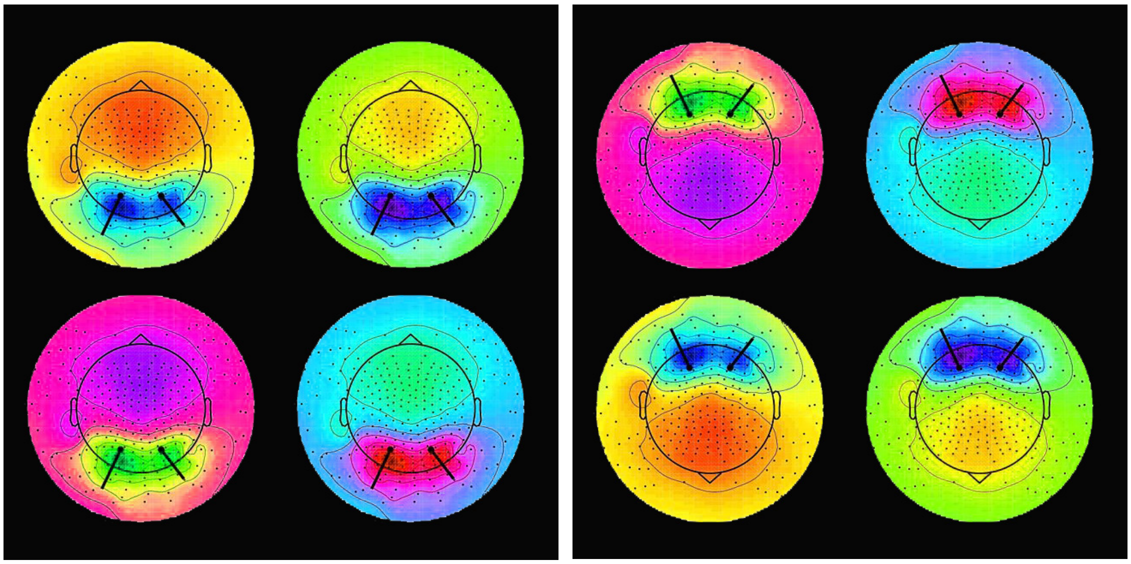
# INCUBATOR

University of California, San Diego
Winter/Spring 2018



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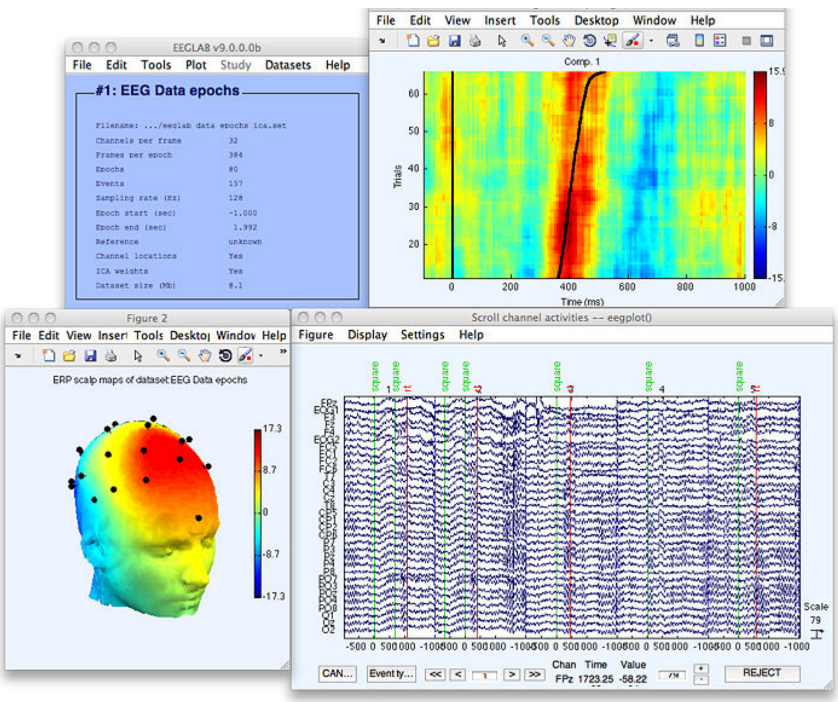
# EEGLAB: THE GIFT THAT KEEPS ON GIVING

When it comes to studying the brain, one of the most powerful techniques is to eavesdrop on the electric signals darting between brain cells. The first instance of recording brain activity from a human was reported in 1929 by German psychiatrist Hans Berger who used electroencephalography (EEG), a minimally invasive method of picking up small electrical potentials from atop the scalp. It wasn't long before this recording method became a clinical tool to help diagnose epilepsy. Beyond the clinical setting, EEG became and still exists as one of the main methods to study how the human brain works. And that is why, in the late 1990's and early 2000's, scientists at UCSD built an open source tool to process and analyze EEG data. EEGLAB, as it is called, continues to evolve to meet the needs of scientists around the world.




