STANFORD BRAIN DEVELOPMENT

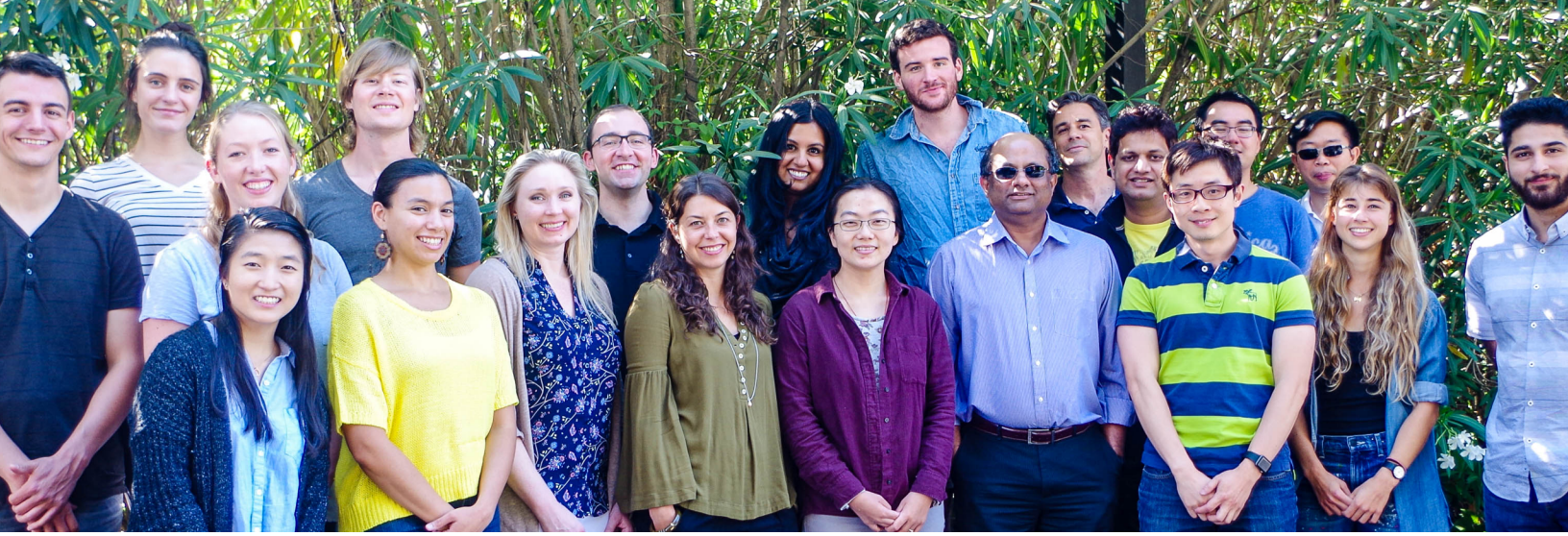
2018 NEWSLETTER

Features

HOW A MOTHER'S VOICE AFFECTS DEVELOPMENT

THE NEURAL BASIS OF MATH DISABILITIES

Stanford Cognitive and Systems Neuroscience Lab



HAPPY NEW YEAR

from Stanford Brain Development!

It has been a very exciting year for our research team. Thanks to our wonderful research participants and their families, we have been able to make interesting scientific discoveries, start new research investigations, and engage the Bay Area Community in our projects. Thank you for making this science possible. We are always looking for new participants for our research studies. Check out our awesome studies that are currently recruiting participants, and please feel free to share with your friends and family.

- The **Math Elements Training** study looks at how children learn math and how different types of math exercises can help children improve their skills. We are actively seeking 2nd and 3rd graders of all math and learning abilities.
- The **Autism Math Learning** study investigates how short-term math tutoring helps children with and without autism learn and how their brains function before and after tutoring. The goal of this research project is to investigate how children learn specific math problems and strategies and apply these to other math problems. We are recruiting both children with and without autism.
- The **ADHD** study investigates cognitive control and attention with a goal of identifying relationships between brain and behavior, particularly with regard to symptoms of inattention and impulsivity. We are recruiting both children with and without ADHD.
- The **Autism Spectrum Disorder (ASD) Memory** study seeks to understand the cognitive and brain mechanisms underlying impaired episodic memory for social stimuli (faces) in children with ASD. We hope this study better informs our understanding of life-long deficits in social interaction in this population. We are currently recruiting 9-12 years old with and without ASD.

