Temporal Dynamics of Learning Center

NSF Highlights 2017

Video Game Training to Improve Eye Gaze Behavior in Children with Autism

Outcome:

Researchers devise experiments to improve the motor planning and execution capabilities of children with autism. Using eye tracking technology, they collaborated with a developer to create a set of video games which use eye gaze as the controller to steer spaceships, blow up mushrooms and play whack-a-mole. So far, preliminary results have been promising. Subjects have shown improvements in other fixation and spatial attention tasks after daily videogame training.

Impact/benefits:

The ultimate question is whether improvements in fixation and spatial attention can translate into meaningful behavioral changes for those on the autism spectrum, like an increase in social engagement. These researchers plan to develop a system for clinical use that can quantify a patient's real-world gaze behavior.

Explanation:

The researchers train spatial attention by taking advantage of the fact that covert shifts of spatial attention and its overt manifestation in gaze shifts share underlying neural circuitry. They use this fact to train spatial attention by using gaze position measured from an eye tracking device as input to the game. This unusual type of input engages spatial attention effectively, especially because we typically make 3-4 fast gaze shifts every second. To play a game with one's eyes, focus is paramount-- any loss of the intense focus on the goal results in a loss in the game. This unique style of game play trains two aspects of attention simultaneously, which researchers believe leads to the increased gains in attention performance they observe in the lab.

Leanne Chukoskie wearing the eye tracking headset

TDLC researchers teach science through making music, and received continued support from the National Science Foundation

If you live in San Diego and you noticed a surge in metalophonic sounds in your neighborhood, this might be the reason: as part of TDLC's commitment to bring high quality science education to the community, cognitive scientists Victor Minces and Alexander Khalil have been working with K-12 schools to teach science through the science of music. In this program, called Listening to Waves, the students actively learn the science of waves and perception as they create electronic music and build musical instruments.

Within the last year, Listening to Waves has served more than 500 students in diverse communities across San Diego County. Drs. Minces and Khalil's efforts have been recognized by the National Science Foundation, which granted them $1.1 M to expand the program and to assess the potential of this educational approach to boost the youth's interest in science and technology. During the three years duration of the grant (Innovative Technologies for Students and Teachers), the program is expected to serve thousands of students.

Domain-specific and domain-general individual differences in visual object recognition

Outcome:

Researchers found that performance on Novel Object Memory Tests (NOMTs) varied just as much as on familiar object, but showed more shared variance across each other (about 25%) than is typically observed among familiar object tests (about 11%). Importantly, they verified that the ability measured in the NOMTs is not explained by cognitive skills, because shared variance between NOMTs remained unchanged after controlling for performance on various measures of general intelligence. Researchers attempting to estimate a general visual ability that is distinct from intelligence should consider using NOMTs or other tasks with novel objects to avoid complications from varying experience.

Impact/benefit: Visual skills are important in many areas of human behavior such as medical diagnosis, security and forensic professions. Accounting for variability between people that is relevant to these areas and that is independent from general intelligence may improve placement and training.The work is a stepping-stone to other new avenues of research. For instance, past studies of expertise have uncovered the neural substrates of category-specific expertise likely related to experience. New studies focusing on domain-general visual skills measured by NOMTs are needed to reveal aspects of brain structure and activity support the ability to acquire expertise in new categories.

Background/explanation:

In recent work, researchers funded by the NSF-supported Temporal Dynamics Learning Center asked if a domain-general visual recognition mechanism could apply broadly and predict how people acquire new visual skills. Because variable experience with familiar categories can contribute to differences in performance, they created Novel Object Memory Tests (NOMTs, see Figure 2). In a large sample of people tested online, performance across different NOMTs revealed a common visual ability that was not accounted for by general intelligence.

