INCUBATOR

Institute of Neural Computation
University of California San Diego

The Incubator is written [in part] and designed by Margot Wohl - INC Newsletter Editor
UCSD Neuroscience Graduate Student
mwohl@ucsd.edu

A DISORDER WITHOUT A NAME

Dr. Mateusz Gola began as a clinical psychologist, seeing patients with various psychological ailments. One day, a patient came to him describing what is now referred to as compulsive sexual behavior disorder. At the time there was no term for the condition and no diagnosis – nothing in the International Classification of Disorders (ICD) or the American equivalent, the Diagnostic and Statistical Manual of Mental Disorders (DSM).

The patient who visited Gola had been turned down by other psychologists and psychiatrists for treatment. But Gola did not use the lack of diagnostic guidelines as a reason to turn down this patient or the others that would follow reporting the same kinds of problems surrounding sexual activity. He saw patients whose compulsions to watch pornography or to seek out prostitutes were negatively affecting their work lives and home lives, a sign that is often used to determine whether a behavior is "disordered". So, Gola began interviewing and documenting the struggles of these patients.

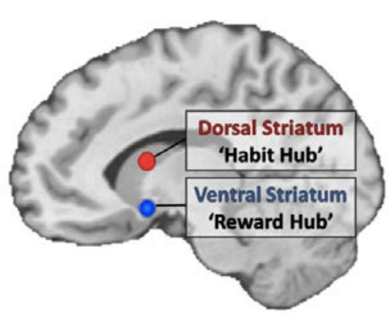
Dr. Mateusz Gola

Interviewing the patients was equal parts tragic and touching according to Gola. Some people had been suffering so long without a diagnosis. However, many were relieved that someone was listening to their stories and that their stories might spawn research on treatments. There was hope, at least on the part of the patients. Colleagues and journal editors, however, were not so excited about the project.

Image: inverse.com

Gola recalls, "People were laughing at me. Colleagues said, 'oh you will ruin your scientific career – it's not a serious topic.' " And journals were reticent at first to publish some of his papers. But with time, journals came on board. As is often the case for new ideas in science, it takes a while for them to gain traction, but once they do, the momentum can grow quickly. Within a decade of Gola's breakthrough research as well as others' studies on sexual compulsions, the 11th edition of the ICD recognized compulsive sexual behavior as a disorder that is characterized by "a persistent pattern of failure to control intense, repetitive sexual impulses or urges resulting in repetitive sexual behaviour." This can include both the act of sex and sexual fantasies. Gola thinks the disorder will also be included in the next edition of the DSM whenever it is released.

Since his first publications establishing the nature of the disorder, Gola has taken his research in many directions to understand the neurophysiology of patients suffering from the disorder as well as determine the best methods for treating compulsion. He has found that the ventral striatum activity is



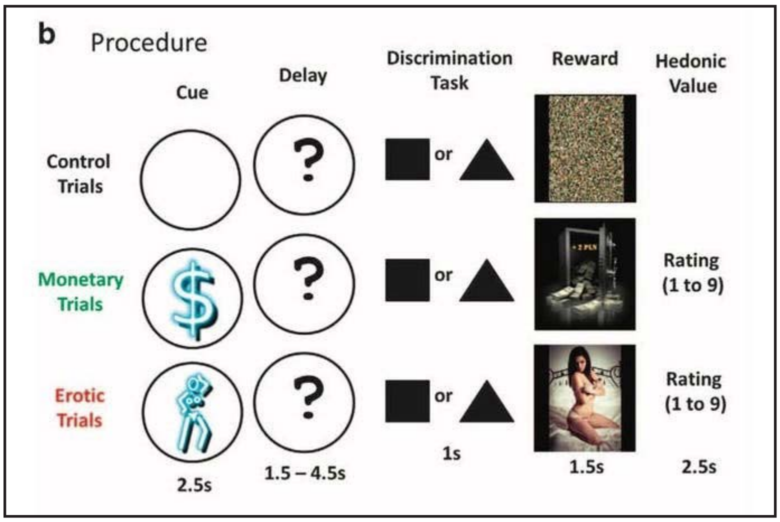
The Ventral Striatum is thought of as the reward system of the brain. Image: brainconnections.ca