Interested in learning more or signing up?

Visit us at *http://med.stanford.edu/braindevelopment.html*

SPEECH PROCESSING STUDY: UNIQUE RESPONSES TO MOTHER'S VOICE

What actually happens in the brain when children hear their mother's voice? According to our research recently published in the *Proceedings of the National Academy of Sciences*, quite a lot!

Psychologists have known for decades that children, even newborns, recognize and prefer listening to their mother's voice over the voices of other individuals. But how do children respond differently to their mother's voice? Instructor Dan Abrams investigates the development of speech processing in children, and wanted to know how a child's brain responds differently to their mother's voice. We conducted behavioral and brain imaging exams on 24 children, ages 7-12. During the imaging session, we used fMRI to measure brain activity while each child listened to recordings of voices: some of unfamiliar female voices, and some of his/her own mother's voice[1].

Exactly what did they find? Researchers compared brain activity when children heard their own mother's voice to when they heard unfamiliar female voices and identified several brain regions that responded more strongly to mother's voice. It turns out that a surprisingly large portion of a child's brain is active when it recognizes his/her mother's voice! Hearing one's mother's voice activates areas involved not only in hearing, but also in a broad range of sensory, cognitive, and emotional processing areas including the amygdala and nucleus accumbens, key regions for emotion and reward processing. Several other brain regions also showed increased activity, including those associated with face processing and detection of prominent stimuli.

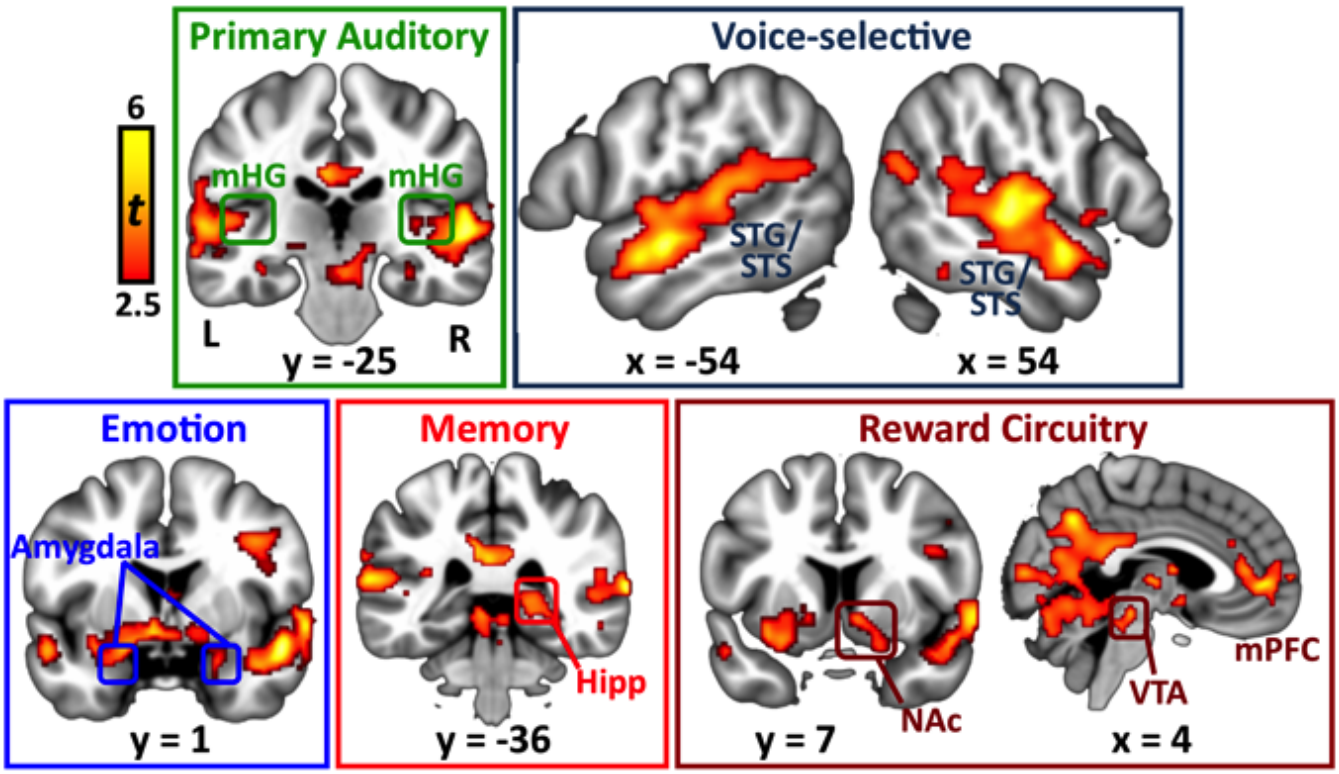


Figure 1: Brain areas that are more active in response to mother's voice than to other voices.