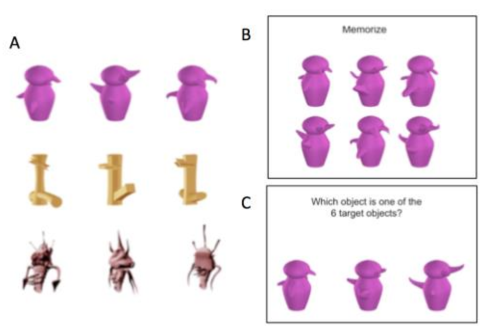


Figure 2. A) Examples of novel objects in NOMTs (Richler et al., 2017). Each object in each set has unique parts although parts can be very similar across objects. There is no rule that can be generalized across categories. B) in each NOMTs, 6 targets are studied individually in two views, then all 6 are shown together to memorize for 20 sec. This is followed by a series of 3-alternatives forced choice trials as shown in C).

Richler, J.J., Wilmer, J.B., Gauthier, I. (2017). General object recognition is specific: evidence from novel and familiar objects. *Cognition,* 166: 42-55.

Using game-based technology to enhance real-world interpretation of experimental results

Outcome:
Research on how the brain combination of visual, auditory and movement information are typically conducted in a tightly controlled albeit rather impoverished environment. Virtual reality (VR) presents a unique opportunity to maintain stimulus control in a way that places the observer in a truly immersive environment.

Impact/benefits:
By using the more immersive setting that scientists can control in VR, researchers are able to test whether models developed in impoverished environments apply in more naturalistic settings.

Explanation:
Our team developed a game for a VR Brain Game Jam that incorporated visual and auditory noise gradients in an immersive search task-- where a mother whale is searching for a baby in an ocean of many visual and auditory distractions. The visual and auditory noise gradients can be specified according to research needs and the baby whale can be '"hidden" on each trial in any position in 360 degree space.

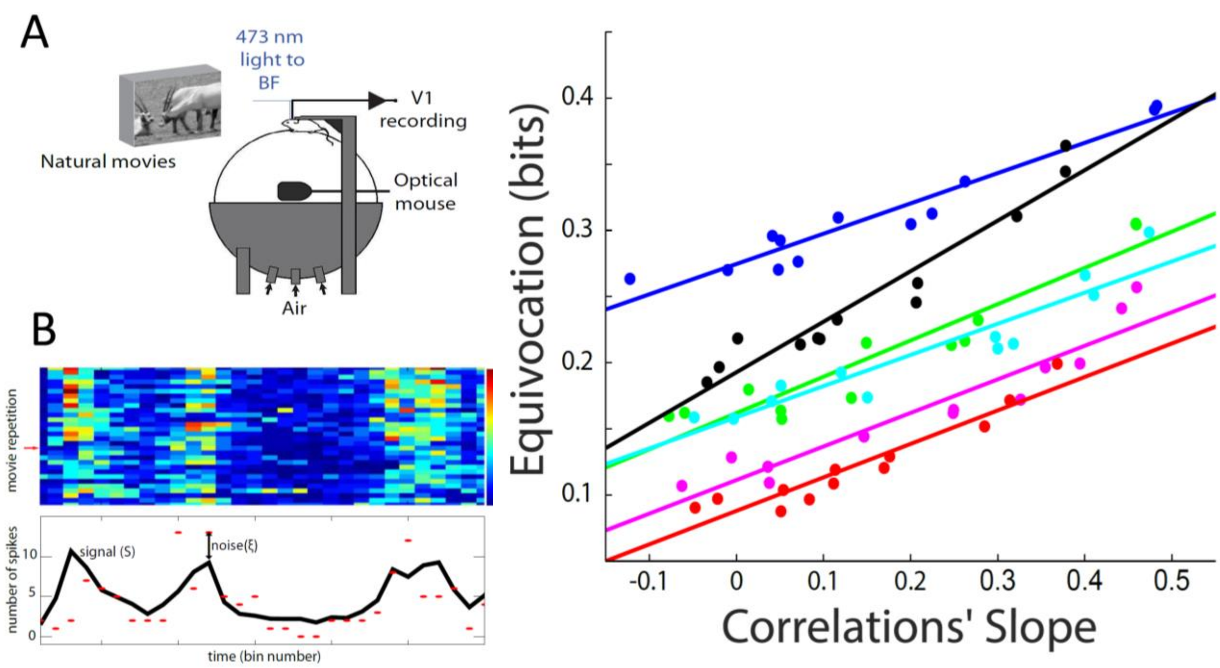
[Click here for a link to the VR game slides for Marco]

