our study and making this research possible!
Top-down Sensory Prediction in Neonates
Naiqi G. Xiao, Claire E. Robertson, Kachina R. Allen, and Lauren L. Emberson

Our lab has found a signature of very sophisticated type of learning in 6-month-olds brain activity: A form of prediction neural activity based on associations they experience in their environments. Following this line of research, we started a study to explore whether this learning capacities are present in the first days of life of full-term babies.

We recorded infant brain responses using a non-invasive neuroimaging technique called Near-Infrared Spectroscopy (NIRS). NIRS uses light to estimate the amount of oxygen in the blood using the same technology as the pulse oximeter but with many light sources and applied to the head. We record changes in oxygenation that are induced by neural activity in the brain so as to indirectly measure neonates’ brain activity.

While the newborn babies were sleeping, we presented them an auditory vocal sound, such as “Ba”, which was followed by a soft light as visual stimulation. After presenting this audio/visual associated events for 10 mins, we expect the sleeping neonates learned the audiovisual association. To examine how this particular learning experience modulates their brain activity, we occasionally presented only the sound, but not the visual light, and see how the brain dealt with this “unexpected” situation.

If newborns possess the learning ability like infants at 6 months of age, they should be able to predict the visual event based on the sound. Our result is consistent with this hypothesis, which showed neural response by the predictive sound even no visual stimulation was presented. This finding suggests that the ability to rapidly adapt visual systems to the environment is already available at birth, which may play a crucial role in supporting early development.

The study takes place in the Center for Maternal and Newborn Care in Penn Medicine Princeton Medical Center. Babies usually participated in our study 48 hours after their birth.
As babies learn about the world, they develop representations of different categories of objects in the brain. For example, children learn that a Beagle and a Greyhound are both representations of dogs. Uncovering object representations in infancy is necessary in understanding the organization, nature, and limits of mental representations early in life, and how these representations change with as they grow. However, measuring the representation of multiple objects, particularly within a single infant, is very difficult.

In order to tackle this problem, we have begun an experiment in the Baby Lab that hopes to collect lots of data from each baby who participates in our study. Over 4-5 sessions, infants will view 8 familiar objects (things like babies, hands, books, and shoes) while we passively record their brain activity using fNIRS. Each object is represented by two exemplars presented in different view-points (for example, a Greyhound and a Beagle to represent Dogs). Objects were chosen to be highly familiar to young infants based on previous research findings and parental report. In addition, the stimuli have been normed for brightness and colorfulness both by computers and by our helpful families on Facebook!

This project is ongoing, and we are in the middle of running this project. Thank you to all of our families who have participated so far!
New Lab Space opens in Trenton
Evelyn Perez, Juliana Trach and Casey Lew-Williams

The Princeton Baby Lab has recently opened up a second location and we are now serving the greater Trenton area! We have run three different studies in our new location and are looking forward to running even more studies there in the near future. This second location has given the opportunity to many new families to help us in our research. The Trenton office has opened up the lab to a more diverse population as two of our studies can be run not only in English but completely in Spanish as well! In the Baby Lab, we are curious on what factors play into how children learn and how language plays into that. Being able to run studies specifically for families who are bi-lingual or mono-lingual in a language other than English is very beneficial in helping us understand more in depth how and why language develops the way it does.
Never been to the Baby Lab?

We'd love to have you visit us!

Our goal is to make visits to our lab enjoyable for the whole family. First and foremost, we design our studies to be fun and short (often 5 minutes or less!), so that your child has a good time. Taking home a children’s book and lab t-shirt helps with that too.

We also try to make it an interesting outing for parents by telling you about our studies and answering questions about early learning. And siblings who tag along during each appointment often have a great experience. They get to play in our beautiful, playful, and bright lab space with enthusiastic Princeton students, many of whom are pursuing careers related to child development, education, neuroscience, statistics, speech therapy, parenting, health, and medicine.

If you're interested in coming in to visit the Baby Lab, please email us at babylab@princeton.edu, call us at 609-258-6577, or sign up on our website at babylab.princeton.edu.