A DISORDER WITHOUT A NAME

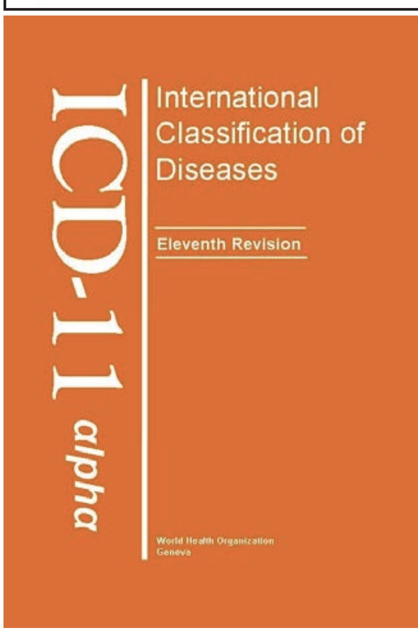
higher for heterosexual males seeking treatment for problematic pornography use when presented with cues preceding display of erotic imagery, suggesting that the increased "wanting" or "anticipation" of pornography might be represented in this area of the brain. Additionally, he has examined the efficacy of twelve step programs and the serotonin reuptake inhibitor, paroxetine, on minimizing symptoms associated with compulsive sexual behavior disorder.

But recently, he's been working on a new approach to stem compulsive behaviors as part of a company he started in 2016 called PredictWatch. The PredictWatch Guardian app, which can be downloaded on a smart phone or watch, checks in on subjects' behavior using a method known as ecological momentary assessment. The app asks users throughout the day to assess how they are feeling, what their stress level is like, and how strong their cravings are. This information can be combined with physiological measurements like sleep quality or heartrate to help predict relapses. The goal is for the app to be so good at prediction, that it can intervene before a relapse to help the user stave off the craving. The app is still undergoing testing for multiple disorders including opioid addiction, alcoholism, and binge eating.

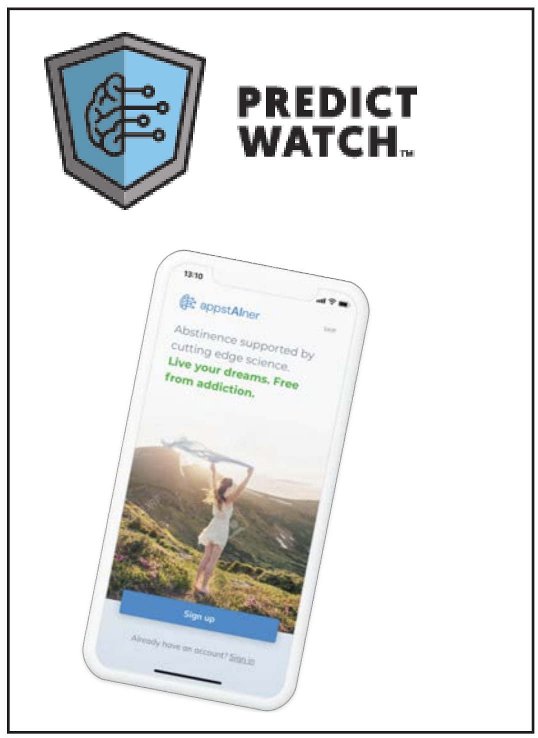
Gola has been able to take part in the rapid progression within the field of psychiatry of studying a patient population, to acknowledging the disorder they suffer from, to investigating the disorder etiology and identifying treatments. He hopes that similar advancements can take place for other disorders that have yet to be named.



TOP A schematic of the behavioral paradigm used in Gola's study of problematic pornography consumption. Monetary trials were used to make sure that the brain signals recorded were not just a reward signal.



LEFT: The International Classification of Diseases manual's latest version, published in 2018, recognized Compulsive Sexual Behaivior Disorder..