*Participants: TDLC researcher, Leanne Chukoskie, in conjunction with a graduate student, Patrick Beukema (CMU) and a game development company, Game Theory Company, Burlington, VT.

Neuromodulator Acetylcholine increases the capacity of the brain perceive the world

Acetylcholine is a neurotransmitter secreted by specific neurons in the brain. These neurons are typically active when an animal is in a heightened state of arousal. Members of TDLC worked synergistically to unveil a surprising effect of acetylcholine: When acetylcholine is very active, the neurons in the visual cortex of an animal become more independent of each other. This increased independence boosts the capacity of the visual cortex to represent visual stimuli. The results, published in the Proceedings of the National Academy of Sciences, are the result of the synergy between theoretical studies on neural coding developed by Victor Minces and Andrea Chiba in UCSD, and experimental data gathered by Lucas Pinto and Yang Dan at UC Berkeley.

Reference: **V. Minces**, L. Pinto, Y. Dan, & A.A. Chiba (2017). Cholinergic shaping of neural correlations. Procedures of the National Academy of Sciences (PNAS), 114-22 p. 5725-5730.



Face Camp: A chance for children to explore the science of face recognition

Outcome: Researchers at the University of Victoria have developed an innovative model in STEM education blending scientific research with scientific outreach. At Face Camp, children are introduced to the psychology and neuroscience of face recognition.

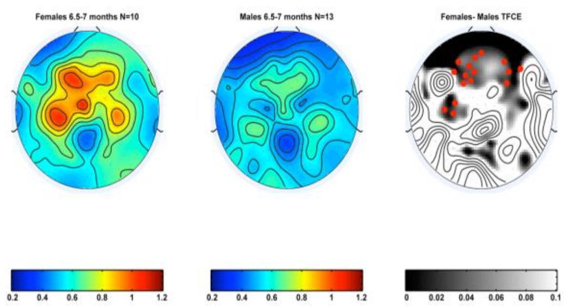
Impact/Benefits: In its ten-year history, over 1200 school-age children, ages six to twelve years, have attended the summer Face Camps. Face Camp is an integrated camp welcoming typically developing children and children with special needs, such as autism and Downs Syndrome. Results from Face Camp studies have yielded important findings regarding the development of brain specialization in face recognition, the role of movement in how we recognize people, the parts of the face are critical to face recognition and how can we improve face recognition for children on the autism spectrum.

Explanation: Funded by the Temporal Dynamics Learning Center, Face Camp is a one-day event where children try out the newest technologies in face recognition and explore questions such as “how many facial muscles does it take make a smile?,” “what happens in your brain when you recognize a familiar face?,” and “what makes a face attractive?” At Face Camp, children participate in laboratory experiments in face recognition and thus, learn first- hand about the value of scientific research. Face Camp is free and in addition to the camp activities, children enjoy a pizza lunch and receive a colorful Face Camp t-shirt. The camps are run by a trained staff of over 25 volunteers from the university and community who generously donate their time to work as curriculum planners, counselors and activity leaders.



Brain waves during sleep in human infants are differentially associated with measures of language development in boys and girls.