*EEGLAB electroencephalography data analysis and visualization toolbox in action.*

The beginnings of the EEGLAB project stemmed from a desire to share resources within the EEG scientific community. Scott Makeig attended a meeting in Carmel in 1998 where he proposed an idea to make an open repository of EEG data. He took a poll of the room, filled with EEG researchers, to see if they would contribute their data to the repository. As Makeig puts it, "The response was tepid at best." So he put forth another idea, an open source software based on the analyses that Makeig and others were using to make sense of their data. This time, the response was more than tepid, it was enthusiastic. Makeig recalls, "Hands shot up all around. I knew then that our software sharing effort that later became EEGLAB might have a strong future."

EEGLAB filled a need for data analysis that only very expensive, proprietary, and thus non-transparent software, could provide. EEG data is notoriously difficult to analyze. The first hurdle is removing artifacts, or signals that don't originate from the brain. An artifact could be the twitch of a facial muscle or electrical interference from a nearby machine. This problem seems easy in comparison to the next concern - how to separate and spatially pinpoint the origin of brain signals that are mixing together as they are picked up by electrodes distributed across the scalp.

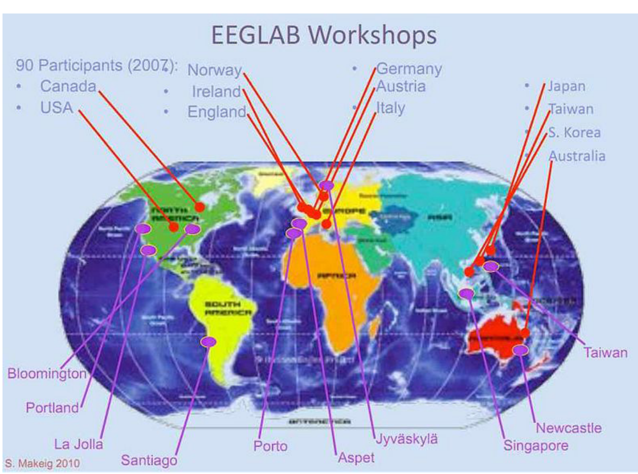
You can think about this problem as the difficulty you might face when you are a parent and all of your kids are talking to you at the same time. The sounds mix together into one cacophonous audio stream that is difficult to decipher. But, given the right kind of algorithm, you can separate the sound that reaches your ears so that you can listen to what each kid said individually without the interruption of the others. That is the power of a technique called ICA, or independent components analysis. It allows scientists to uncouple and localize the fundamental brain signals contributing to an EEG signal.

Artifact removal and ICA are just two of the tools that make EEGLAB so powerful. It's these tools that University of Minnesota researcher, Scott Burwell, says makes EEGLAB indispensable. He uses EEGLAB to see if brain responses picked up by EEGs can predict differences in performance on cognitive tasks between adolescents diagnosed with attention deficit hyperactivity disorder, and those without that diagnosis. Burwell says, "Without EEGLAB providing an easy interface to [perform] some more advanced functions... I may not even explore certain avenues of data analysis." He adds, "It would take days, weeks, or months to produce a satisfying substitute."

# EEGLAB: THE GIFT THAT KEEPS ON GIVING


*Super cool swag from a previous EEGLAB Workshop held in San Diego. Another workshop will be held in San Diego this year around the Society for Neuroscience Meeting.*

Burwell is the not the only researcher indebted to EEGLAB. Google Scholar shows that the EEGLAB reference paper has 8,420 citations and the software itself was downloaded over 19,000 times just in 2017, with each year yielding more downloads than the last. Currently there are 4,247 opt-in researchers on the EEGLAB discussion mailing list, and 9,265 researchers on the EEGLAB news list, anticipating updates to the code. EEGLAB documentation lives online, but learning all of the possibilities of the software is best done in person. The creators of EEGLAB and foreign organizers provide workshops anywhere between two to five times a year. The workshops are held throughout the world and each workshop accepts forty to one hundred and fifty attendees. Last year, workshops were held in in Mysore in south central India, Tokyo, and Be'er Sheva, Israel. Upcoming workshops will be held in Pittsburgh on September 3rd and 4th and in San Diego November 8-12 following the annual Society for Neuroscience meeting.




*Some of the many locations that previous EEGLAB workshops have been held.*


*Scott Makeig presenting at an early EEGLAB Workshop held at UCSD.*

Perhaps the coolest part about an open source program such as EEGLAB is that it never stops growing and transforming. Users can suggest changes, make bug fixes, and add new functionalities with their own contributions to the code. Currently, over seventy-five plug-in toolboxes for EEGLAB, contributed by labs all over the world, are freely available through the online EEGLAB Extension Manager. The base code itself contains a whopping 125,271 lines of code which works out to 533 stand-alone functions. It is likely to keep changing as more researchers contribute and add suggestions. For instance, Burwell hopes that the EEGLAB code will become compatible and accessible with Python, an open source coding language that continues to incorporate more imaging processing tools.

For now though, the EEGLAB creators are focusing on another new capability for researchers who use the code. The project, funded by the NIH, will allow outside researchers to use the UCSD supercomputer 'Comet' to run EEGLAB scripts. The current trend of collecting larger amounts of data and applying computation-heavy analyses requires lots of computing cores that some researchers do not have access to. The team hopes that access to Comet will allow labs without high-performance computing to apply the most sophisticated signal processing that EEGLAB has to offer. It is clear that EEGLAB has, and will have, a huge impact on the field of cognitive neuroscience and that it will continue to evolve to meet the needs of the scientists that rely on it for the study of the human brain.

