Technology Observer

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NJIT
New Jersey's Science &
Technology University

What seems astonishing is that a mere three-pound object, made of the same atoms that constitute everything else under the sun, is capable of directing virtually everything that humans have done: flying to the moon and hitting seventy home runs, writing Hamlet and building the Taj Mahal — even unlocking the secrets of the brain itself.

—Joel Havemann

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Message from the Editor

How is it that a single something, which is still largely not understood, can be responsible for all of our greatness, our flaws, and our ability to shape our world? Modern science has gained a great deal of understanding regarding the qualities of tangible objects and their physical laws and the nature of our world. Yet our minds mostly remain a mystery. Technologies in the field of neuroscience are continuously advancing, allowing for more discoveries about the human brain. Perhaps one day, the secrets of our minds will be understood.

Neuroscience, the study of the nervous system, dates back to the ancient Egyptians. Trepanation, one of the oldest forms of surgery, involved drilling into the skull in order to relieve headaches or cranial pressure. In ancient Greece, it was Hippocrates who first suggested that consciousness, sensation, and intelligence involved the brain. However, it was not until recently that technology and innovation have allowed mankind to unlock some of the hidden secrets of our consciousness. With the invention of the modern microscope in the 1890's and with the eventual development of sophisticated neuroimaging techniques such as MRI, the field of neuroscience has grown significantly.

New technologies show time and time again that the human brain is a vast sea of information, innovation, and many, many secrets. This issue of the *Technology Observer* will examine how neuroscience helps us to unlock the mysteries of our own minds. The article topics range from new gadgets and technologies to new research in mental diseases and illnesses. We are fortunate to be living in a time when the field of neuroscience is growing rapidly. As our understanding of the brain continues to grow, human limitations are continually pushed higher. We are confined only by our imaginations.

There is no doubting the high level of devotion and skill of those who contributed to this publication. I would like to thank Dr. Miura for his expertise in neuroscience and Dr. Dine for his continued support and advice. On behalf of the staff of this publication, it is my honor to present to you the twelfth issue of the *Technology Observer*.

Respectfully yours,
Peter Besada
Editor-in-Chief

Photographer: Mona Taherisefat

About New Jersey Institute of Technology
THE EDGE IN KNOWLEDGE

The New Jersey Institute of Technology is a public research university enrolling over 8,800 students. The university offers bachelor's, master's and doctoral degrees in 120 programs through its five colleges: Newark College of Engineering, New Jersey School of Architecture, College of Science and Liberal Arts, School of Management and Albert Dorman Honors College. A top-tier research university, NJIT houses laboratories in 48 key areas and 20 state-of-the-art multidisciplinary centers. Research initiatives include manufacturing, microelectronics, multimedia, transportation, computer science, solar astrophysics, environmental engineering and science, and architecture and building science.

About Albert Dorman Honors College
ENGAGING THE FUTURE

The vision of the Albert Dorman Honors College is the engagement of the brightest students with the best faculty, original research, and practice-oriented projects. The context of this engagement is inquiry-based learning, a computer-intense campus, an urban setting, diverse population, global relationships, and an environment that is erudite and transformational.

The Albert Dorman Honors College curently enrolls over 640 students, with average SAT scores above 1320. Students are enrolled in honors courses, participate in leadership colloquia, partake in professional projects, and conduct research with faculty at various NJIT research centers. These scholars work closely with national and international businesses and industries, and participate locally in community activities. They are leaders on the NJIT campus, and future leaders in the science, engineering, mathematics, and technology professions.

For more information :: honors.njit.edu

Fellows of the Honors College

The Interdisciplinary Design Studio (IDS), established under the Albert Dorman Honors College, teaches honors students how to become innovative entrepreneurs. Introduced in the fall of 2011, 24 honors freshman working in small teams are given the opportunity to work with faculty advisers and industry mentors who counsel them on aspects of their projects.[1] Two such industry mentors have recently been appointed to the IDS Advisory Board and will guide honors students in their prospective entrepreneurial endeavors. Mr. Kevin Carswell and Mr. Manish Patel have been named *Fellows of the Honors College* and are available both on and off campus to help honors students carry their careers forward.

Mr. Kevin Carswell, Vice President of Intellectual Property Engineering and Operations for International Business Machines, is responsible for helping run IBM's Patent and Technology Licensing business. He has been directly involved in the development of IBM's most powerful and versatile high-end computer systems, leading the effort to develop specialized processors for all three major current-generation gaming consoles: Sony PS3, Microsoft Xbox 360 and Nintendo Wii. He was specifically involved in the development of IBM's BlueGene and Roadrunner supercomputers.[2]

Mr. Manish Patel (l.) and Mr. Kevin Carswell (r.)

Mr. Manish Patel, co-founder of an innovation-branding-marketing firm called The Think Cloud, brings an engineering background with product development experience to provide clients with well-rounded and efficient teams with talent and vision. He had opportunities to drive many high visibility projects across a wide range of industries, including delivering water pumps for the Everglades Restoration project, delivering the Champion 4 while at American Standard, and working on the Business Week Gold winning fire extinguisher for The Home Depot.[3]

"Those of us in the mentoring program look at all of their projects as potential revenue streams of the future for the university. They have the potential to turn their ideas into real business opportunities. The topics the students have chosen are relating to energy/safety/aging population/medicine/etc. Those are all real issues that require their help and create opportunity for them."

-Mr. Manish Patel

"Work hard. Learn the fundamentals. And have some fun. If you establish solid foundations in the basic core engineering skills — math, physics, analysis and problem solving you can go just about anywhere. Find an area of engineering where you can feel passionate about your work. If you do this, you will find both success and happiness."

-Mr. Kevin Carswell

Mr. Carswell and Mr. Patel are both highly qualified and experienced in their fields and both IDS board members have very long lists of personal achievements built over their time in the entrepreneurial world. In the midst of it all, it may be quite easily forgotten that they were once NJIT students. But they were; they experienced everything NJIT had to offer, and it was their experience here that made them want to give back to future students by helping them to succeed in any way they could.

Mr. Patel expressed his deepest respect for the campus and everything that had been accomplished in the years since he had graduated. "I had the chance to work with Judith Sheft on a potential project with NJIT, and in doing so gained insight into all of the recent growth in areas like the School of Architecture and Design,"[3] said Patel. "Those recent interactions with the university led me to offer any assistance I could to help build on the tremendous recent achievements at the school. What is happening now is truly amazing and I am extremely proud to say I went here."[3]

Mr. Carwell made his involvement with IDS nothing short of goodwill towards students, also stating, "I had worked closely with Dr. Atam Dhawan in the ECE Department and had many discussions with him about the Interdisciplinary Design Studio concept. When Dr. Dhawan went over to the Honors College to formally set up the program, I was happy to join his advisory board to help make the program a success. When I started to interact with the IDS students, I was very impressed with their passion and drive."[2]

Message from the Dean

Welcome to the twelfth edition of the *Technology Observer*, a publication founded, managed, researched, written, designed and edited by Albert Dorman Honors College students. In this number they report again on several emerging technologies of high societal impact. Editor Peter Besada and the rest of the team focus this time on research in neuroscience and address some of the key challenges raised by neural disorders and diseases as well as how to define consciousness.

Neurological disorders and mental health in general together form the leading healthcare issue in the world today. A report issued by the World Health Organization (WHO) estimates the number of people suffering from neurological disorders worldwide as close to one billion, a total that is steadily increasing as populations age still further. Cerebrovascular diseases, which represent a massive healthcare burden in both developing and developed countries, are also the leading cause of death worldwide. In the United States alone, neurological disorders and diseases account for about one third of total healthcare costs or for some $900 billion a year. Recently WHO passed a Resolution (EB 130.R8) entitled "*Global Burden of Mental Disorders and the Need for a Comprehensive, Co-ordinated Response from Health and Social Sectors at the Country Level*," a Resolution that was adopted by all member states. It requires collaboration across borders combined with national agency partnerships to bring about the development of a comprehensive Mental Health Action Plan.

Faculty and students at NJIT are addressing this critical need in our society: in their research they are contributing toward developing innovative technologies that improve our understanding of neurological functions and help diagnose and monitor associated disorders in order to improve healthcare. This issue of the *Technology Observer* elucidates some of the important technological concepts necessary to highlight such trends in cutting-edge research as well as complex functional behaviors of the brain that we refer to as cognition and consciousness.

In his article, David Thompson explores the recent technological advances in neuroimaging, while Fatima Ali sheds light in hers on Optogenetics, an emerging technology that characterizes cellular behavior with non-invasive light interaction, and presents the results of her study of neurodegenerative diseases such as Alzheimer's. Brain disorders related to Autism are investigated in an article by Nicole Antonicello. Even though our understanding of neuroscience in regard to the functions of the brain is still limited, the article by Tanseem Hossain introduces us to the use of smart and adaptive approaches to some of the better-known neurological functions utilized in the DARPA "super-soldier" project. Neuroscience also covers the study of brain functions connected with cognition and behavior: here Jeremy Jen explores what gives rise to consciousness and Riyashat Kazmi looks into the natural or social causes of extremes in human emotional behavior that result in psychiatric disorders and criminal acts. Walter Church introduces us to two new technologies aimed at providing eyesight both to those who have lost it and also to those who have never had it.

The next section highlights the cutting-edge research of some of our faculty as interviewed by honors students. Basim El-Toukhy discusses complexity of brain functions with Dr. Bryan Pfister, Interim Chair, Biomedical Engineering Department, on his ongoing research that is focused on understanding nervous system responses to ambient constraints and physiological conditions. Pooja Banginwar interviews two biomedical engineering faculty members, Dr. Sergei Adamovich and Dr. Richard Foulds, on neuroplasticity that refers to the brain's ability to alter its structural connectivity to change so that it can adapt and learn new activities. Andrew Helbers explores a biophysics research area with Dr. Gordon Thomas, who is pursuing exciting multidisciplinary research on hydrocephalus in collaboration with Harvard Medical School researchers and a company, Infoscitex.