Sleep brain wave activity in 6½ month-old girls is positively correlated with expressive language measures, while in boys, similar activity is negatively correlated with receptive language measures. These differences may be related to sleep spindle bursts that first appear during “mini-puberty”, at 8 weeks of age, when there is a burst of hormones in the brain. Temporal Dynamics of Learning Center researchers, Drs. Sue Peters and April Benasich, at the Center for Molecular and Behavioral Neuroscience, Rutgers University-Newark, have shown that brain rhythms in the sleep spindle range, differ between boys and girls, this difference is prominent on the left side of the brain, and is associated with language measures. At 6½ months, the strength of slower activity was positively correlated with expressive language in females, whereas the strength of faster activity was negatively correlated with receptive language in males. This data suggests that early language-based neural network development is associated with the frequency and layout of spindles in the brain, and that these differences in infant sleep spindles may contribute to sex differences in neural processing of language.



Mean spectral power at 15.25Hz, for female (left) and male (center) infants at 6.5-7 months of age, and a map of p-values (right), using the permutation controlled TFCE method. Red circles denote electrodes with $p<.05$ significance with significant channels of females higher power than males.

Impact/Benefit: Infant sleep spindles may comprise a sensitive measure of individual differences in brain network development, thus contributing to group-level sex differences in neural processing of language. During this time, infants are developing pre-linguistic auditory cortical maps that support emerging language. Mini-puberty, a burst of gonadal hormones that occurs at about 8 weeks-of-age, concurrent with spindle onset, may well impact later language development.

Background/Explanation: The topography of spectral power in the spindle frequency range (10-16Hz) during daytime naps was mapped in typically developing infants, aged 3.5-4 and 6.5-7 months. Concurrent behavioral assessments allowed examination of sex-based differences between topographical spindle spectral power and its association to standardized measures of behavior and cognition. Sleep spindles are patterned bursts of oscillatory brain activity, visible in the scalp EEG, associated with NREM sleep, neuroplasticity and cortical development. In infants, spindles are a biomarker of maturation, first appearing about 4-9 weeks of age, reaching peak duration and density between 3 and 6 months-of-age. During this time, infants are developing pre-linguistic auditory cortical maps that support emerging language. Spindle-specific sex differences in infants have not been previously examined.

From: Peters, S.E. and Benasich, A.A. (submitted, 2017). Sleep spindle topography in 6.5 month-old human infants is sexually dimorphic, correlated with language measures, and functionally left-lateralized.

Making Games with Movement

Outcome:
Prizes were awarded to teams that demonstrated the most effective use of motion controls, the most creative use of motion controls and the best game using motion controls.

Impact/benefits:
The results of the Hackathon were impressive and created opportunities for some of the students to exhibit their work in the Fleet Science Center.

Explanation:
Thirty-five high school and college students participated in a "Making Games with Movement" Hackathon, held June 22-23, 2017. The students made video games that required movement as input. This event was held in conjunction with a computer science workshop that highlighted the potential of young student capabilities with early computer science educational opportunities. The workshop featured computer science education experts sharing their perspectives gleaned from years of teaching. The event ended with presentations from the thirty-five high school and college students participating in the game-based Hackathon.

* The Hackathon was sponsored by Qualcomm Institute, Temporal Dynamics of Learning Center, and Learning through Movement Network.

SIMPHONY Study

Studying the Influence Music Practice Has On Neurodevelopment in Youth (SIMPHONY)

Outcome: To understand how music affects the structure of the brain, participants will be asked to lie still in an MRI scanner for up to one hour while watching a video. To understand how music affects cognition, participants will do simple computerized tasks. These sessions will occur at different points in their music education and will be conducted in association with CHD's PLING Study.

Impact/Benefit: Researchers hope this study will ultimately increase our understanding of how music affects the structure of the brain, and even influences the development of skills like language and attention.

Background/Explanation: How does musical training influence the child's brain and the development of skills like language and attention? The Neurosciences Institute, UC San Diego, and the San Diego Youth Symphony have formed a new partnership to address these questions. They are recruiting children between 5 to 8 years of age who receive or plan to receive instrumental/vocal music instruction to participate in the SIMPHONY study.