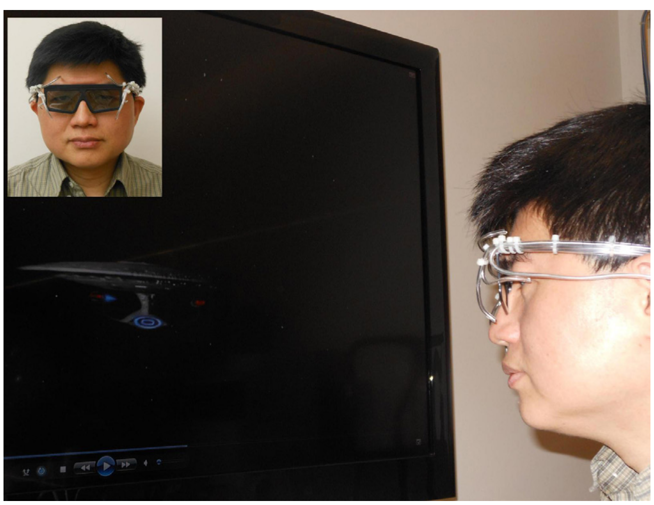
# NEW '4-D GOGGLES' ALLOW WEARERS TO BE 'TOUCHED' BY APPROACHING OBJECTS

A team of researchers at UC San Diego and San Diego State University has developed a pair of "4-D goggles" that allows wearers to be physically "touched" by a movie when they see a looming object on the screen, such as an approaching spacecraft.

The device was developed based on a study conducted by the neuroscientists to map brain areas that integrate the sight and touch of a looming object and aid in their understanding of the perceptual and neural mechanisms of multisensory integration.

But for the rest of us, the researchers said, it has a more practical purpose: The device can be synchronized with entertainment content, such as movies, music, games and virtual reality, to deliver immersive multisensory effects near the face and enhance the sense of presence.

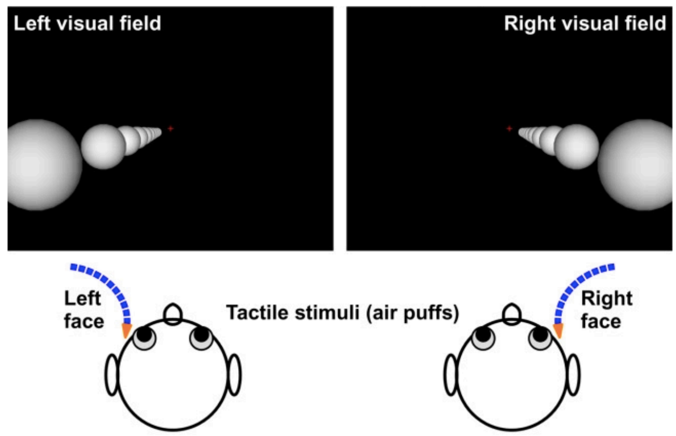
The advance is described in a paper published online February 6 in the journal Human Brain Mapping by Ruey-Song Huang and Ching-fu Chen, neuroscientists at UC San Diego's Institute for Neural Computation, and Martin Sereno, the former chair of neuroimaging at University College London and a former professor at UC San Diego, now at San Diego State University.



*4-D goggles developed at UC San Diego. Photo by Ching-fu Chen*

"We perceive and interact with the world around us through multiple senses in daily life," said Huang. "Though an approaching object may generate visual, auditory, and tactile signals in an observer, these must be picked apart from the rest of world, originally colorfully described by William James as a 'blooming buzzing confusion.' To detect and avoid impending threats, it is essential to integrate and analyze multisensory looming signals across space and time and to determine whether they originate from the same sources."

In the researchers' experiments, subjects assessed the subjective synchrony between a looming ball (simulated in virtual reality) and an air puff delivered to the same side of the face. When the onset of ball movement and the onset of an air puff were nearly simultaneous (with a delay of 100 milliseconds), the air puff was




*Schema of the visual and tactile stimuli used for the study. Subjects were also inside of an fMRI machine while doing the task.*

perceived as completely out of sync with the looming ball. With a delay between 800 to 1,000 milliseconds, the two stimuli were perceived as one (in sync), as if an object had passed near the face generating a little wind.

In experiments using functional Magnetic Resonance Imaging, or fMRI, the scientists delivered tactile-only, visual-only, tactile-visual out-of-sync, and tactile-visual in-sync stimuli to either side of the subject's face in randomized events. More than a dozen of brain areas were found to respond more strongly to lateralized multisensory stimuli than to lateralized unisensory stimuli, the scientists reported in their paper, and the response was further enhanced when the multisensory stimuli are in perceptual sync.

The research was supported by the National Institutes of Health (R01 MH081990), a Royal Society Wolfson Research Merit Award (UK), Welcome Trust (UK), and a UC San Diego Frontiers of Innovation Scholars Program Project Fellowship.