The Albert Dorman Honors College is proud to have such talented and dedicated students who get involved in research early to gain insights into cutting-edge technologies, so that they will be able to take a leadership role in society for the betterment of the quality of life. A recent and related initiative in the Honors College is the Interdisciplinary Design Studio (IDS). This is an enhanced research experience for undergraduate honors students that enables them to create a roadmap to guide them from innovation to entrepreneurship within the framework of addressing critical issues and making an impact on society. Three authors, Jeremy Jen, Tanseem Hossain and Pooja Banginwar also participate in the IDS program.

I would like to thank Peter Besada and his entire team for putting together another excellent edition of the *Technology Observer*. It is my hope that you will also enjoy this issue, the fruit of the interest and vision of the participating Dorman Scholars.

Most sincerely,
Atam P. Dhawan

Dean of the Albert Dorman Honors College

Neuroimaging: Gateway to Our Brains

Neuroimaging refers to the various techniques used or associated with visually modeling the brain. Its applicability, however, has grown to include many different fields of science.

:: BY DAVID M. THOMPSON ::

How does a brain surgeon know on which part of the brain to operate? In times past, doctors had to use crude methods of dissection in order to locate the source of a neurological problem.[1] While exploratory surgery may be an option for physical ailments concerning other parts of the body, it frequently has fatal consequences when performed on the brain. Fortunately, in modern times, doctors can obtain two-dimensional and sometimes even three-dimensional pictures through non-invasive neuro-imaging techniques.

Modern neuroimaging influences and guides developing technologies designed to correct and diagnose problems in the brain, nerves, and spinal cord.

As early as 280 B.C., Erasistratus of Chios, the Greek anatomist, hypothesized that the human brain consisted of several distinct regions.[2] Illustrations in *Cerebri Anatome*, published by Thomas Willis in 1664, were consistent with the findings and predictions of Erasistratus.[3] The replication of these regions into a viewable form and other visual modeling techniques is known today as neuroimaging. Modern neuroimaging influences and guides developing technologies designed to correct and diagnose problems in the brain, nerves, and spinal cord. Erasistratus's theory spawned an entire field dedicated to generating images of his proposed cranial subdivisions.

…CAT scans also develop images of the body in order to help reach a diagnosis.

Frighteningly, although evidence of brain surgery goes as far back as pre-Incan civilizations circa 2000 B.C., it was not until the early twentieth century that imaging a person's brain was possible without dissection.[11] In 1916, Walter Dandy, commonly called the father of neurosurgery, was one of the first to develop images of the brain. "His initial studies involved traditional contrast agents…that could be injected into the ventricles. The early results…were not very encouraging."[4] [5] However, through further research by Dandy, his peers, and scientific posterity, modern neuroimaging techniques like Magnetic Resonance Imaging (MRIs) and Computerized Axial Tomography (CAT Scans) were born.

Well known in the medical industry, MRIs are primarily used to distinguish unhealthy tissue from normal body tissue. By passing electrical currents through coils within the machine, radio waves are generated and magnets begin to spin, placing patients within a strong magnetic field. A computer then receives the resulting data signals and turns them into an image. Often, it takes an experienced doctor with a good "medical gaze" to detect the few subtleties characteristic of diseased tissue. That MRIs are key to early detection is clear in radiologist Moffat's claim that identification of tumors responsive to therapy helps facilitate modification of an ineffective treatment.[8] Stated differently, with the help of an MRI, a skilled doctor can help reveal a treatment option as useless or possibly harmful.

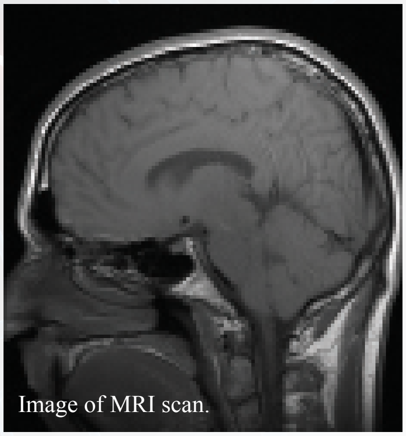


Image of MRI scan.

Similar to MRIs, CAT scans also develop images of the body in order to help reach a diagnosis. However, CAT scans differ from MRIs in that instead of utilizing a magnetic field to generate images, CAT scans analyze waves (i.e., X-Rays) sent through the body, a method called tomography. Anatomic pathologist Melissa Stöppler states that CAT scans "are used to verify the presence or absence of tumors, infection, abnormal anatomy, or changes of the body from trauma" and that CAT scans can help determine when minimally invasive procedures can be used. This reduces the need to perform surgery to accomplish the same goal.[6] Occasionally, contrast materials and dyes are employed intravenously to improve scan results.

The MRI Diagnostic Machine located at the NeuroSpine Center of Wisconsin.

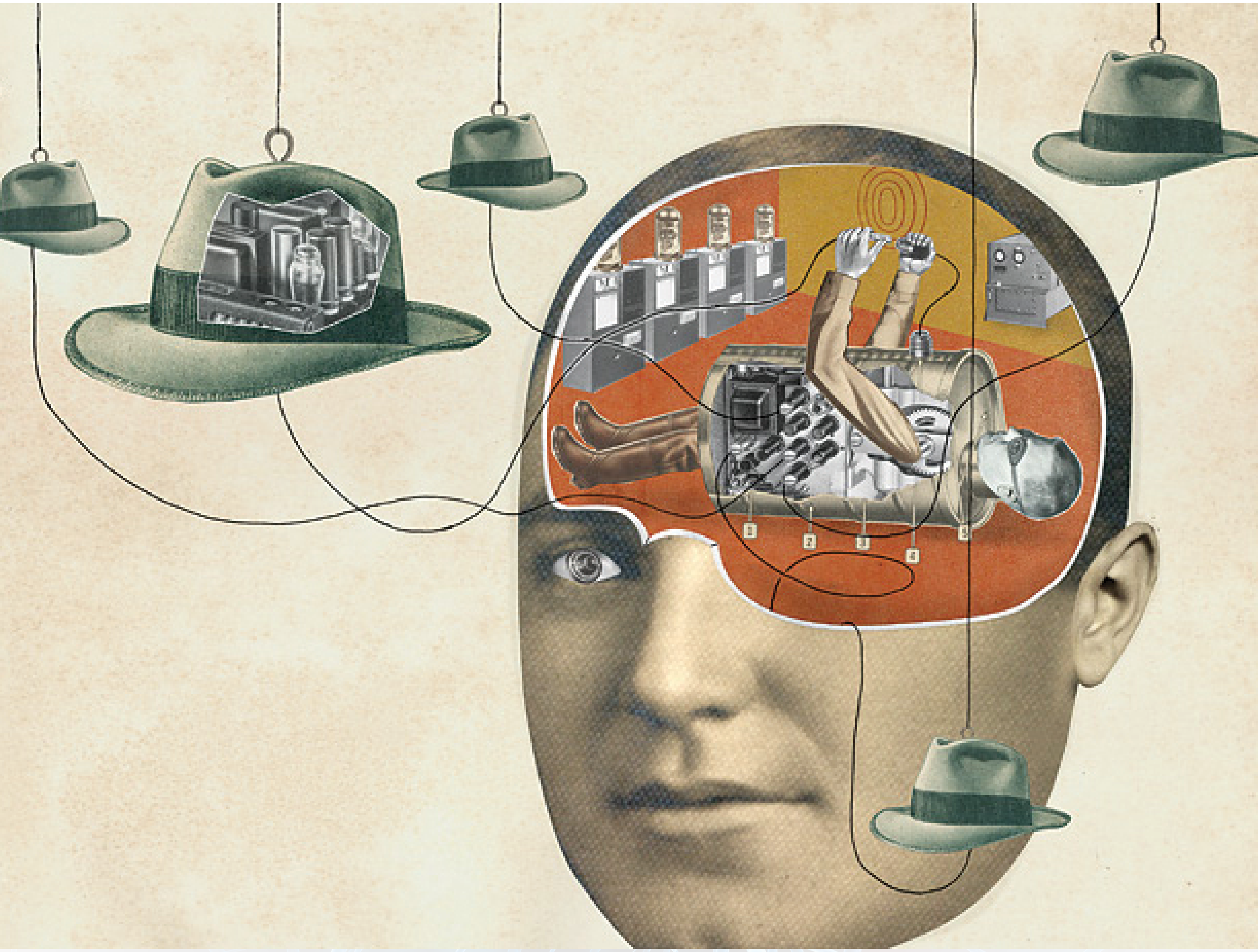
Intuitively, one might believe that neuroimaging techniques would solely find utilization in fields such as neuroscience, neurology, or other brain-related specializations. Astoundingly, a biological article published in 1998 by Capowiez, et al. documents a bizarre application of neuroimaging techniques completely unrelated to these fields. In this study, CAT scan imaging methods were used to generate three dimensional images of earthworm burrowing systems in Switzerland over a two-year period.[9] The team successfully concluded that these earthworms have different burrowing patterns depending on the season. The discovery of this new application may significantly change both how paleontologists study fossils and how biologists view worm behavior in general.

Modern neuroscience studies show that human beings have a uniquely designed capacity to enjoy and experience music.

One of the most interesting things about neuroimaging is how closely it relates neuroscience and the detailed study of the brain. Complementary work done between these specializations allows doctors and scientists alike to gain new insights about psychology and the human brain. For example, modern neuroscience studies show that human beings have a uniquely designed capacity to enjoy and experience music. While listening to music, human brains employ chemicals such as dopamine to create a pleasant sensation. On the other hand, dogs and other animals hear the sound of music, but they do not recognize it as anything special.[7] Perhaps knowing that human beings' brains have a section devoted to recognizing and enjoying music, one can better comprehend and appreciate the various types of music with which we come in contact.

The immense significance of neuroimaging can be clearly seen by technological advances such as MRIs and CAT scans. Neuroimaging boosts the ability of imaging by expanding its horizons to include biology and psychology. As University of Missouri sociology professor Amit Prasad puts it, "Development of imaging techniques allows for the production of new images that represent further reconfigurations of the body and thereby further extend the medical gaze."[10] It is easy to place confidence in the future of neuroimaging. Innovative techniques will soon extend numerous and diverse opportunities for human beings throughout the world.

David M. Thompson is a fourth year undergraduate student studying chemical engineering at NJIT.



Harnessing the Power of Brain Plasticity

One research project at NJIT is examining ways to use robotics and human-computer interaction to take advantage of neuroplasticity to help victims of brain trauma develop new neural pathways.