Understanding how the brain represents and processes complex, time-varying streams of sensory information

Dan Feldman and his team at UC Berkeley, members of the NSF-funded Temporal Dynamics of Learning Center, have made an important advance in understanding how the brain represents and processes complex, time-varying streams of sensory information. This issue is central for understanding how organisms recognize temporal patterns of sensory input, including in speech perception.

The researchers studied how the rodent brain represents touch information from the whiskers, which function similarly to human fingertips. Feldman and lab members Leah McGuire, Greg Telian and Keven Laboy-Juarez trained rats to discriminate temporal series of whisker deflections, and showed that rats guided their behavior by the time-averaged intensity of the whisker stimulus train, not by the precise timing or order of individual deflections. Thus, the brain temporally integrates tactile inputs for perception.

The team made neural recordings during behavior in primary somatosensory cortex, and found that neurons represented each individual whisker impulse on a rapid time scale, without signs of temporal integration. This indicates the primary sensory cortex primarily represents immediate sensory information, which must be integrated in higher cortical areas. Thus, these findings suggest a multi-step temporal integration process for sensory perception in cerebral cortex.

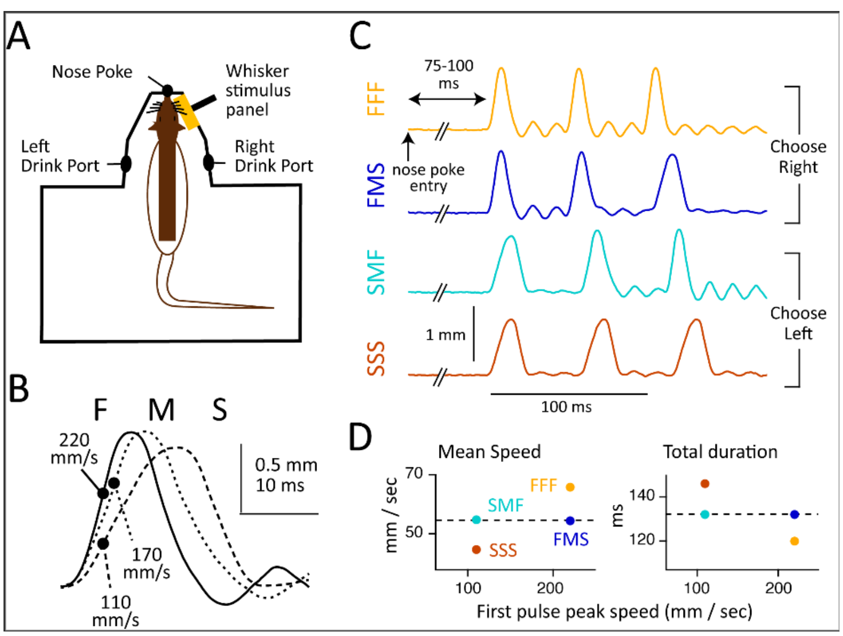


Fig 1. Whisker stimuli and behavioral apparatus. (A) Schematic of training apparatus, showing the rat's right whiskers resting on the moveable stimulus panel. (B) Panel kinematics for fast, medium, and slow impulses. Circles indicate maximum velocity. (C) Panel kinematics for FFF, FMS, SMF, and SSS sequences. Data for this panel are in S1 Data. (D) Mean speed, total duration, and first pulse peak velocity for the four sequences. SMF and FMS sequences had similar mean speed and duration (dashed lines).

This highlight summarizes the findings of the paper:

McGuire LM, Telian G, Laboy-Juárez KJ, Miyashita T, Lee DJ, Smith KA, Feldman DE (2016). Short Time-Scale Sensory Coding in S1 during Discrimination of Whisker Vibrotactile Sequences. PLoS Biol. 14(8): e1002549. doi: 10.1371/journal.pbio.1002549.