A mock up of the Predict Watch mobile app
image: Predictwatch.pl

COLLABORATORY EXPLORES LONELINESS

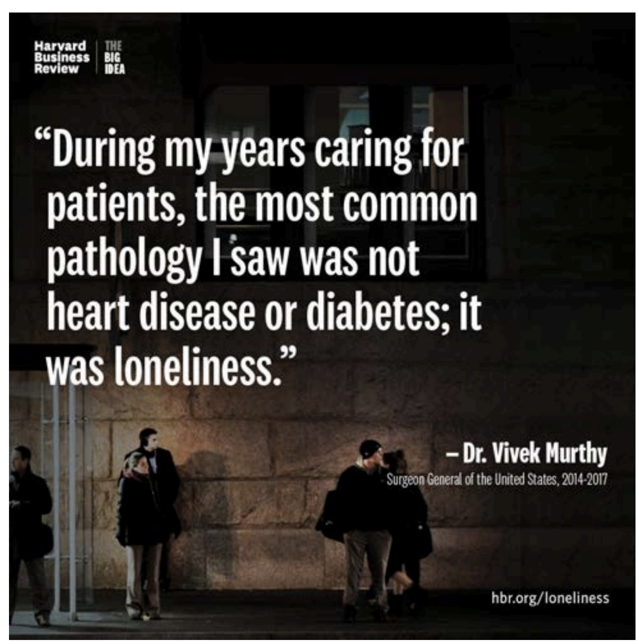
In 2017, former U.S. surgeon general Dr. Vivek Murthy equated loneliness to a public health crisis in a Harvard Business Review essay. He cited a study that equated loneliness to smoking fifteen cigarettes a day in regards to its impact on life span. A year later, the UK appointed its first Minister for Loneliness. This national awakening led the Collaboratory Science in Society leaders to choose "Loneliness" as the topic for their second ever event held in February at Sanford Burnham. In the packed Roth Auditorium, three scientists talked about their varied research on how isolation is instantiated in the brain, what causes loneliness and what we can do to combat it.

Dr. Kay Tye, a new addition to the Salk Institute, thinks of loneliness as a way to reach social homeostasis that has been evolutionarily programmed into many species. Being social can confer advantages like safety in numbers, and so there is likely a physiological readout of a lack of social contact, just like the readout we have for lack of food - hunger. For instance, the common fruit fly when isolated, become hyper social – courting females more vigorously and fighting males more often. Obviously, it's hard to say whether other species feel "loneliness" per se, as it is a subjective emotion. However, we can at least study how isolation can affect the brains of other mammals in the hopes that it will help us understand what happens in human brains in similar situations.

By isolating mice and using genetic, optical, and electrophysiological tools, Tye's research group was able to find a set of brain cells that seem to encode a negative state associated with loneliness that then motivates mice to be prosocial. It's unclear how this will relate to human loneliness and if this information can or should be used for treating feelings of isolation. Perhaps it is best to nip loneliness in the bud by finding its underlying causes, which is the focus of invited speaker Dr. Candice Odgers' research conducted at Duke University and UC Irvine.

Odgers studies how smartphones are affecting our sense of social connectedness, especially in adolescents. It makes sense logically, that being on a device prevents real-life human to human interaction, but is there data to back it up? Odgers' research team digs through survey data, metanalyses, and runs experiments to test the association between digital device use and negative emotions.

One recent surprising, and much publicized finding is that there is very little association between the smartphone use and feelings of loneliness. The way she thinks about technology like smartphones is as a mirror of an adolescent's outside life – if they are struggling online, they are likely struggling offline. She even acknowledges the many ways that the internet and social media can assuage loneliness in cases where adolescents have trouble finding commonalities in their immediate communities. So, if digital devices aren't the cause, we have to look to other reasons why teenagers are experiencing higher rates of isolation,



COLLABORATORY EXPLORES LONELINESS

anxiety, and depression than ever. Dr. Odgers thinks that blaming our phones or iPads may be distracting from other sources negatively affecting mental health. The jury is still out on why we feel loneliness, but even without this understanding, we may still be able to mitigate it.