*Written by Kim McDonald*

*Originally appeared in UCSD News in February of 2018*

# SMART: FACIAL RECOGNITION FOR MOLECULAR STRUCTURES

An interdisciplinary team of researchers at the University of California San Diego has developed a method to identify the molecular structures of natural products that is significantly faster and more accurate than existing methods. The method works like facial recognition for molecular structures: It uses a piece of spectral data unique to each molecule and then runs it through a deep learning neural network to place the unknown molecule in a cluster of molecules with similar structures.

The new system is called "SMART," which stands for Small Molecule Accurate Recognition Technology, and has the potential to accelerate the molecular structure identification process ten-fold. This development could represent a paradigm shift in the chemical analysis, pharmaceutical and drug discovery fields since 70 percent of all Food and Drug Administration (FDA)-approved drugs are based on natural products such as soil microorganisms, terrestrial plants and, increasingly, marine life forms such as algae.

"The structure of a molecule is the enabling information," said Bill Gerwick, professor of oceanography and pharmaceutical sciences at UC San Diego's Scripps Institution of Oceanography. "You have to have the structure for any FDA approval. If you want to have intellectual property, you have to patent that structure. If you want to make analogs of that molecule, you need to know what the starting molecule is. It's a critical piece of information."

Chen Zhang, a nanoengineering Ph.D. student at UC San Diego collaborating with Gerwick and the first author of the paper published in Nature Scientific Reports, said that determining a molecule's structure can be a bottleneck in the natural product research process, taking experts months and even years to accurately determine the correct and complete structure. While each molecule and its identification timeline is different, the SMART approach gives researchers an early clue into what family a new molecule falls under, drastically reducing the time it takes to characterize a new natural product.

"The way we were able to accelerate the process is by essentially using facial recognition software to look at the key piece of information we obtain on the molecules," Gerwick said. The key piece of information the team uses is called a heteronuclear singular quantum coherence nuclear magnetic resonance, or HSQC NMR, spectrum. It produces a topological map of spots that reveal which protons in the molecule are attached directly to which carbon atoms, an arrangement unique to every molecule.

*Gary Cottrell.*

Zhang and Gerwick teamed up with Gary Cottrell, a computer science and engineering professor at the UC San Diego Jacobs School of Engineering, to develop a deep learning system trained with thousands of HSQC spectra pulled from previous research. This convolutional neural network takes a 2-D image of the HSQC NMR spectrum of an unknown molecule and maps it into a 10-dimensional space clustered near similar molecules, making it easier for researchers to elucidate an unknown molecule's structure.

"Chen took this approach to getting NMR spectra of over 4,000 compounds from the literature by literally cutting out the images from the PDFs of the papers," Cottrell said. "It was an awesome effort! Even so, this is normally not enough data to train a deep network, but we used a technology called a Siamese network, in which you train on pairs of images. This amplifies your training set by roughly the square of the number of compounds in a family, and is what made this project feasible." This collaboration is the first time Gerwick has mentored an engineering student, and the exchange of ideas proved fruitful.

"It's been a wonderful interaction. UC San Diego has something really quite magical about it, and that is the depth of collaboration that occurs between departments—it's phenomenal," Gerwick said. "When you try and thoughtfully take from another discipline something that is maybe even commonplace in that discipline and apply it in a new and unique way in our discipline, it's an opportunity to really have this kind of paradigm-shifting thing. And I think this technology, with some advancement, could be a real paradigm shift in the way we do all kinds of chemistry and chemical analysis."

*Written by Katherine Connor*
*Press Release for The Jacobs School of Engineering,*
*October 2017*

# WHAT LEARNING LOOKS LIKE: CREATING A WELL-TUNED ORCHESTRA IN YOUR HEAD

What does the brain look like when you're playing music? According to students at Kellogg Elementary School in Chula Vista, it's definitely pink and, if you could shrink yourself down and step inside, a relaxing place to be. "I imagine a little mattress, but brain, and like in the cartoons when there's music, there's little notes in there," said Abel Beltran, 10. "I would compare my brain to this toy that I have at home," said Andrea Sandoval, 10. "It's like a ball that closes and opens." "I think it might move a bit, because as we're playing music, not only are we playing it, we're also learning something new," said Bezalel Shin, 11.

UC San Diego neuroscientist John Iversen said they're not too far off. "I think that actually shows some deep insight," Iversen said. "Even when you're just listening to music, youre brain is not just sort of passively recording what comes in. It's actually actively engaging with the sound."

*Anthony Medina plays cello with other Kellogg Elementary School students, Nov. 29, 2017. Photo by Megan Burks.*

Iversen just wrapped up a five-year study on the brains of children who play music in the San Diego Youth Symphony's Community Opus after-school program, like the students at Kellogg. He and SDYS want to use the data comparing brain changes in kids who played music and those who didn't to answer this question: "Much the same way that increased nutrition might change the path of growth of a child's height, are there certain activities such as music that might change the trajectory of growth of the brain?" Iversen said. They hope the answer will make the case for bringing arts education back to public schools.

For the past few decades, standardized testing has put an intense focus on reading and math in U.S. schools. Educators say that and budget cuts have caused enrollment in arts classes to plummet. In the western United States, the number of students enrolled in arts classes dropped from 35 percent in 2008 to 33 percent in 2016, according to a federal survey.