This finding is particularly significant because it establishes that vocal sounds can be rewarding, and can elicit activity in reward areas like the nucleus accumbens. Interestingly, this is the same area that responds to preferred stimuli, including pleasant music. The rewarding nature of a mother's voice may play an important role in early language acquisition.

This study also examined how different parts of the brain communicate with each other when processing their mother's voice. The research team discovered a link between children's social function – the ability to interact and relate with others – and the strength of brain communication between "hearing" parts of the brain and reward, emotional, memory, and face-processing regions during their mother's voice perception.

This could have important implications for future studies of social development, particularly for autism.

Taken together, results show how widely mother's voice is broadcast throughout a child's brain, and that activity in these brain systems provides a biological "signature" or "fingerprint" of social communication abilities. We look forward to applying this approach to better understand changes that occur in the brain as a child develops into adolescence as well as in various clinical populations in which social communication abilities are impaired, such as Autism.

1. Abrams, D. A., Chen, T., Odriozola, P., Cheng, K. M., Baker, A. E., Padmanabhan, A., Ryali, S., Kochalka, J., Feinstein, C., Menon, V. (2016). Neural circuits underlying mother's voice perception predict social communication abilities in children.*Proceedings of the National Academy of Sciences*, 113 (22), pp. 6295-6300.

INVESTIGATIONS OF MATH LEARNING

We have been studying the brain systems involved with math learning and math learning disability (MLD) for several years. With the help of our wonderful participants, we have learned a lot about math learning in the brain. Our results are based on trends among many people, so they might not apply to any individual participant. Here are some highlights from our recent studies:

- Children with math learning disabilities show different brain activation compared to their peers.
- Math tutoring often helps children with math difficulties improve their math skills.
- There are noticeable brain-level changes after tutoring.

Children who go through math tutoring show changes in brain activity

MLD is surprisingly common, affecting 20% of children and adolescents. These disabilities have long- term consequences, including poorer academic performance, lower economic status, and risks to personal health. This is probably because we use math and number skills to perform many of our daily tasks, like managing money, measuring medications, and keeping track of calendar dates. Educators have developed several effective learning programs for children with MLD. However, little is known about the underlying causes of MLD in the brain, or how math learning programs can change how the brain functions.

Traditionally, psychologists have associated performing math-related tasks with the parietal cortex, an area of the brain near the crown of the head, and therefore it seemed likely that math disabilities would be associated with this area of the brain. Recent neuroimaging studies have told a much more complex story.

Several systems in the brain are engaged while we perform math. These include brain areas associated with symbols' recognition and quantity processing, as well as attention and working memory. Some neuroimaging studies using functional magnetic resonance imaging (fMRI) have found that these areas are more engaged in children with MLD compared to children without MLD.

Stanford research scientist Dr. Teresa Iuculano and her colleagues studied how math tutoring may affect brain activation between children with and without MLD[2]. They designed an 8-week, individual math tutoring protocol which included the participation of a total of 30 children (15 with MLD and 15 without MLD). Before and after the tutoring, the researchers collected brain data – via fMRI scans – on the children while they were solving addition problems. They found that before tutoring, children with MLD were significantly less likely to answer math problems correctly than their peers were. The children with MLD improved in their math accuracy over the 8 weeks of tutoring.

The researchers also found that **several distinct brain regions were more active in the MLD group compared to the non-MLD group.** Before tutoring, the MLD group showed greater activation in regions of the prefrontal cortex that are generally associated with attention and working memory when solving math problems. The MLD group also showed greater activation in the parietal cortex, which is associated with quantity processing (i.e. deciding which one is larger in quantity between 4 and 3), and in regions devoted to symbols' recognition in the visual cortex.