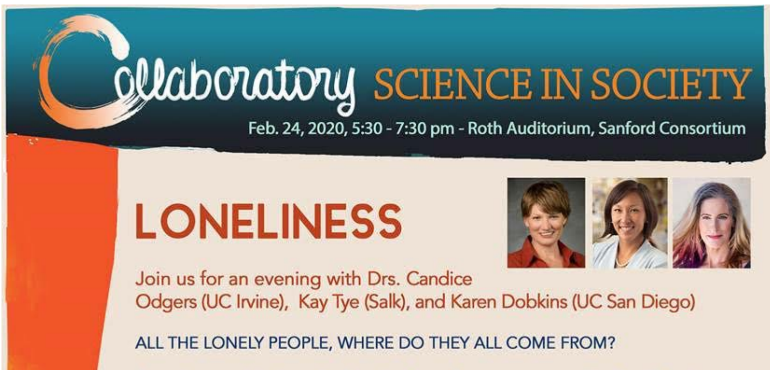
The third speaker, UCSD Psychology professor Dr. Karen Dobkins, primarily studied early brain development until about ten years ago, when she shifted her research inquiry to mental well-being. As she put it, we get an education in history, math, science, language, but we don't get an education on how to be human, how to be connected to oneself and to others. Moreover, she posited that connection to self and others might be connected – that the ability to sense one's own body, also known as interoception, might track with feeling socially connected.

To test this theory, Dobkins compared peoples' scores on surveys that measured both. She found that having a heightened awareness of one's body was correlated with feeling socially connected. One way to increase interoception is through mindfulness practices like meditation. Dobkins is studying various mindfulness methods to see if they are a tonic for loneliness.

After Dobkins' presentation, the evening evolved into a lively conversation among presenters and the audience, in which many participants shared their feelings of loneliness, and shared their attempts at combatting it. Peter Ellsworth, President of the Legler Benbough Foundation, brought up the importance of community engagement and service for creating a stronger sense of belonging.

We still have a lot to learn about isolation and its counterpart, loneliness. Roger Bingham, Director of the Collaboratory, notes, "How ironic that we [had an event] on loneliness which was then followed by this unprecedented era of social distancing."

Many studies will likely arise from this unintended experiment in isolation. The hope is that we can all maintain a sense of connection whether through social media or mindfulness exercises and continue to learn more about ourselves, our human emotions, and how they affect and are affected by the brain and the body.

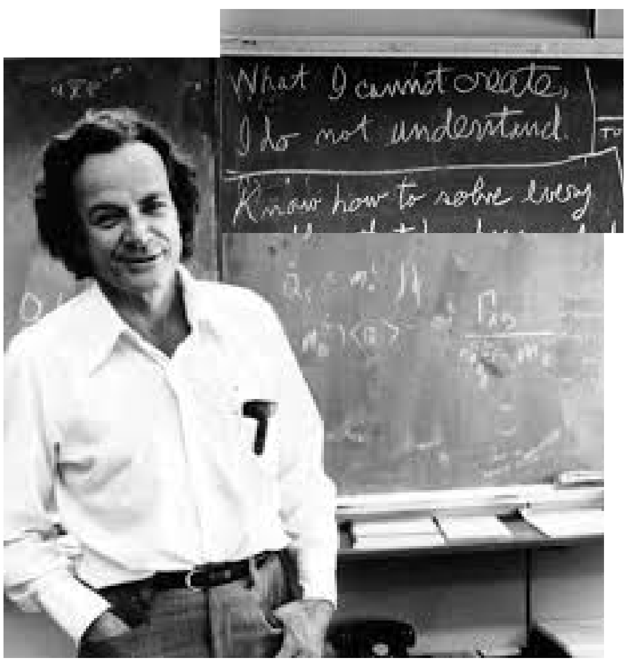


TOP: Collaboratory invitation to "Loneliness" event.
MIDDLE: (left to right) Odgers, Tye, and Dobkins answer questions from attendees.
BOTTOM: Dobkins presents to a rapt audience.
Image credits: Margot Wagner and Lara Sievert

BUILDING A BRAIN

Dr. Gert Cauwenberghs, co-director of the INC, likes to quote the final phrase found on Richard Feynman's blackboard: "What I cannot create, I do not understand." Cauwenberghs applies that quote to the human brain. To better understand it, one must be able not only to take it apart, but also put it together, using equivalent electronic circuits. This is the basis of much of Cauwenberghs' research trying to emulate what the brain does using silicon integrated circuits, a field referred to as neuromorphic engineering.