:: BY POOJA BANGINWAR ::

Neuroplasticity: the plastic brain. An idea once considered impossible, has today opened the way to many remarkable possibilities. Neuroplasticity refers to our brain's ability to alter its structure and function through thought and activity.[1] Before plasticity in the adult brain was discovered, it was known that in the initial stages of development after birth, the brain is highly susceptible to change and learning, but it was supposed that after a critical period, the brain was not capable of such change.[2] We now know this to be false, because, in reality, our brain is capable of altering and forming new connections, even as we age. Throughout our lives, our experiences, actions and thoughts all influence the way our brain is shaped, and therefore who we are. Each of our experiences is like a footprint that leaves its mark, which, depending on whether it is revisited or forgotten, deepens or fades away. This concept is important because it is what allows us to continually adapt to new situations, and to exercise and strengthen what skills are most applicable to us through reinforcement. In medicine and therapy, this is applicable because it means that, sometimes, proper stimulations and repetitions can prove a better remedy than any medication. And, in education, it is relevant because it means understanding that, because we are all shaped differently, applying a standard method towards teaching or solving a problem does not always work.

Each of our experiences is like a footprint that leaves its mark, but which, depending on whether it is revisited or forgotten, deepens or fades away.

Neuroplasticity stems from the word neuron, referring to the billions of nerve cells which carry electrical signals throughout our body and brain, and the word plastic, meaning "changeable, malleable, flexible."

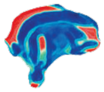
Localization verses Plasticity

Previously, the model of the brain was based on the concept of localization, the idea that each of our functions and abilities was controlled by a specific area on our brain map (a map that relates the brain's structure to its function), and that this control area remained mostly the same for our entire lives. This impression was based on the perception that the brain was like a machine, with fixed parts controlling different functions. If a part failed, or was damaged, it was understood that it could not be fixed or replaced on its own. Thus, brain damage, whether pre-natal or resulting from injury or disease, was considered permanent.[1] For years, this prevented doctors and therapists from taking a proactive approach towards helping affected individuals regain lost function, because it was not considered possible. Instead, the focus was on "compensation" treatments which created methods that allowed individuals to work around their weaknesses. So, if an individual had impaired vision, they were taught to use their auditory abilities to make up for the limitation.[1] If the problem was an impaired limb, the person was taught to function entirely on the good limb. Although these treatments taught individuals how to live with their limitations, they did nothing to help them overcome them. It was only when scientists began to see discrepancies in the theory of localization, when patients with allegedly fixed brain damage recovered lost functions, and when evidence of brain maps perpetually changing became evident, that scientists began considering the possibility of a "plastic" brain. Still, the idea was taboo for many years, for it clearly challenged the foundation of the brain model, which was widely accepted by the scientific community, and taught by institutions worldwide.[1]

…when we are born, each of our neurons in our cerebral cortex has about 2,500 synapses.

Neuroplasticity and its Forms

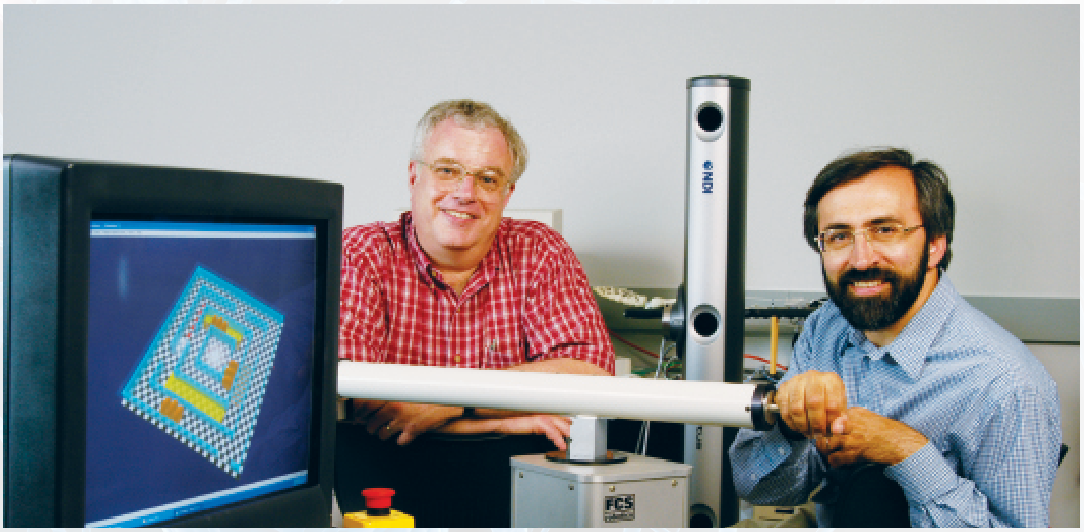
Neuroplasticity stems from the word neuron, referring to the billions of nerve cells which carry electrical signals throughout our body and brain, and the word plastic, meaning "changeable, malleable, flexible."[1] A nerve cell, or neuron, is the basic unit of our nervous system, which is responsible for carrying information throughout our body. It is made up of three main parts: the cell body, the axon, and dendrites.[3] Electric signals carrying information are transmitted along the axon of a neuron until they come to a synapse, which is the space connecting the axon of one neuron to the receiving dendrite of another. When we refer to plasticity, and the new connections that are continually being formed between neurons, we refer to the synapses, or connections being formed between axons and dendrites. In fact, when we are born, each of the neurons in our cerebral cortex has about 2,500 synapses. By the age of two or three, this number grows to about 15,000 synapses per neuron.[4] However, as we age



further, our brain keeps the connections that are important, and eliminates those which are either unused or unnecessary through a process called synaptic pruning.[5] Consequently, the adult brain has fewer synapses per neuron, than the brain of a child at the age of two or three.

Plasticity can be applied as a general term, but there are actually various types of plasticity. Three main types include synaptic plasticity, neurogenesis, and functional compensatory plasticity.[6] Synaptic plasticity may be called the most common, because it is what allows us to learn on a day-to-day basis. For instance, when we meet someone new and learn his or her name, connections form between certain neurons that allow us to register the person's appearance, voice, and name collectively. If, after the initial meeting, we revisit this person and name repeatedly, the initial connections formed grow stronger and allow us to retain the knowledge in our memory. However, if what we learned is not revisited, the connections may fade away, and we start to forget parts such as the person's name. It is no lie when people say, "practice makes perfect," because revisiting the connections used for a certain activity strengthens them and makes them more efficient. Another type of plasticity is neurogenesis, and this occurs when new nerve cells, or neurons, arise from stem cells and multiply. Earlier, it was not believed that neurons that died could be replaced in the adult brain. However, after 1944, scientific evidence showed that neurogenesis occurs in the hippocampal area of the brain and that new neurons migrate to areas where they are required to replace old ones.[6] This has been shown to occur especially after cases of abrupt neuronal death, such as after a stroke, and serves the function of making way for alternative pathways to replace damaged ones. Lastly, there is functional compensatory plasticity which explains how, in spite of age, some retain exceptional neurocognitive abilities. This occurs because, even if there is some neurological decline with age, sustaining mental stimulation allows our brain to create compensatory pathways when old ones are damaged.[6] Hence, even if certain pathways grow weak with age, constant stimulation allows our brain to find compensatory alternative pathways to maintain the same level of function.

Another type of plasticity is called neurogenesis, and this is when new nerve cells, or neurons, arise from stem cells and multiply.



Dr. Richard Foulds (l.) and Dr. Sergei Adamovich (r.) shown with the HapticMASTER, a force-controlled robotic arm used in virtual reality.

Neuroplasticity Research in Correlation to Therapy

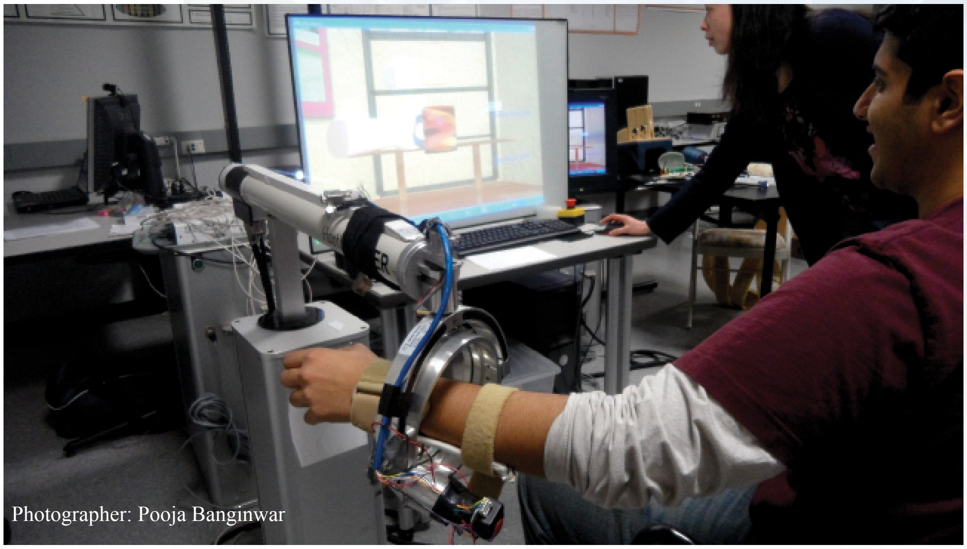
Dr. Adamovich and Dr. Foulds, both Associate Professors in the Biomedical Department at NJIT, are currently working with a team of researchers from UMDNJ-NJMS and Ph.D. students on brain plasticity research involving the use of virtual reality and robotics to help patients with Cerebral Palsy and Stroke regain function in their upper limbs. They believe that virtual-reality-based rehabilitation techniques may provide the motivation necessary for patients to stimulate their impaired limb(s) repeatedly, and consequently regain function. This new research stems from the relatively recent understanding that our brain is capable of compensating for lost function through stimulation and learning. Robots such as the HapticMASTER, a force-controlled robotic arm, and the Cyberforce, a system that allows for tactile feedback on the fingers, are used in conjunction with virtual reality programs, and allow Dr. Adamovich and his team to achieve the combination of physical and visual feedback necessary for stimulation. Individuals with brain damage resulting in the impairment of limb function, due to Stroke or Cerebral Palsy, work with these robots as a part of the research and interact with virtual reality environments to practice routine movements such as placing a mug on a shelf or playing a piano. The most important part that comes out of this research, however, is that individuals are seeing real results.