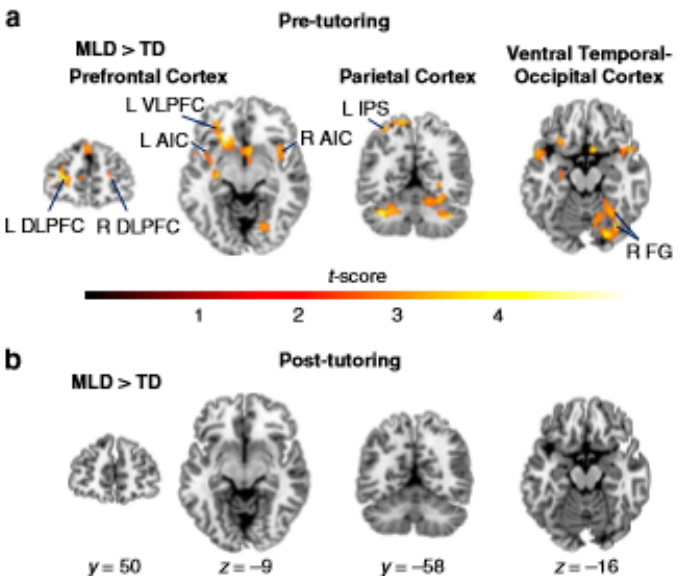


Figure 2: a) Several regions are more active in the MLD group than in the control group before tutoring. **b)** these differences are not seen after tutoring.

Importantly, the MLD group showed a significant change in their brain activity before and after tutoring. Specifically, children in the MLD group showed reduced levels of activation in areas that were previously over-active before the tutoring took place. Most importantly, **after tutoring, the two groups** (i.e. MLD and non-MLD peers) **no longer differed in the level of activation in any brain region important for math cognition**. These results show that brain function in individuals with MLD can be altered with effective tutoring. These findings are supported by the fact that, in children with MLD, the greater the brain-level changes, the better the performance improvements after tutoring.

2.Iuculano, T,. Rosenberg-Lee,M., Richardson, J., Tenison, C., Fuchs, L., Supekar, K., Menon, V., (2015). Cognitive tutoring induces widespread neuroplasticity and remediates brain function in children with mathematical learning disabilities. *Nature Communications,* 6, 8453.

MATH ANXIETY

Another aspect of MLD is math anxiety, or feelings of extreme nervousness and discomfort in situations that involve mathematical problem solving. Up to 50% of children in the US have some form of math anxiety. This anxiety often persists into adulthood and may discourage people from pursuing careers in math and science fields.

Drs. Kaustubh Supekar, Teresa Iuculano, and Lang Chen investigated whether math anxiety, much like other kinds of anxiety, can be reduced with repeated exposure to the distressing stimuli. Specifically, they investigated whether eight weeks of intensive math tutoring that repeatedly exposes children to what they fear—mathematical stimuli and social situations involving mathematical problem solving—alleviates math anxiety. Additionally, they examined the brain mechanisms underlying such a reduction in math anxiety[3].

Forty-six children in grade 3, a critical early-onset period for math anxiety, participated in the tutoring program. High math-anxious children showed a significant reduction in math anxiety after tutoring. Remarkably, tutoring remediated aberrant functional responses and connectivity in emotion-related circuits anchored in the amygdala. Crucially, children with greater tutoring-induced decreases in amygdala reactivity had larger reductions in math anxiety. These results support the hypothesis that math tutoring can act as an exposure-based therapy and reduce math anxiety in children. Our findings are likely to propel new ways of thinking about early treatment of a disability that has significant implications for improving each individual's academic and professional chances of success in today's technological society that increasingly demands strong quantitative skills.

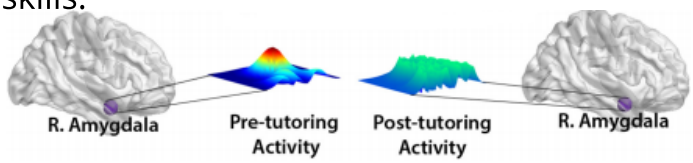


Figure 3: HMA group shows significantly reduced amygdala activity following eight weeks of math tutoring when solving math problems. This also correlates with reduced math anxiety

3. Supekar, K., Iuculano, T., Chen, L., Menon, V., (2015). Remediation of childhood math anxiety and associated neural circuits through cognitive tutoring. *Journal of Neuroscience,* 35 (36), pp. 12574-12583.