"The demand that everything be addressing the test undermined other academic learning that wasn't seen as directly addressing the test," said SDYS President Dalouge Smith. "Unfortunately, music suffered, when the science shows us that music actually does contribute to learning of language, learning of mathematics, learning of vocabulary. That correlation was not as evident at the time, and we still have to make that case strongly."

So Iversen and Smith are conducting their own tests — in the form of MRIs and EEGs — to study developing brains, particularly the outer, noodly part called the cortex.

"It's almost like a crumpled ball of paper. It's wrinkled up so it can fit inside our skull. But if you were to straighten all of those wrinkles out, you would see it's just a sheet of neural tissue," Iversen said. "So what we're looking at is basically how different regions of that are growing and shrinking over time."

At a very basic level, the ear and brain kind of work like the equipment I used to record my interview with Iversen. "The microphone is picking up my soundwaves. It's turning it into a voltage. So that's kind of like what the ear is doing. But then once we get into the computer, it's turned into a digital file, so it's just turned into numbers," he said. "So that's a pretty good analogy in some sense for how the brain is recoding things from analog to digital."

The cochlea turns sound waves into nerve impulses that travel through the brainstem to the cortex. Brain scans show multiple parts of the cortex respond to sound, especially if it has rhythm and lyrics or is accompanied by movement.

Iversen is in the very beginning stages of analyzing his data, but early findings suggest playing music is linked to stronger language development. "What we found is that the size of the motor cortex, this area that controls movement and planning of movement, predicted individual differences in the ability to

## WHAT LEARNING LOOKS LIKE: CREATING A WELL-TUNED ORCHESTRA IN YOUR HEAD

and lyrics or is accompanied by movement.

Iversen is in the very beginning stages of analyzing his data, but early findings suggest playing music is linked to stronger language development. "What we found is that the size of the motor cortex, this area that controls movement and planning of movement, predicted individual differences in the ability to perceive a musical beat," Iversen said. "So it's suggesting that there's something about this connection between hearing and moving that may develop this ability to hear patterns in time. And that, of course, is really the foundation of learning language — the processing of sound." That's not to suggest, however, that music makes brains bigger. Think of it more as training the brain, especially the connections we use to learn.

The University of Southern California's Brain and Creativity Institute released findings in November from a similar study that showed kids who played music not only exhibited thickening of the auditory cortex, but also had more robust white matter, the part of the brain that carries signals through the brain.

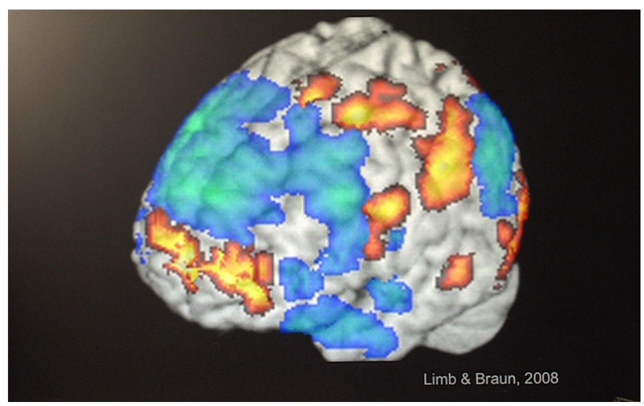
"There's an idea (in neuroscience) that the brain grows exuberantly at first — it actually creates more connections than we end up with as adults — and that over time, experience might prune out some of the connections that aren't important," Iversen said. So playing music at an early age might help the brain cortex function like a well-tuned orchestra. And the better your orchestra, the better your academics.

Iversen said another way music might help with learning is by creating a tiny conductor for that brain orchestra. Research from UC San Fransisco scientist Charles Limb shows when they improvise, jazz musicians and rappers suppress activity in the parts of the cortex that control the inner dialogue and make you overthink. "We tend to think of brain building as muscle building — just make everything bigger and better. But it's really about control," Iversen said. "So one thing that this suggests that music helps kids learn is how to regulate their own brain."

Anecdotal evidence seems to back Iversen up. "Music did change his life," Carol Medina told me of her 12-year-old son, Anthony, who has autism. "Bringing him to orchestra here, it just opened a whole new world for him. He had new friends. We started noticing a lot of parts of his learning expanding more." Medina said Anthony caught up with his Kellogg Elementary classmates in reading after joining Community Opus. And he seems to have that tiny conductor helping to regulate his thoughts and emotions. "It helps me when I have stress or more stuff," Anthony said. "It's like a good feeling."

His classmates, too, said they think of music — even chord progressions — when they need to calm down during a test in another subject. And the Chula Vista Elementary School District reports better classroom behavior, improved attendance and deep parent engagement after increasing music offerings at its schools in 2010.

Symphony President Smith said he's working with other researchers at UCSD to track those more qualitative outcomes in addition to Iversen's brain research.




*A musician's brain activity during improvisation. The blue areas show a suppression of activity in the parts of the brain that are thought to control the inner dialogue. Red shows areas that are more active during improvisation.*

"This is not just about giving kids in San Diego County access to music and arts education," Smith said. "For the San Diego Youth Symphony, this is really about helping the whole of the country understand the importance of this choice and choosing to make it."

He might want to recruit Anthony. "I love playing music," he said, hugging his cello like a close friend. "It's the best thing that's ever happened to me."