In an interview, two of Dr. Adamovich's Ph.D. students working on the project, Soha Saleh and Qinyin Qiu, and his collaborator, Dr. Foulds, share their experiences and the pleasing anecdotes they have heard from patients. Further, they provide insight on the topic of neuroplasticity and its real life implications.

Highlights from the Interview

What is the purpose of this research and what are the basic principles of neuroplasticity that guide it?

Dr. Foulds: The basic principle of what we are trying to do is encourage a person to move and it is believed that successful and intentional movement triggers a remapping of the brain. So there is neural damage due to cerebral palsy or stroke. Stroke is caused by ischemia, which prevents blood supply to the tissue and the tissue dies, or you have a hemorrhagic stroke, in which a weak blood vessel in the brain bursts [and leaks]. If blood comes into contact with neural tissue, the tissue dies. Cerebral palsy is a condition which in many ways mimics stroke. It is just more diffused damage, not as focal, but there will be multiple small lesions throughout the brain, but again limiting physical capacity. And these guys (Ph.D. students) are trying to take people with limited physical movement, which means there is brain damage that is preventing them from controlling the movement completely. And then what [they] do is say there are other healthy parts of the brain that can be convinced to take up the function that is necessary to perform the lost task. We can afford to kill off brain cells as we live, and there is enough redundancy still that we can keep doing what we did before without losing much function. But if you have a traumatic injury to the brain, there is so much of the tissue missing that what is left is not able to perform the normal function…What you want is a little bit of the function remaining, you want some of those cells that are functioning but small in number to still be able to give you some semblance of a movement, and you guys (referring to Ph.D. students sitting beside him) are tapping into this process of learning. Neuroplasticity is nothing more than neural learning. Brain cells will take on functions, largely based upon the need for those functions. If you do a task often enough, more brain cells are co-opted for that task. So, the idea is to give people mass practice, convince the brain that it needs to learn, and to convince the brain that it needs to find nearby cells that are healthy, and to move the function in the brain to a healthier spot.



Photographer: Pooja Banginwar

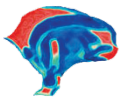
Simulation of the HapticMASTER and the virtual reality world. In this virtual reality, the patient must place a mug on the shelf shown on the screen.

What is the reason behind using a robot for therapy?

Ms. Qiu: The reason we are using a robot is that these patients are not able to finish their movement all by themselves sometimes, and they need constant help in their activities. So we have the robot give them assistance whenever they need it, and at the same time it allows us to calculate the force, velocity, and position during the movement and training. [However], active movement is very important in our training system. The patient has to initiate the movement themselves to trigger the robot to help them move forward.

Can you explain the difference between the HapticMASTER and the Cyberforce?

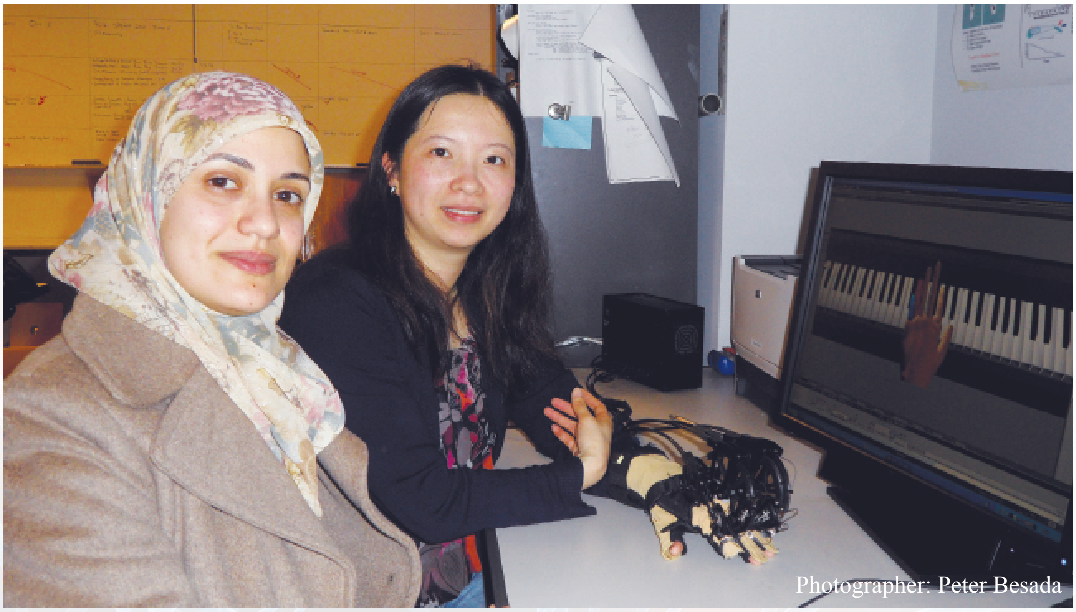
Dr. Foulds: The HapticMASTER moves the whole arm. The Cyberforce moves the fingers. So, upper extremity control is really a combination of the two. It is a process of positioning your hand and then being able to grasp. When someone has neural impairment, they have lost both gross motor control and fine motor control so the idea is to combine them. Ultimately you would like to have a robot that has both built into it, but for now we don't. So we deal with one robot that moves the arm around, and then the other is a grasping robot that assists in extensions.



What is virtual reality?

Dr. Foulds: In virtual reality you are providing feedback.

Ms. Saleh: And the feedback comes from the environment that the subject interacts with. In the training we have the video games, and there is a virtual environment, like a virtual piano they can play, or singing birds that subjects are supposed to catch. So it is an environment that the patient interacts with during training, and they interact to make hand movements.



Photographer: Peter Besada

Soha Saleh (l.) and Qinyin Qiu (r.) demonstrate the use of the Cyberforce in a piano simulation.

Dr. Foulds: (to Ms. Saleh) So, the purpose is encouragement to actually perform the hand movement.

Ms. Saleh: And to perform the movement repeatedly with a higher number of repetitions…If a therapist encourages a subject to move his or her hand, there is a limited number of repetitions that they can achieve. And, the help from the therapist will be random, may be subjective and unengineered so to speak. In virtual reality, or with the robot, with more interactive environments we are able to have many more repetitions of movement, and the robot is much more engineered to make specific movements and decide whether assistance is necessary.

Ms. Qiu: Another reason for using a virtual environment is that we are able to set variables about this environment. We can make the space bigger or smaller…We can make the game difficult or easier to play based on the impairment of the individual. So, all those variables can be set up before the game starts and can also be changed in between.

Dr. Foulds: The third part is that the individual gets feedback (visual and tactile). If they are making a hand movement [using the HapticMASTER or Cyberforce], they are seeing a graphically rendered hand performing the task, so they are not actually reaching out and touching things. They are watching a hand move on the screen, which ideally should move exactly as their hand should move if it were not impaired.

How does using virtual reality in association with the robots, correlate with neuroplasticity?

Dr. Foulds: If a task is to reach something on a shelf, you can scale the movement of the virtual arm so that it reaches the full object. When a person is making a less than ideal movement, they can program the virtual reality system so that the person gets full success, and that is encouraging the person to go to their full limit. As the person accomplishes that, the task is made harder so the person has to push beyond their limits. They get the success of seeing it happen. The brain says, "Aha, there is success!" It should then say that a successful movement should be reinforced, by acquiring more neural territory to control it. And, as you acquire more neural territory, you should be able to make the movement a little bit better each time. The idea is to make the task more challenging, so the next time it is harder to get the same success. This continues this process of reinforcing.

Can we quantify plasticity?

Ms. Saleh: Quantifying plasticity is a challenge. Cell-based research quantifies plasticity at the cell-synapse level. In our lab, we try to quantify plasticity at the brain level using functional MRI (brain lights up where there is neural activity) and transcranial magnetic stimulation (TMS), but that is challenging given that the pattern of plasticity is not well defined.

What inspired this line of research?

Dr. Foulds: Dr. Adamovich, who is currently leading all the research, came over from Rutgers having done a lot of virtual reality work. He was talking about using virtual reality not for solving the problem, not having a robot reach up and get the glass off the shelf for you, but having the robot help you learn to get up and reach the glass with your own arm. That was totally new to me, and he taught me that…The whole idea is driven by the fact that technology can be of assistance. There is a nice emerging neuroscience research that says that the brain learns, and that the brain can continue to learn. That is relatively new. That has been in the last twenty years. Before that, people thought there was not much that could be changed when there was brain damage. The whole theory of neuroplasticity is what has led to this neural engineering work. And the issue with adding engineering is finding ways to encourage the human sensory system to see what is going on, to feel a reward, and to put the person in a situation where they want to do it (repeat a movement) over and over again because it takes many practices to make this happen, and therapy costs a fortune. Therapists also don't always have the time to do this with people. And you want a system that is not simply moving a person's limb, but one that is allowing a person to move as much as they can, and then assisting them to be successful. And that is where technology comes in.

What impact have you been seeing from the research so far?

"For me, by far the most important thing is that, when this is all done, has it been worth someone's while?"

Ms. Qiu: We have a couple of subjects coming in who have told us that all of a sudden they are able to hold the TV remote control with their impaired hand without even noticing it. Also, a subject started playing the violin again after not being able to after stroke.

Ms. Saleh: Another subject emailed us saying that her mom noticed that she was cutting a strawberry with her impaired hand without noticing it. Sometimes functional improvement is natural so subjects do things they were not able to before, without realizing it.