In 2016 AlphaGo, a neural network developed by Google DeepMind, dominated the world's highest ranked player in one of the most complex strategy games, Go. This was a remarkable feat as previous attempts in the 50-year history of artificial intelligence had failed to outperform even a novice player. The defeat of an exceptional human by AI didn't bring us closer to understanding the brain because there are key differences between AlphaGo and eighteen-time Go World champion Lee Sedol.



Richard Feynman in front of his whiteboard. One of the last things found on his whiteboard after his death was the phrase, "What I cannot create, I do not understand."
Image: caltech.edu

For one, AlphaGo required millions of simulated training games to hone its abilities. And most strikingly, it required about three thousand times the amount of energy required of the human

Lee Sodol looks distressed as he tries and fails to beat the AI AlphaGo
Image credit: wikipedia.com

brain to think through its every move in the game. One key reason for this energy disparity is the relative inefficiency of the computer architecture and algorithms behind AlphaGo which used centralized computation separate from memory storage, a set up that is substantially different from the structure and organization of neural computation and synaptic connectivity in the brain.

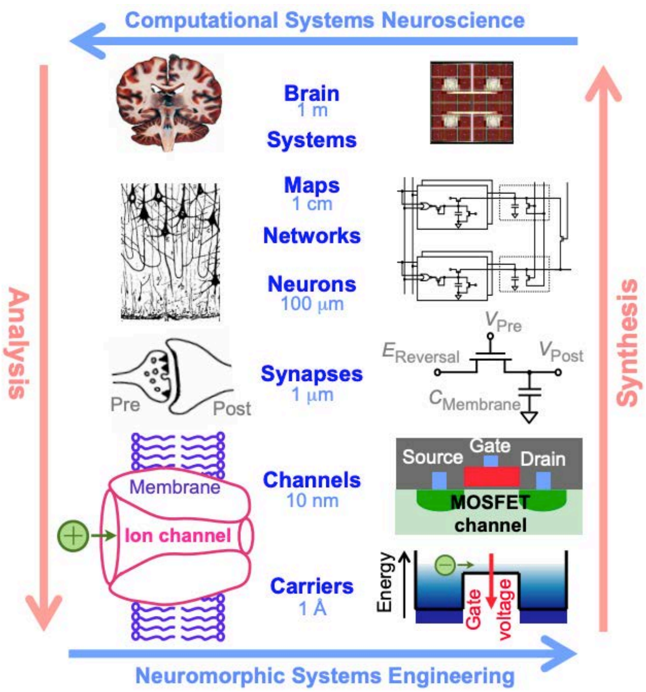
Cauwenberghs' lab is leading efforts in the scientific community to change that, building computer chips that not only mimic the function of biological neural networks, but also approach the extreme energy efficiency and error resilience of their structural organization.

The brain is a highly complex hierarchy of information systems. At the smaller scale, brain cells communicate to each other using electrochemical signaling. These connections aren't always stable; they can change weight and can sometimes even change polarity, going from excitatory to inhibitory. Synaptic plasticity, as these changes are called, is thought to underlie memory and learning. Additionally, signals transmitted from one cell to the next are not reliable; they exhibit a behavior called stochasticity. Sometimes, they just don't fire.

Stochasticity and plasticity at a synapse can be modeled using silicon chips constructed using traditional complementary metal-oxide-semiconductors (CMOS), novel nanoelectronics transistors such as resistive switching memory (RRAM), or phase change memory (PCM) elements that mimic the thermodynamics

BUILDING A BRAIN

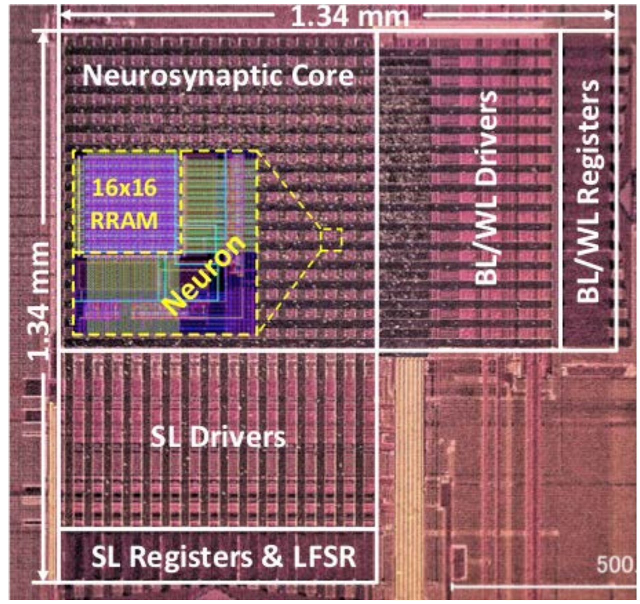
of ion transport through biological membrane channels. These elements can then be assembled in a network to mimic the spiking neural circuits that make up the dynamics of biological brains.