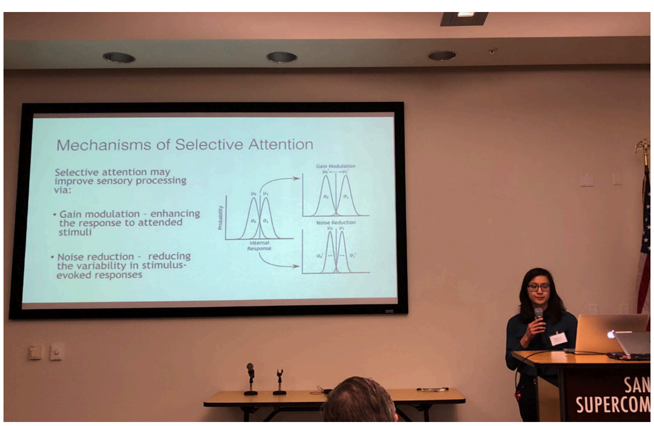
*Written by Megan Burke*

*Originally appeared on KPBS in December, 2017*

# INC RETREAT RECAP

Spring has sprung, and with it comes the annual INC retreat, a gathering of young scientists whose work is funded by the INC led National Institute of Mental Health training grant. The training program funds pre and postdoctoral scientists with an emphasis on training for the advanced analysis of neural data to understand cognitive processes like selective attention, perception, learning, memory, and how these cognitive processes are affected by mental disorders. The grant trainees gathered at the Supercomputer Center Auditorium to share the most recent results of their research. Each presenter was given just five minutes to discuss their research and Eric Halgren, co-leader of the training grant, promised a yet to be determined prize to the presenter that came closest to the five minute mark. Project topics ranged from selective attention to the neuroanatomical basis of behaviors associated with a rare neurodevelopmental disorder. If you weren't able to attend, here is a recap of some of the science that was presented.

Robert Kim is a first year graduate student in the Sejnowski Lab whose presentation, "Dynamic subtypes of schizophrenia", started with a problem: that there are no good biomarkers for the diagnosis and prognosis of schizophrenia. Robert analyzed EEG data from the Consortium on the Genetics of Schizophrenia that was collected while subjects performed an auditory mismatch task. He used delay differential analysis to extract nonlinear features from the EEG data and then correlated those features with neurophysiological scores. While the results are promising, the dataset is still fairly small and he hopes to apply his analysis to more data to assess the diagnostic ability of EEG features.




*Tammy Tran, a UCSD Neurosciences graduate student, presents her research about the influence of selective attention on trial by trial variability of human EEG activity.*

Aaron Sampson, also of the Sejnowski lab, used a type of delay differential analysis to examine information flow within the brain during sleep. During slow wave sleep, high frequency activity can be observed in the hippocampus. This activity is thought to arise as a result of hippocampal cells replaying patterns of neural activity that were generated during waking hours. Aaron analyzed data from epilepsy patients who already had depth electrodes placed in the hippocampus and in cortical areas for treatment purposes. He observed a back and forth exchange of activity that originated from the hippocampus, traveled to the cortex and then returned to the hippocampus. It's possible that this back and forth may hold clues for how memories are strengthened during sleep.

A postdoc at the INC, Kari Hanson, studies the brains of deceased patients that were diagnosed with Williams Syndrome, a rare neurodevelopmental disorder that arises from the deletion of genes on the seventh chromosome. Persons with the deletion have lower than usual IQs, but with spared language facilities and they are typically hypersocial and empathetic. Kari counted the amount of brain cells - both neurons and glia - within different brain regions in the postmortem brain tissue. Compared to neurotypical brains, the caudate nucleus of William Syndrome brains had a higher density of glia. Kari says this difference may help account for a decrease in inhibitory control that could lead to the increased sociability seen in Williams Syndrome individuals.

See below for titles of the other fantastic presentations from the INC training grant Data Blitz:

*Ethan McBride,* UCSD Neurosciences, Predoctoral Fellow "Local and global influences of spatial selection and locomotion on mouse V1"

*Lyle Muller,* INC / Salk Institute, Postdoctoral Fellow "Traveling waves in cortex: spatiotemporal dynamics shape perceptual and cognitive processes"

*Josh Nichols,* UCSD Neuroscience / Salk Institute, Postdoctoral Fellow. "Cortical microcircuit connectivity of inhibitory subtypes"

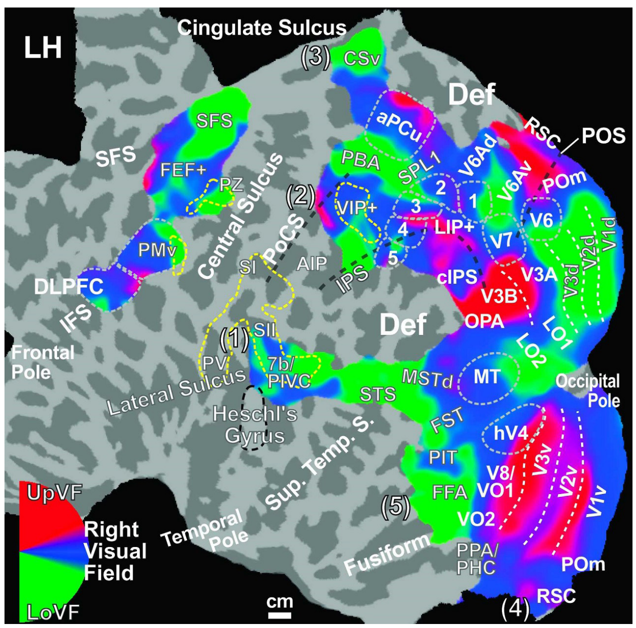
*Tammy Tran*, UCSD Neurosciences, Predoctoral Fellow "Selective attention reduces the trial-by-trial variability of human EEG activity."