WHAT'S NEXT?

We are excited to announce that we have officially kicked off our new **Math Elements Training Study**!

What is this study?

This study investigates how children learn math, which type of training helps children learn, and how their brain function changes with math training. Based on findings from our previous studies, we have designed two math training programs. One type of training focuses on speeded practice of addition problems and the other focuses on training children to use physical representations of numbers to perform addition. This study will help us address many questions including: Which regions of the brain and which brain systems are involved with learning math skills? How do they change when children go through math training? We will also investigate whether learned math skills are applied to new problems, and how that is reflected in brain activity. Finally, we will study whether adaptive software, such as tablet games that are interactive and give feedback, can help children build and retain math skills.

Why are we doing this study?

Math learning disabilities are a common occurrence in the United States. As described above, one in five young adults in the US are functionally innumerate, meaning that they struggle to use math in everyday situations. These problems are especially common among people with Autism Spectrum Disorder. In addition, we hope that studying math learning in the brain will help us study how the act of learning can affect the flexibility of the brain. We hope to study how memory is connected to spatial reasoning and how connections in the brain change over time. We hope to not only learn the mechanisms involved with math disabilities, but also learn how specific types of in-person and computerized math programs can help improve math abilities. We hope that these discoveries will eventually contribute to more effective identification and treatment of math disabilities.

Interested in learning more about this study? Visit us at
http://med.stanford.edu/braindevelopment.html

KIDS CORNER

S	H	J	L	Q	X	P	F	Z	U	H	L	I	R	D
T	C	T	O	N	C	Z	W	V	N	T	N	K	R	V
U	R	G	S	L	G	P	A	L	Q	V	O	O	F	Z
D	A	N	E	U	R	O	N	B	E	I	F	X	C	H
Y	E	I	B	E	V	V	L	S	Q	N	E	R	L	K
B	S	W	Q	R	S	N	T	Q	A	R	X	H	A	R
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C	O	S	I	S	E	H	T	O	P	Y	H	U	I	N
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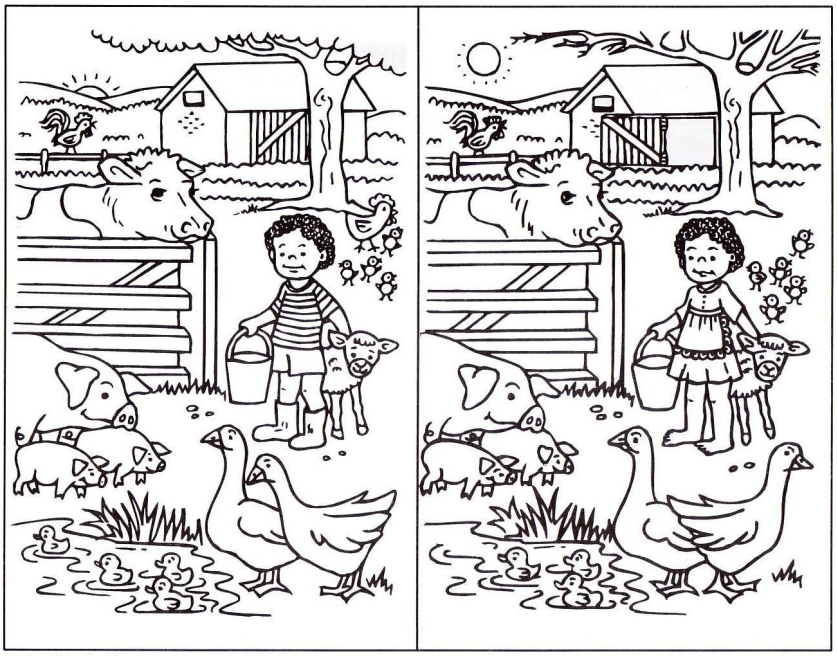
H	Y	C	O	W	P	F	E	J	C	X	D	V	K	I
U	U	Y	Q	C	L	R	V	U	X	Y	H	Y	X	L

Find all these words in the puzzle! They could be going up, down, forward, backward, or diagonal!

BRAIN
HYPOTHESIS
INVESTIGATION
MIND
NEURON
QUESTION
RESEARCH
STANFORD
STUDY

Can you find all 8 differences between these pictures?



Token from Bridging with a Smile