A schematic of the different scales of computation of the brain and the corresponding neuromorphic systems. (Adapted from Churchland and Sejnowski 1992)
(G. Cauwenberghs, "Reverse Engineering the Cognitive Brain, "PNAS, 2013)

While these new chips embodying neural principles are still at early stages in approaching levels of biological realism to be useful as a modeling tool for neuroscientists studying brain function, some significant progress has already been made. For instance, chip sizes have decreased along with energy consumption making them ideal for applications in the engineering of highly efficient, real-time information processing systems.

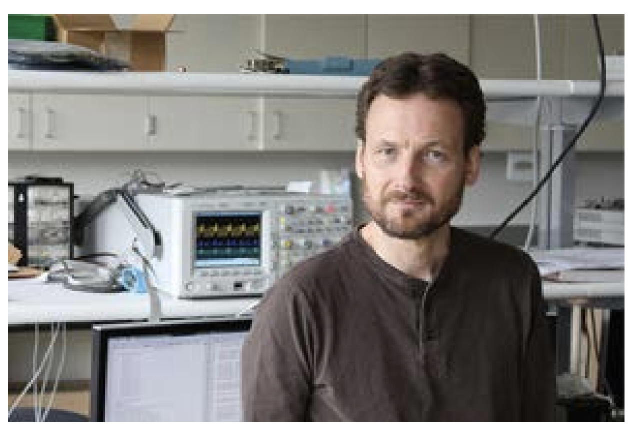
The Cauwenberghs group has been part of those advances, developing some highly optimized chips for image processing that operate at less than a femtojoule per synaptic operation, on par with the efficiency of synaptic transmission in the human brain. Ongoing work extends these processing components to implement deep learning algorithms modeling synaptic plasticity in the cortex and other areas of the brain, including



One of Cauwenberghs' latest integrated circuits is an interwoven mesh of CMOS neural processing elements and RRAM synaptic connections at record 13fJ energy per synaptic operation. (Wan et al, IEEE ISSCC 2020)

long-term memory consolidation in the hippocampus, and reinforcement learning in the basal ganglia. As Cauwenberghs puts it, "we aspire to build the brain from the bottom up." To do so, his team of collaborators draws from the many disciplines that the INC encompasses from nanoscience, to computer science, to cognitive science.

It's a difficult endeavor, to try to recreate something that evolution has spent hundreds of millions of years refining. But that does not seem to deter Cauwenberghs.



Dr. Gert Cauwenberghs posing in front of an oscilloscope.
Image: inc.ucsd.edu

ART + EMPATHY LAB

What is it that we feel when we look at a piece of art? Are aesthetic preferences universal or culturally influenced? How does artistic engagement contribute to individual and community health?

These are the questions at the heart of the Arthur C. Clarke Center for Human Imagination's new Art + Empathy research project, led by Ying Wu, Ph.D., research scientist at the Swartz Center for Computational Neuroscience, and Robert Twomey, Ph.D., artist, engineer, and Clarke Center postdoctoral scholar. While many studies of art engagement have produced fragmented insights, the Clarke Center's Art + Empathy research project will provide a comprehensive perspective of attention, arousal, empathic response, and emotional regulation in real-world encounters with art through a series of in-gallery studies with our partners at the San Diego Museum of Art.

*Dr. Ying Wu leads the Art + Empathy project.
Image: punapress.com*

Initial support for this project comes from the California Arts Council's "Research in the Arts" program, which fosters original California-based research to contribute to a growing body of international scholarship about the profound impact that the arts have in many aspects of human experience. Research can lead to the development of crucial tools for the field, and for the information of our legislators and other key decision makers.