# SCIENTISTS CONSTRUCT GOOGLE-EARTH-LIKE ATLAS OF THE HUMAN BRAIN

Two neuroscientists have produced a new kind of atlas of the human brain that, they hope, can be eventually refined and improved to provide more detailed information about the organization and function of the human brain.

In an invited chapter published online this week in the Handbook of Clinical Neurology, Vol. 151, The Parietal Lobe, neuroscientists Ruey-Song Huang of UC San Diego and Martin Sereno of San Diego State University detail their surface-based human brain atlas.

The chapter and atlas are based on more than ten research papers the two researchers published in leading scientific journals, such as Nature Neuroscience, PNAS and the Journal of Neuroscience.




*A group averaged retinotopic map shown on a flattened left-hemisphere cortical surface.*

"Making a map is the first step in exploring a new world, whether it is an uncharted territory on the Earth or a new planet in outer space," said Huang, a neuroscientist at UC San Diego's Institute for Neural Computation. "For more than 25 years, noninvasive functional magnetic resonance imaging has allowed researchers to probe and map the human brain, one of the final frontiers, in unprecedented detail."

He and Martin Sereno, the former chair of neuroimaging at University College London and a former professor at UC San Diego, said their atlas contains visual, somatosensory, multisensory, motor, action and motion maps that were pieced together from their own as well as other researchers' functional magnetic resonance imaging, or fMRI, studies.

For neuroscientists, the two researchers said their new brain atlas reveals more than 40 "retinotopic areas" distributed across five visual streams — a more comprehensive picture of the human visual system than the initial division into a dorsal "where" pathway and a ventral "what" pathway. Full-body tactile stimulation and wide-field visual stimulation, they said, revealed a new multisensory homunculus located at the border between somatosensory and visual maps.

The scientists said their multilayer maps rendered on the same cortical surface—a map overlay method typically used in geographic information systems like "Google Earth"—provide insight into understanding how visual, somatosensory and motor maps partially overlap each other to support sensorimotor functions such as eye movements, pointing, reaching, grasping, eating, ducking and walking in daily life.

They expect that the areal and functional definitions in this atlas will be refined and updated by future studies using high-resolution brain imaging and more sophisticated stimuli and tasks tailored to regions with different specificity.

The researchers said their ultimate goal is to construct an online surface-based atlas containing layered maps of multiple modalities that can be used as a guide map to understand the topological organization, functions, and disorders of the human brain.

This online atlas will be constructed for searching and browsing brain areas and functions, they said, include interactive multi-layer features similar to "Google Earth." These include spherical surface coordinates, gyri/sulci, boundaries of areas ("GPS coordinates," "geographical features" and "county lines"), and embedded links to publications and figures ("Google Scholar" and "Google Images"), all on the same interface.

The research effort was supported by the National Institutes of Health (R01 MH081990), a Royal Society Wolfson Research Merit Award and the Wellcome Trust.

*Written by Kim McDonald*

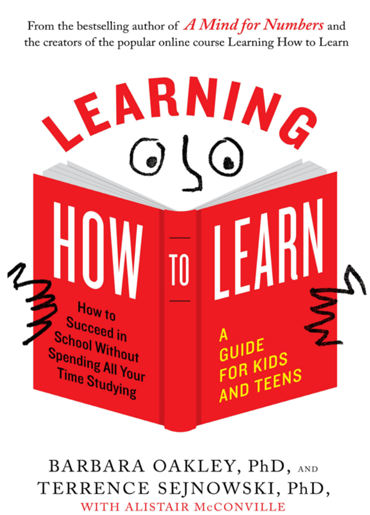
*Originally appeared on KPBS in December, 2017*

# LOOKING BACK AND FORWARD WITH TERRY

I'm sitting with Terry Sejnowski in his office at the Salk Institute. I came to chat about the past, present and future of the Institute for Neural Computation (INC). I'm caught off guard when Terry suddenly addresses Alexa, the Amazon developed virtual assistant. "Alexa, what time is it?" I can't see Alexa's source, but I hear her stilted voice as she faithfully recites that it is indeed 9:22 AM, Eastern Standard Time. "Deep learning is powering Alexa and the INC worked on it."