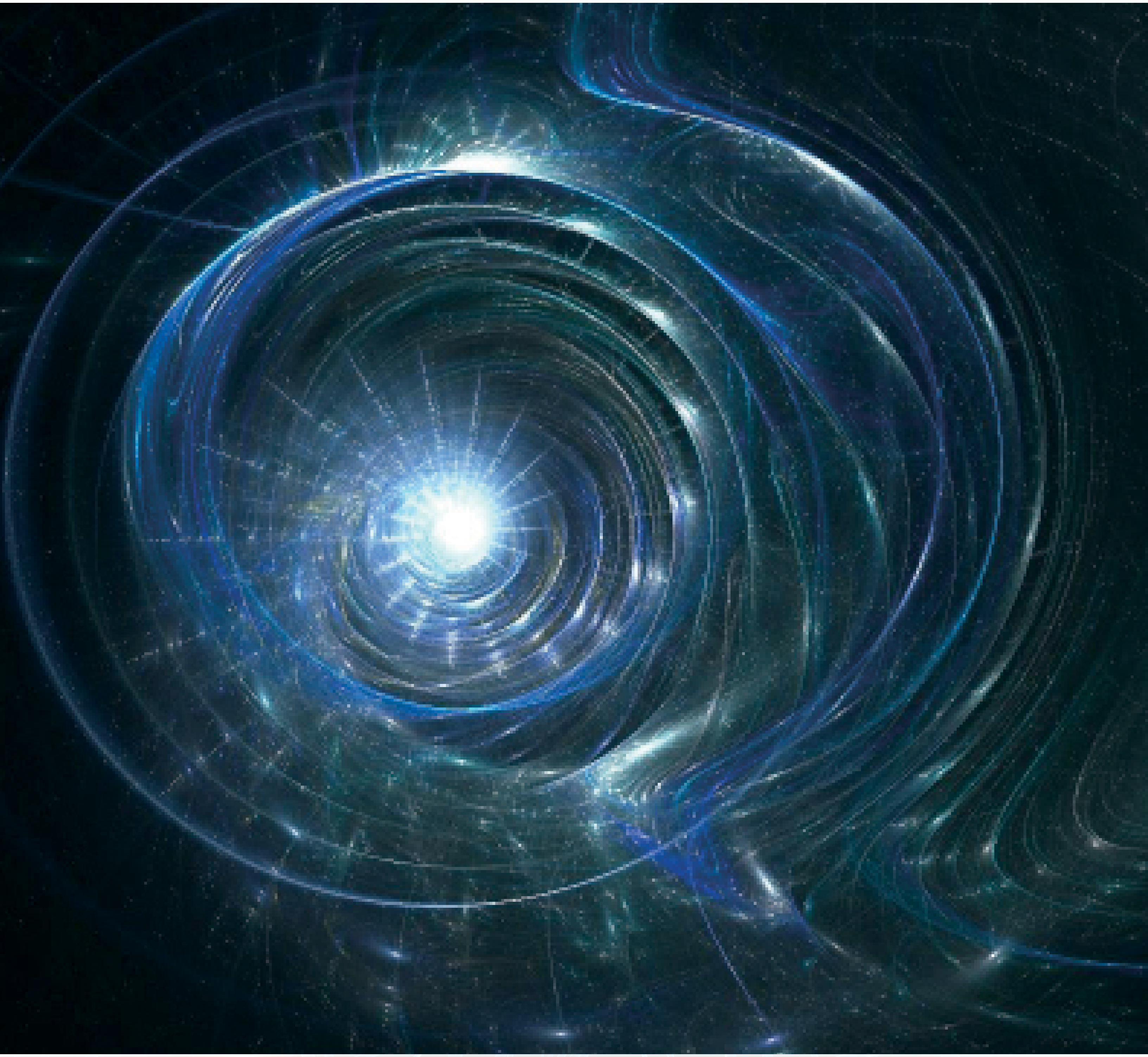
Dr. Foulds: For me, by far, the most important thing is that, when this is all done, has it been worth someone's while? Has it changed someone's life? And, I like hearing these stories, because you are coupling those anecdotal stories with hard evidence that something actually happened. They are generating functional change in their everyday lives that is being stimulated by the work they are doing. And that is what the goal really is; the goal is to be able to see that this is a better way to provide therapy, that this is a better way to provide a service to the population.

Conclusion

Neuroplasticity is a continually expanding area. As more is being discovered, we are realizing that the brain has many mechanisms for accommodating life changes, damage, and age-related decline. However, it follows the "use it or lose it" motto,[1] and failing to realize its potential may mean failing to use its potential. By continually engaging ourselves in new learning, however, we can maintain and increase the level of function of our brains. Still, Dr. Adamovich's, and Dr. Foulds' research shows that simply learning new things does not help if the interest, or motivation is not there. It is only when the learning is relevant, and attracts our focus and attention, that it has the capacity to make a plastic change. This concept of learning being more effective when engaging, is now being used by many researchers and companies to devise brain fitness programs that target children and adults, in want of either sharpening or maintaining their skills. As can be seen from the aforementioned research, it is also being used in devising therapeutic programs for individuals who need neurological rehabilitation, because in order for the body to relearn a lost function, a lot of motivation is required to overcome frustration. Essentially, our understanding of neuroplasticity is allowing us to branch out into many areas that explore the potential of our plastic brain. Whether it is in medicine, education, therapy, or another field, understanding neuroplasticity is allowing us to refine our understanding of how the human brain works, and therefore leading to better treatments, better approaches, and a better life.

"…we are realizing that the brain has many mechanisms for accommodating to life changes, damage, and age-related decline."

Pooja Banginwar is a first year undergraduate student studying biomedical engineering at NJIT.



Cause of Consciousness

The examination of free will, determinism, the experimental work of Benjamin Libet regarding conscious decisions, and why it matters.

:: BY JEREMY JEN::

Consciousness is experienced by each one of us every morning when we awake, yet we are still unable to pin down the precise meaning of this concept. Just stop reading and think for a minute: how exactly *would* you define "consciousness"? According to Time Magazine, consciousness is simply "the activity of the brain," mere responses to outward stimuli.[5] However, computers and other machines are designed to respond to outward stimuli. Do they then possess "consciousness"? As even the authoritative resource, *Human Brain Function*,[1] written and compiled by eight neuroscientists, declared, "At this point, the reader will expect to find a careful and precise definition of consciousness. You will be disappointed. Consciousness has not yet become a scientific term that can be defined in this way." Therefore, in this article, we will follow in the footsteps of these neuroscientists, to "adopt William James' approach and claim that we all know what consciousness is."[1] As we more deeply examine determinism and free will, as well as look at current brain research, it may be possible to more fully understand the cause of consciousness, as well as its definition.

Determinism can be defined as the belief that events are predetermined, and free will can be defined as the ability to change events through one's choices.

Before we plunge headlong into this immense sea of complexity, let us first define what determinism and free will are. Determinism can be defined as the belief that events are predetermined, and free will can be defined as the ability to change events through one's choices. Probably the most famous clashes between these two stances originated from the monotheistic religions, especially Christianity, which proposed a Superior Being who not only controls all "earthly" activity, but also gives humanity a will free to act independently. Throughout the past two millennia, this conundrum has continued to divide not only theologies and philosophies in the Western world, but also scientific thought concerning how the physical world operates. As the *New York Times* noted in 2011,

> "At an abstract level, people seem to be what philosophers call incompatibilists: those who believe free will is incompatible with determinism … But there is also a school of philosophers — in fact, perhaps the majority school — who consider free will compatible with their definition of determinism. These compatibilists believe that we do make choices, even though these choices are determined by previous events and influences."[8]

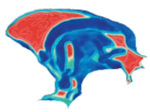
Even today, this question of determinism and uncertainty has not been solved and is a major conflict in the field of philosophy.

However, why is this discussion about determinism and free will important and relevant to consciousness? Even though this discussion seems better left to a paper on philosophy, not on neurology, determinism and free will are actually integral parts to understanding the cause of neurological consciousness. As we shall see, they are directly related to the brain experiments of Dr. Benjamin Libet.

Benjamin Libet (1916-2007) was, in his own words, "a neuroscientist who carried out fundamental experimental research on brain processing in conscious experience."[7] Born a Jewish Ukrainian, this brilliant scientist did extensive research on human consciousness in an attempt to uncover more information concerning this mysterious topic. His most famous work was published in the 1970s, when he recorded human brain activity in subjects before and during their physical actions to determine when individual conscious intentions, or will, would appear.[2] His extensive work, though highly critiqued by fellow scientists, has contributed much to our current understanding of neurology and human consciousness.

His experiments were roughly as follows: A clock was constructed to fully revolve in 2.56 seconds, rather than the 60 seconds of a usual sweep-second clock hand. This 2.56 second clock was divided into 60 segments, ensuring that each marked-off "second" was just under 43 milliseconds of actual time. The precision of this measurement was then determined to be roughly that interval of time. Equipment was readied to measure the so-called readiness potentials (RPs) of the subjects, or changes in electronegativity in their scalps, indicating brain processes. Then, in the actual experiment, subjects were told to flick their wrists whenever they wanted, and to note at exactly which time they were conscious of initiating their wrist movement. These results were tabulated.[2] The results of this experiment showed the readiness potentials that corresponded with the wrist movement first appeared about four hundred milliseconds before subjects noted a conscious will to act, with Libet noting that "this value was the same even when subjects reported having preplanned roughly when to act!"[2] Four hundred milliseconds is nearly half a second, which brings us to the next perplexing question: how can this actually occur?

Libet himself implied that, based on the experiment, a person's "will to act" subconsciously begins in the brain half a second before the person himself is aware of it.[2] However, in sports



such as basketball or table tennis, sudden reactions to sudden movements take much less than half a second to occur. How would Libet's hypothesis explain a decision based on split-second timing? Libet counters this decision-making with the assertion that "a quick reaction to an unwarned stimulus also lacks a preceding RP, and it is not a freely voluntary act."[2] Such actions are not the result of conscious decisions, but quick, non-premeditated responses. Nevertheless, this still does not explain human reaction. How does one then train oneself to respond differently to different unwarned stimuli? The reaction of a trained automobile driver in a dangerous situation is extremely different from the reaction of an untrained driver, yet if a quick reaction is not a "freely voluntary act," is it possible for one to act differently in similar situations?

"Our own preconscious mental processes look like neurochemical and associated physical activites in our brain."

The answer, according to Max Velmans, professor of psychology at the University of London, lies in the apparent fact that consciousness is bound up within the physical neural complexes that we call the brain. Through observations proving how conscious experiences affect the brain, Velmans disagrees with Libet, stating, "Our own preconscious mental processes look like neurochemical and associated physical activities in our brains."[9] However, in the appendix of the same article he again states, "It is important to remember that no discovery that reduces consciousness to brain has yet been made. Physicalism, therefore, is partly an expression of faith, based on precedents in other areas of science."[9] Even though Velmans believes that "physicalism," i.e., the idea that consciousness is comprised of solely physical matter, is still not fully proven by science, he concludes that regardless of personal belief, all consciousness is ultimately derived from physical sources.