The Art + Empathy project will establish a novel framework for understanding variations in physical and emotional responses to art and how this variability relates to prosocial predispositions and performance in tasks that require empathy and compassion. Researchers are collecting data using a cutting edge multi-modal approach that leverages innovations in wireless and wearable biosensing to monitor brain and heart activity, as well as wearable eye and motion tracking, and computer vision facial expression analysis. These diverse modalities of data, along with participants' own subjective responses, will be combined to better understand how people integrate visual information during art engagement and relate to moving or unsettling aspects of an art encounter. This information will provide an integrated perspective on neurological, physical, and behavioral responses to art that reveals the basis for individual differences in aesthetic engagement and identify the role of cultural differences in art appreciation.

Participants rating their feelings after viewing art at the San Diego Museum of Art in Balboa Park.

The Clarke Center is one of 10 grantees chosen for the Research in the Arts program. The award was featured as part of a larger announcement from the California Arts Council, with grant funds totaling a projected $24,508,541 for 2018-19, the highest investment in statewide arts programming since the 2000-01 fiscal year.

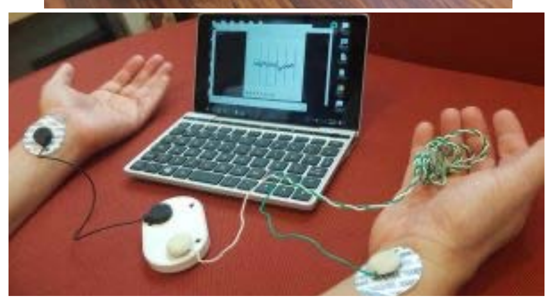
"Arts and culture are inextricably linked to our humanity," said Nashormeh Lindo, California Arts Council Chair. "They serve as a universal touchpoint for understanding and addressing our societal issues -- dismantling inequity, healing trauma, reframing justice, inspiring truth and shaping futures. The Council is humbled to support the vital work of the Arthur C. Clarke Center for Human Imagination and its passionate efforts to make a better California for us all."

*Written by Patrick Coleman
Originally published in the San Diego Museum of Art Member Magazine, February-May 2020*

ESCAPE ROOM 2.0

It was only about ten years ago when escape rooms began popping up all around the US. These interactive game spaces require small groups of players to solve various puzzles that allow them to "escape" from their fictitious detention. Dr. Ying Wu realized the potential of the trendy pastime as a means to study problem solving, particularly what tactics are used, how stressors affect the cognitive resources recruited for solving puzzles, and how signals from the brain are modulated during game play.

To track users' strategies and physiological responses in a controlled way, Wu knew that the escape room could not be held in the physical world, that it must be conducted in virtual reality. With VR, she can monitor eye movements, integrate these data with electrophysiological signals from the brain and heart, and label fixated objects using tags that are programmed into the virtual environment. She enlisted undergraduate visual arts major, Joshua Pallag, to help design the game. Joshua already had lots of experience with game rooms as a participant. But translating that real-life experience into a virtual one was challenging.



TOP: Example of woman playing with virtual reality scenes created by Dr. Ying Wu and undergrad developer Robin Xu

BOTTOM: Hearty Patch system designed at SCCN to stream realtime Electrocardiography (ECG) signals that can be synchronized with EEG signals. Electrocardiography estimates mental states related to stress.
Image: insight.ucsd.edu

Undergraduate Joshua Pallag designed the Escape Rooms.

A bookcase in an escape room. The spotlit region signals where the player is looking.
Image: insight.ucsd.edu

He set out to build escape rooms that would last about twenty-five minutes and involve three puzzles that needed to be solved to escape. The challenge was making them hard enough to require problem solving skills, but not so difficult that players would be stumped. When players would enter the virtual environment, they would see a sparsely furnished room with some book cases, vases, and chairs. They would be in one of three game scenarios. Each scenario required that players find a blue key, but the puzzles leading to the key unlocking the exit door differed.

So far, the games are still in demo phase while Wu runs pilot subjects to assess the relative difficulty of the three different scenarios. Soon, she will begin recruiting healthy adults who she will adorn with wearable EEG, eye tracking, and heart rate monitoring devices.

Do you want to participate in this study? Email ycwu@ucsd.edu