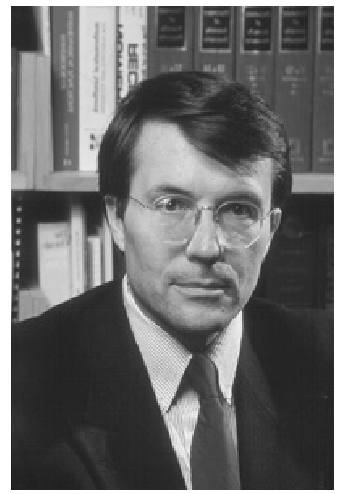
The INC has worked on many things since its start in the early 1990's. It was conceived as a way to bring engineers, neuroscientists, and other great thinkers together to try to answer the question, how do brains compute? Another way of putting the question is, how can a collection of brain cells packed together in a three pound mass lead to sensation, movement, and consciousness? Sejnowski figured that this daunting biological mystery could best be explored in groups of interdisciplinary teams with scientists cooperating together. This is in contrast to the traditional model, for which each faculty member gets their own grant, "every boat on its own bottom," as he puts it.

UCSD had a system in place for such interdisciplinary ventures as the one Sejnowski envisioned. The INC became one of twenty four Organized Research Units (ORUs) at the university. ORUs are non-permanent entities up for review every five years. Basically, ORUs are intended for hot areas of science that fall between the cracks, that don't fit into the normal department structure. The INC definitely hit upon some of the "hottest" categories of science with researchers studying topics that are buzzwords in Silicon Valley like brain machine interfaces, machine learning, artificial intelligence, and big data. Often INC scientists were some of the first to study these subjects, not in the service of building an Alexa, but for understanding the brain. For Sejnowski, that's what it is all about - the unexpected impacts that INC members have had on technology and education that flowed naturally from studying cognition.




*Cover of the book inspired by the success of the online course "Learning How to Learn." The book will be released in August of 2018 and is targeted towards middle school children and will be the companion to a new MOOC..*

In addition to traditional scientific training of graduate students and postdoctoral fellows, the INC has had a much broader impact on learning. Scientists from the Temporal Dynamics of Learning Center, part of the INC, study the neural basis of learning. Findings from their studies may help inform ways to improve attentiveness in the classroom and ways to tailor education for students with learning disabilities.



*A young Sejnowski not yet privy to the convenience that is Alexa.*

Sejnowski puts a big emphasis on education and believes that meta-education is a skill that often goes untaught. Thus, with University of Oakland professor Dr. Barbara Oakley, he launched "Learning How to Learn" in 2014, now the most popular Massively Open Online Course (MOOC) on the internet, with over 3 million learners. The course, taken by people across the globe, focuses on techniques to overcome procrastination and to break big projects into smaller, more manageable pieces.

Sejnowski says that he wants the research of the INC to go beyond academic journals and make it into the real world. He and others have done so in the realm of education. Yet another way that INC research permeates is through scaling and adapting methods first developed at UCSD to build successful technology businesses.

One such example that Sejnowski mentions is Emotient, a company recently acquired by Apple. The technology behind Emotient began in the 90's as a research project of Dr. Marian Bartlett with Drs. Paul Ekman and Sejnowski to train deep learning networks to recognize facial expressions independent of the identity of the face. At first, it took hours to train a

## LOOKING BACK AND FORWARD WITH TERRY

network on a small database of faces. But, fast forward twenty years and computers are orders of magnitude faster and can run through huge databases enabled by the internet. Now the networks trained by Bartlett were able to recognize emotions like joy, sadness, and disgust so rapidly and accurately that they were actually commercially useful. Bartlett and colleagues realized that this technology was going to be very valuable.

*The many emotions that can be represented with facial expressions and that can be detected with Emotient software. From emotient.com*

Bartlett founded Emotient in 2008 with seven other researchers. A UCSD article written by Doug Ramsey highlighted the many uses of such a technology, "The startup's technology has already helped advertisers assess how viewers are reacting to advertisements in real time. Physicians have used Emotient software to interpret pain levels in patients who otherwise have difficulty expressing what they're feeling, while a retailer has employed the company's AI technology to monitor consumers' reactions to products on store shelves."

It's clear from talking with Sejnowski that the INC has had many unexpected impacts that reverberate outside of academia and make it into education and into technologies that we now take for granted. As for the future of INC, Sejnowski says that he has learned enough from past experience to know that future impacts of the INC are hardly predictable. But, if he had to guess, he thinks that insights from the brain, including its massively parallel architecture, will likely improve hardware and software that advance the capability of computers to process natural language, visual signals, and perform complex tasks like driving cars.

Sejnowski takes a look at the analog clock on the wall and sees that it is time to wrap up our conversation. He leaves me with one last message, "We are experiencing the beginning of the information age and the INC is at the forefront, at the tip of the spear."

*Sejnowski says the Information Age is upon us.*

PoNG
POWER OF NEUROGAMING CENTER

### LEANNE CHUKOSKIE LEADER OF THE NEW POWER OF NEUROGAMING CENTER AT UCSD

In a previous newsletter, we explored some of Dr. Chukoskie's research which uses videogames to study autism spectrum disorders. Now, she is in charge of the new Power of Neurogaming Center (PoNG) at UCSD's Qualcomm Institute. The center is meant to bring together video game developers and researchers who use video games as part of their studies - whether it be for medical therapy, diagnosis, skill building or just plain fun. Also, with help from the San Diego Foundation, the center will be providing internships to young adults on the autism spectrum to teach them game development skills like programming and soft skills that can help with employment.