However, what is the perspective of Libet on this matter? Interestingly enough, Libet himself supports the idea that the human will is able to overcome its subconscious urges. As he writes, "My conclusion about free will, one genuinely free in the non-determined sense, is then that its existence is at least as good, if not a better, scientific option than is its denial by determinist theory."[2] However, is there a free will *beyond* the physical components, or, as Velmans asserts, is that free will bound up *within* the physical brain? According to his paper, *Can Conscious Experience Affect Brain Activity*, written as a response to Velmans' paper, Libet wrote of his proposed *Conscious Mental Field* (CMF) theory. This theory "proposes a mode of intracerebral communication [that] can proceed without requiring neural pathways."[3] In other words, the Conscious Mental Field is a property existing in the brain that cannot be observed physically, and that allows conscious decisions within the brain to be made without neural pathways. This theory, according to Libet, "provides a 'mechanism' that fits the known properties of conscious experience, including that of conscious free will;"[3] in essence, a "soul-like" component of our mind that allows us to make conscious decisions.

This latest view by Libet, a mental field seemingly immeasurable by scientific methods, seems rather radical compared to the physicalism theory. However, as Velmans pointed out, both views on consciousness have not been scientifically proven yet. There is also some speculation in this area regarding Near Death Experiences (NDEs), i.e., an out-of-the-body incident when near death. A Gallup poll recently reported that "about 34% of all adult Americans who at sometime in their life were resuscitated [have] had an NDE."[6] If the brain were capable of thought while biologically dead, this would support Libet's view of a distinction between the brain and the human "self." Some report obtaining objective sensory information while brain activity is thought to have ceased. According to Michael Schroter-Kunhardt of the Journal of Scientific Exploration, "Certain elements of NDE-like experiences can be induced by, for example, electrical stimulation of the right temporal lobe or the use of hallucinogenic substances … Nevertheless, there are NDE-elements, such as the frequently reported life-review and certainly the acquisition of external, verifiable information concerning the physical surroundings during the experience, that cannot be explained by physiological causes."[6] While there may be some bias in that cases of false objective information may be underreported by individuals, obtaining sensory information would present a new problem, in that current understanding of the senses all involve brain processes. There is a known phenomenon of the brain developing false memories under trauma that the experiencing individual perceives as true, sometimes based on related memories, known as confabulation.[10] Still, the possibility of brain activity without known physical processes, if verified by experiment, would validate Libet's theory.

The reaction of a trained automobile driver in a dangerous situation is extremely different from the reaction of an untrained driver, yet if a quick reaction is not a "freely voluntary act," is it possible for one to act differently in similar situations?

One may look at all that we have discussed and ask the age-old question, "So what?" Why should it matter whether consciousness is controlled by physical, predetermined causes, or whether it is decided through non-physical, free decisions? The implications are immense either way. For example, if we truly lived in a deterministic world, where consciousness is not voluntary but already predetermined, humans cannot be held responsible for their actions, as even conscious actions are already determined to occur. This can lead to no logical reasons to enforce laws since these errant behaviors are already predetermined and fixed in time, so one cannot be blamed for his actions. Even if enforced punishment is able to change future actions, this method of providing social order can be justly argued as forced, unjust pain and suffering on those who performed a crime through no fault of their own. In this hypothetical world, criminals would not be responsible for their crimes, and forcing them to spend years of their lives in jail for actions out of their control is both cruel and unusual punishment.

"…the belief in free will may seem naïve to the psychologists and neuroscientists who argue that we're driven by forces beyond our conscious control."

However, if we lived in a world with total free will, problems also occur. Firstly, according to all the data we observed and received from the sciences, our human consciousness makes decisions based on information it has already received. As the New York Times notes, "… the belief in free will may seem naïve to the psychologists and neuroscientists who argue that we're driven by forces beyond our conscious control."[8] In addition, if there is a side of the brain that cannot be measured through experiments, but whose decision-making and effect is palpable and real, what are the origins of that unknown side? Scientists have been trying for years to measure that field of consciousness, but have been unsuccessful up to now.

However, what if one were able to measure consciousness? Would this be a physical attribute, perhaps a natural property of enough neurons coming together in the right way, or something more akin to a force in nature, like the gravitational field? Religious groups will claim that the CMF description of consciousness, closer to the latter of these, exactly correlates with the soul; Libet vigorously denies this, saying that this state cannot exist outside of the brain.[3] In his writings, Libet outlines a method by which one would be able to confirm his CMF theory. The experiment would require the isolation of "a small slab of sensory cortex" neurologically, yet that slab must be kept alive through continued attachment to blood vessels. As he writes, "The prediction is that electrical stimulation of the sensory slab will produce a subjective response reportable by the subject."[4] This would then prove a certain mental field is indeed present, though not directly observable by current techniques.

Nevertheless, even if Libet's experiment were performed and results were as expected, it would in no way remove the possibility of the CMF being the same as a soul. According to common religious beliefs, the soul is an entity separable from its corresponding physical body, while the CMF, according to Libet, cannot be separated from the brain tissue itself. Proving that subjects can still sense stimulations to their cortex even when not connected neurologically will merely confirm beyond a doubt that this mental field is outside of known physical phenomena, but would not differentiate between the two. The only way to determine whether consciousness is a soul or a mental field chained to the body is to perform an experiment after death, at which point the soul would presumably separate from the body. However, due to the complete inability to measure this field after human death, and the inherent difficulties in proving a negative, this distinction may be impossible to make. Still, the existence of either would provide some support for the free will stance, in that decisions could be made independently of known physical processes, provided such phenomena are not also subject to their own deterministic laws of nature.

Through examining the determinism and free will conundrum, as well as writings of both Libet and Velmans, one is able to see the vast complexity inherent in investigating the cause of consciousness through experimentation. However, as we continue to improve human technology and research, it may be possible to strike at that elusive field. Even though no final conclusion can be made concerning the cause of our human consciousness, the implications of both fields of thought possess far-reaching effects. We can only hope that one day, through the combined efforts of human minds and wills, society will be able to finally grasp the very foundation of human understanding and knowledge, the cause of consciousness.

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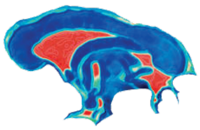


Exploring the Abyss of Criminal Psychopathy

Can we lower the incidence of violent or criminal psychopaths by changing their upbringing, or is this determined mostly by genetics?

:: BY RIYASHAT KAZMI ::

Are criminal psychopaths made or are they born? What exactly drives cold and guileful murderers like Theodore (Ted) Bundy to kill ruthlessly? Psychopathy is a mental disorder associated with many traits that may predispose one to criminal behavior, though not all psychopaths are violent or criminal. Symptoms include lack of emotion or feeling, impulsive behavior, superficial charm, failure to accept responsibility for one's actions, and a grandiose sense of self-worth.[1] Is psychopathic behavior caused by anatomic abnormalities at birth or is it a degeneration of the mind as a result of poor social conditioning? These are all thought-provoking questions that can be addressed from the nature versus nurture paradigm of psychology. Specifically, the concept of nature versus nurture speculates how much behavior is shaped by pre-existing biology and how much personality is dictated by interaction with others.[1] Given how difficult it is to ascertain the contribution of nature and nurture, making a statement as bold as "psychopaths are only born, not made" is problematic. Nonetheless, identification of the stark differences between normal and psychopathic individuals is an excellent vantage point from which to reach some consensus regarding this issue.

Psychopathy is a mental disorder associated with many traits that may predispose one to criminal behavior, though not all psychopaths are violent or criminal.

Psychopaths are described as individuals who are deceptively charming. Superficially, they appear to be no different from normal people. Upon scrutiny, however, psychopaths are notably egocentric, have little regard for others, and act upon irresistible impulses that have no logical basis. Two salient traits that are present in virtually all psychopaths are callousness and lack emotion.[7] Furthermore, many psychopaths are manipulative individuals who pursue casual yet unsympathetic romantic relationships primarily because of their synthetic charm.[5] This deceptiveness is what allowed the notorious serial killer, necrophile, kidnapper, and rapist, Theodore (Ted) Bundy, to fulfill his criminal machinations. Ted Bundy is an extreme example of a psychopath, who was not encumbered by a conscience that normal people possess, like all psychopaths.[4] This points to an intriguing behavioral pattern that emerges in psychopathic criminology; most psychopaths do not assume responsibility for their actions and solely blame others when convicted.[5] Oddly enough, most psychopaths tend to be males.[2] It is reasonable to attribute these psychopathic manifestations to changes in the anatomy and chemical composition of the brain.

A stark contrast between normal and psychopathic individuals can be observed using fMRI (functional magnetic resonance imaging). By scanning the brain for regions of increased blood flow, it is possible to detect hyperactivity of the prefrontal cortex of psychopathic subjects. Heightened prefrontal cortex activity indicates problem solving, planning, restricting and promoting of certain behaviors, and selectively manipulating information in the working memory; this hyperactivity was not observed in non-psychopathic subjects. Studies of psychopaths using fMRI have thus shown that more cognitive effort is required to project an alter ego and convincingly lie, as psychopaths execute their modus operandi.[8] The neurochemistry of psychopathic individuals is also eerily different. Both neuroanatomy and neurochemistry (examples of nature) play a momentous role in shaping antisocial behavior and have led criminal psychopaths to become ruthless killers and manipulative masterminds.

Psychopaths comprise roughly 25% of the prison population in the United States, and there are many who have eluded retribution for their heinous crimes.

Psychopaths comprise roughly 25% of the prison population in the United States, and there are many who have eluded retribution for their heinous crimes.[1] Exploring aspects of a criminally psychopathic individual's mind and brain can shed light on prospective treatments for psychopathy as well as the necessary changes by psychiatrists, criminologists, and researchers in their approaches to psychopathy.

Empathy is the ability to comprehend the emotional state of others and commiserate with them. The limbic system encodes this ability.[4] The limbic system is what sculpts a person's comprehension and experience of mother-child bonds, romance, and friendships. The angular cingulate cortex (ACC) and the insula are components of the limbic system that appear to be highly affected in persons with personality disorders or psychopathy. These are vital structures that bridge the connection between the limbic system and higher-level cognition. The insula becomes active when a person experiences strong emotions such as pain and disgust. The same phenomenon happens when a normal person observes others experiencing these emotions. The ACC coordinates error detection and becomes active when a person faces social rejection and physical pain. For individuals with personality disorders and in patients with psychopathy, these structures exhibit hypoactivity in the presence of emotional stimuli.[9] Scans obtained with fMRI validated these findings.

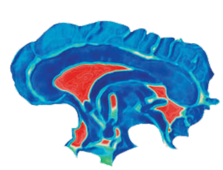
Of particular interest to criminologists and researchers, however, are the orbital-frontal region and the amygdala in the brain. The orbital-frontal region is responsible for learning from punishment and rewards. It also allows for behavioral flexibility, impulse regulation, and emotional as well as social decision-making. A plausible explanation for why men are more likely to become psychopathic murderers is that their orbital-frontal region is smaller compared to that of women. In a stressful and confrontational situation, women will be more likely to control their aggression compared to men.[2]

A plausible explanation for why men are more likely to become psychopathic murderers is that their orbital-frontal region is smaller compared to that of women.

The amygdala is an almond-shaped structure that evaluates sensory information and produces emotional responses. It is the structure of the limbic system that controls fear and aggression. Naturally, the amygdala sends an impulse signal to the brain to stimulate aggression and violent behavior. However, since women have greater orbital-frontal brain mass, they will be more able to subdue aggression than men.[2] This information is crucial because the orbital-frontal region shares an extensive nervous connection with the amygdala; it is, therefore, expected that deficiencies in one will adversely affect the functions of the other, as evident in psychopaths. Adrian Raine, chair of the Department of Criminology at the University of Pennsylvania, conducted a study that followed 1,795 individuals between the ages 3-23 and quantified these subjects' growth and development. Fear conditioning was performed on the subjects, and it was used to quantify response to fear. In essence, a particular stimulus (such as a sound) was simultaneously delivered with a displeasing stimulus (such as an electric shock). The sound was then replayed and the subjects' involuntary responses were recorded. Raine's findings were published in the American Journal of Psychiatry. The findings suggested that subjects lacking fear conditioning are more likely to become criminals. It was discovered that 137 of the subjects that became criminal offenders did not exhibit any involuntary response when provided the stimulus. Involuntary responses include: elevated heart rate, changes in pupil diameter, sweating, hand gestures, etc. Raine's behavioral findings demonstrate a dysfunction of the amygdala because the subjects that could not be conditioned by fear did not show involuntary responses and grew to become fearless criminals.[6]

The neural structures mentioned so far: the angular

Neurotransmitter testing is now available to detect brain neurotransmitter imbalances. New sophisticated equipment and tests are now available to evaluate neurotransmitter imbalances using a urine or blood sample.



It can be argued that the Joker's criminal behavior may be due to a poor diet and biochemical imbalances which affect prosocial behavior.

cingulate cortex, insula, and amygdala, collectively sustain acceptable social behavior and enable individuals to empathize with others. These structures are regions of the limbic system that activate when particular stimuli are present. Hypoactivity in these regions is thus observed in individuals who exhibit callousness and lack of emotion, the red flags for developing psychopathic and criminal behavior. In particular, this hypoactivity affects how a person senses and recognizes fear in others (including their victims). It also influences how a person exhibits positive social behaviors such as feeling magnanimous, altruistic, and resourceful in helping others who are enduring personal hardships. This provides greater evidence of why psychopathic individuals struggle with processing their own emotions and retiring their pernicious, self-destructive lifestyles.[9] The anatomical differences and psychopathic characteristics with respect to brain structures underpin how psychopaths are made from a "nature" standpoint. Most of these circumstances may appear by birth, with genetics playing an imposing role. Although differences in gross anatomy may suggest a greater influence on behalf of nature, a cursory glance at the link between diet and neurotransmitter production suggests otherwise.

Studies in nutritional biochemistry have established links between abnormal behavior and poor diet. Diet affects the levels of neurotransmitters that modulate prosocial behavior.[3] This suggests that nurturing plays a role that cannot be dismissed because diet is an aspect of culture influenced by external factors such as level of education, income, and social conditioning. Now, we shall study the biochemical imbalances that account for undesirable changes in the concentrations of neurotransmitters, particularly from a nurture viewpoint.

Neurotransmitters are neural messengers that are released from axon terminals of nerve cells for the purpose of transmitting information to other nerve cells. Significant physiological abnormalities in the brain and deviant behavior of psychopaths have been attributed to deficiencies in these naturally existing chemicals. Mass murderers and violent people tend to have very low levels of serotonin. Serotonin modulates mood arousal and its production is dependent on the nutritional intake of an amino acid known as tryptophan. This is substantiated by the fact that supplementing a diet with a high dosage of tryptophan increases serotonin levels. A note of caution is that a balance must be maintained because excessive production of serotonin has been associated with schizophrenia. Low levels of serotonin, on the other hand, have been associated with sleep disruption, obesity, depression, and intellectual deficits. Alcohol consumption also lowers serotonin levels and can play a role in cultivating violent behavior among individuals already susceptible to lowered levels of this neurotransmitter.

The concept that diet comprises the nurture aspect of a psychopath's development stems from the fact that culture and social factors heavily impact diet.

Tyrosine, an amino acid, is a precursor of dopamine and norepinephrine synthesis, chemicals also associated with mood and arousal. Abnormal tyrosine levels can cause emotional and behavioral disorders such as mania, depression, schizophrenia, and psychopathy. Tyrosine's role as a neurotransmitter precursor is further supported by its effectiveness in increasing brain concentrations of dopamine to treat depression. Tyrosine and tryptophan are two amino acids that can be obtained via a proper diet. The production of these two neurotransmitters and secretion of hormones is affected by glucose levels in the blood. A chronically high consumption of refined carbohydrates is known to cause hypoglycemia (low blood sugar), irritability, and distractibility (carbohydrate intolerance). Low blood sugar levels will impair the functions of the brain, which is metabolically active and requires a large supply of glucose and oxygen. Although this does not substantiate the claim that consuming refined carbohydrates will make people psychopathic, it does allow for an understanding of psychopathy through specialized diet and nutritional studies. This field is specifically known as psychoneuroendocrinology.[3]

Low blood sugar levels will impair the functions of the brain, which is metabolically active and requires a large supply of glucose and oxygen.

The concept that diet comprises the nurture aspect of a psychopath's development stems from the fact that culture and social factors heavily impact diet. Children at a very young age are influenced by what their guardians or parents provide as sustenance. Families with lower income, lower educational background, hermetic cultural/social customs, or neglect of the well-being of their family may inadvertently provide a diet rich in refined carbohydrates. Such families may also unknowingly neglect quality sources of vitamins and minerals. The children may thereby become accustomed to eating nutritionally deficient foods such as candy, chips, white bread, soda, sugar, white rice, etc. There may be social pressures and habits linked to a certain diet that would preclude the developing child from changing his or her diet in the future. Changing old dietary habits requires immense effort. An analogous scenario is the consumption of alcoholic beverages (known to lower serotonin levels) from a very young age. In addition to poor diet, toxic elements, such as cadmium found in refined carbohydrates or lead found in old housing complexes, may impair the brain functions of younger children. Cadmium affects glucose metabolism and regulation since it accumulates in the liver and kidneys. Lead intoxication, on the other hand, leads to hyperactivity and violence. These toxins can accumulate in complexes that house low-income families who are unable to regularly afford high quality foods such as milk, meat, and poultry. Such quality foods contain higher levels of zinc and calcium, which cleanse toxins by binding to them.[3]

The possibility of a viable link between diet and brain development, which in turn may cultivate psychopathic pathophysiology and behavior, is of importance for this matter. Additionally, the social and cultural effects of nurture (as opposed to purely nature) further enhance this link. Concrete substantiation for these claims is limited by current research; studies that observe specific neurotransmitter pathways affected by crucial amino acid restrictions from diet must be conducted. The reason why the aforementioned nurture-based scientific findings are not as robust as their nature-based counterpart is the complexity of psychoneuroendocrinology. Ineluctably, incorporating criminal psychology, neurology, endocrinology, and nutritional studies within a sphere of societal factors is an ambitious undertaking. In spite of that, fragments of evidence are being amassed to support dietary influences on a psychopathic criminal's brain. It is only a matter of time until more significant findings will be published.

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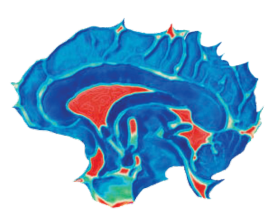


Defense Wins Battles with the Help of Neuroscience

New research in neuroscience is being considered to aid the military in areas ranging from recruitment and equipment to tactical planning.

:: BY TASNEEM HOSSAIN ::

To be a successful soldier, one needs to be brave, courageous, and physically fit; however, one key aspect that is often forgotten is the mental strength that is also required. The battlefield is an unstable environment. It is filled with surprises and constant violence. Service members need to have the ability to handle the associated stresses. They need to make instant decisions and be alert at all times in case of danger. For this reason, the military has invested in the field of neuroscience to provide better preparation. Often aimed at the possible creation of "super-soldiers," the field of neuroscience has produced research with "high pay-off potential."[1] The organization that is leading this research is the Defense Advance Research Project Agency (DARPA), a military-funded research group. DARPA is trying to use the field of neuroscience to find direct military applications that would increase a soldier's alertness; they are trying to configure a "super-soldier." So far, research in neuroscience has come up with some results and inventions that help recruits and officers cope with the stresses of the job. These advances in neuroscience allow the military to invest in inventions and research that may save the lives of the brave soldiers that go into the battlefield.

By predicting how stressed an individual will become after completing a tour or a particular mission, military doctors can properly debrief the soldier and provide different treatment options.

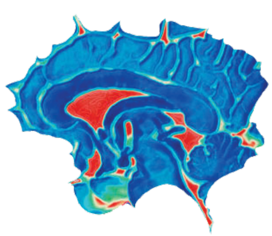
One method being developed in neuroscience is the use of biomarkers among soldiers and prospective soldiers. These biomarkers allow military officials to look deeper inside the human mind and its psychology to help soldiers in combat. These biomarkers will allow neuroscientists to examine how a particular soldier might respond to the war environment. For example, a neuroscientist would examine the neural functions and hormonal levels of a soldier to see if they become more alert and/or more highly susceptible to stress. By predicting how stressed an individual will become after completing a tour or a particular mission, military doctors can properly debrief the soldier and provide different treatment options. *New Scientist Magazine* reported a story about a soldier who, having just completed a 15-month tour in Iraq, shot five of his colleagues; currently, he is being treated for stress.[1] This incident shows the need for neuroscience to identify such persons and to find ways for improved treatment. The use of biomarkers is one example of how neuroscience could prevent tragedy and save the lives of individuals.

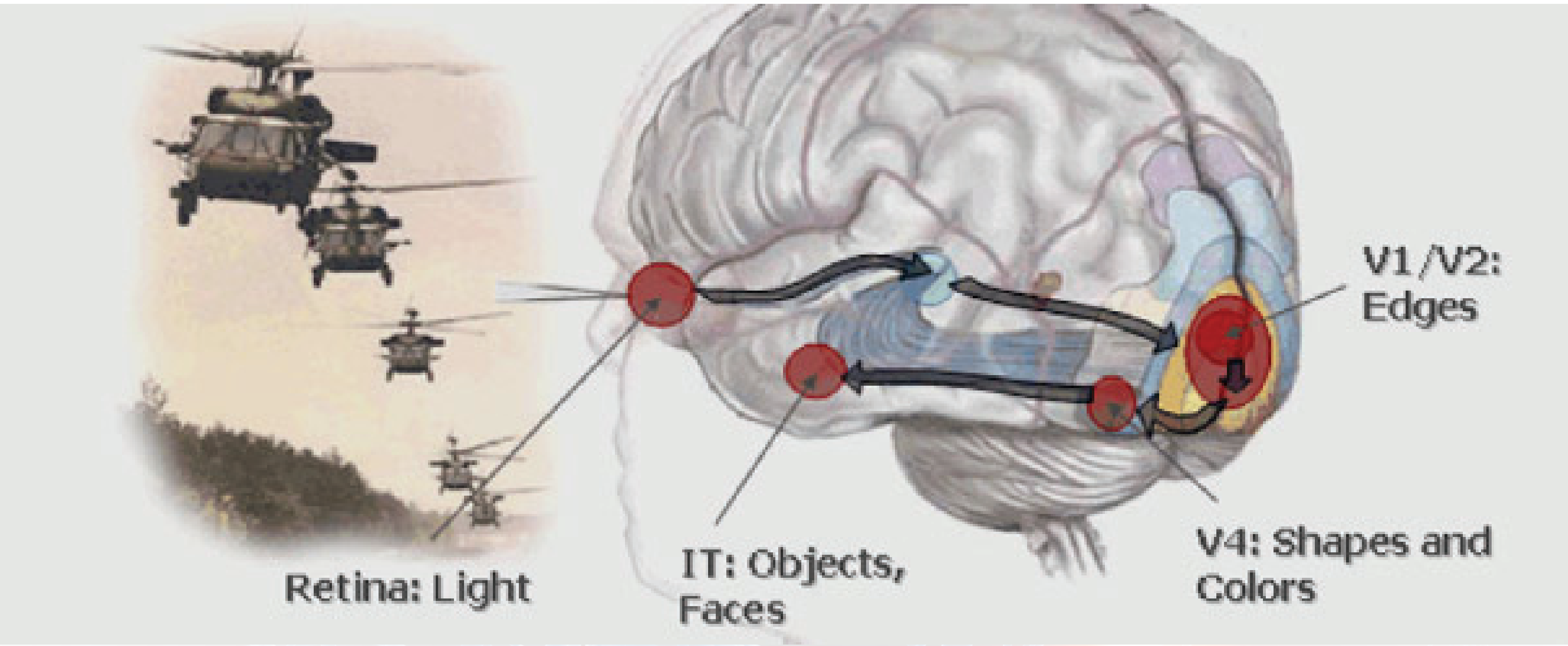
Biomarkers allow military officials to look deeper inside the human mind and its psychology to help soldiers in combat.

In addition, biomarkers have other neuroscience applications for the military, such as recruitment. This information could allow recruiters to determine the suitability of an individual to specialist tasks, such as being a sniper or taking a position in a group like the Navy SEALS. Certain jobs need certain skills; a sniper needs to remain calm and relaxed amidst a hostile situation. Accordingly, recruiters may look at serotonin receptors to see if the prospective soldier has the biological characteristic to be a sniper specialist. It also helps recruiters to see if an individual is mentally prepared for the realities of war. However, finding the exact biomarkers is a difficult task. Still, the results of this research could help the military to properly select people for specific tasks.

As research in neuroscience progresses, some other applications could be to plan strategies and to make tactical moves. As in the above paragraph about recruitment, officers can use neuroscience research to develop precise plans to give their units the advantage. By understanding the brain activity of individual soldiers and how they respond to stressful events, the unit leader can work accordingly to devise a plan that will provide an advantageous outcome. "Tactical-level military leaders can use this new knowledge to understand the effects of combat, to anticipate and recognize cognitive reactions, and to adjust their leadership abilities to succeed in difficult situations."[2] Neuroscience provides useful tools that allow not only the commander, but also the unit as a whole, to succeed.

The military has also explored the possibility of an apparatus that alerts a soldier of nearby danger and helps them to avoid that danger. DARPA has dug deep into the field of neuroscience to start the Cognitive Technology Threat Warning System project. Dubbed "Luke Binoculars," the technology is another example of science fiction meeting reality. It is named after Luke Skywalker, a central character from the movie, *Star Wars*. This device "combines advanced optics with an EEG system that monitors brain wave activity in the prefrontal cortex."[4] It warns the soldier of potential dangers that are in the nearby area by using his own subconscious mind.





A soldier's brain can be monitored in real time with an electroencephalogram picking up "neural signatures" that indicate target detection.

The Luke Binoculars are high tech binoculars that have a range of 1,000 to 10,000 meters. They monitor the brain to speed up the process of finding potential dangers nearby. The technology combines optics and neuroscience into a pair of binoculars. An electroencephalogram (EEG) uses electrodes to record brain waves through the scalp. The binoculars use this technique to monitor neural signals. They measure activity in the prefrontal cortex to detect the premonition of danger before the brain can process the same information. It is basically an expedited warning system. In viewing the surroundings through the binoculars, the unconscious mind may detect some sort of danger in the field. The time it takes for the unconscious mind to "notify" the conscious mind may be too long and cause a slow reaction. However, the Luke Binoculars shortens this step, potentially saving the user's life by prompting him to take action sooner. To better take advantage of this feature, the optics are designed to expand the field of vision to a 120 degree view. Currently, the binoculars and electrodes are placed in helmets. The biggest challenge for this technology is "getting the system down to a target weight of less than five pounds."[3] However, the technology proves to be very promising. It enables soldiers to be more alert and to have faster reaction times.

To better take advantage of this feature, the optics are designed to expand the field of vision to a 120 degree view.

As the need to protect our soldiers is always crucial, continued research in neuroscience is vital. Military technology is expanding and will expand for the foreseeable future. To do so, it will need to find new partners. The "Luke Binoculars" and biomarkers are only a couple of advanced areas in which the military has invested. Whether as an aid in wartime or to create a "super-soldier," the combination of the military and neuroscience can make many advances that improve the well-being of soldiers and the way commanders make tactical plans. Therefore, with the help of neuroscience, the military can stand a better chance of winning battles.

Tasneem Hossain is a first year undergraduate student studying electrical engineering at NJIT.

Artwork by Valeriya Kozhynova

Visual Augmentation: New Visions for the Future

Two new technologies, the BrainPort and the Artificial Silicon Retina, are being used to aid those with poor or non-existent vision using very different approaches.

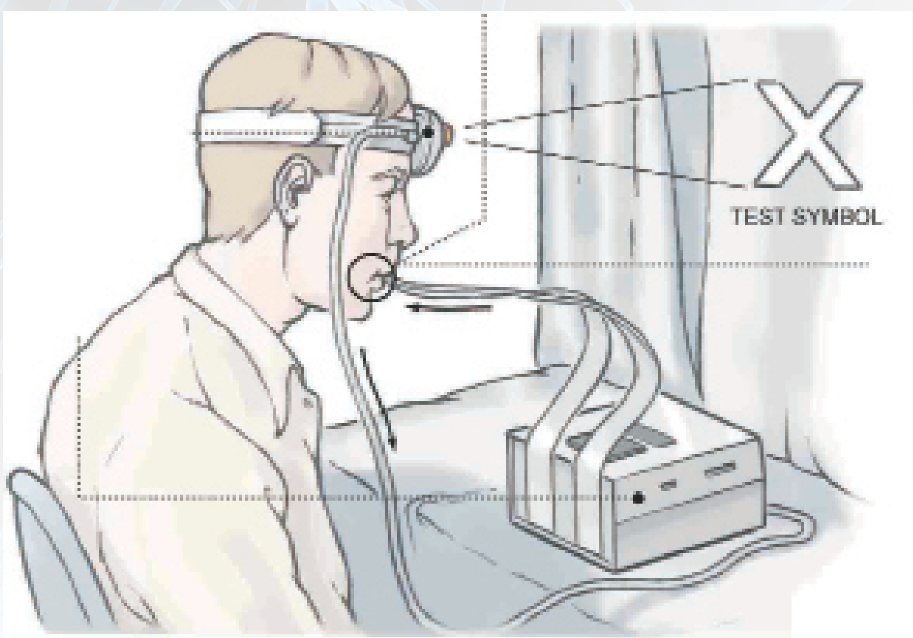
:: BY WALTER L. CHURCH ::

New technologies can often improve the quality of life. This is especially true for those with visual impairments since the future should bring new devices to help them to see. In the field of visual augmentation, there are already new technologies that take advantage of greater understanding of the brain. Two such technologies to aid those with visual disabilities are the BrainPort and the Artificial Silicon Retina. The BrainPort uses different senses in place of vision whereas the Artificial Silicon Retina would be placed directly into a patient's eye to replace defective portions of the retina.

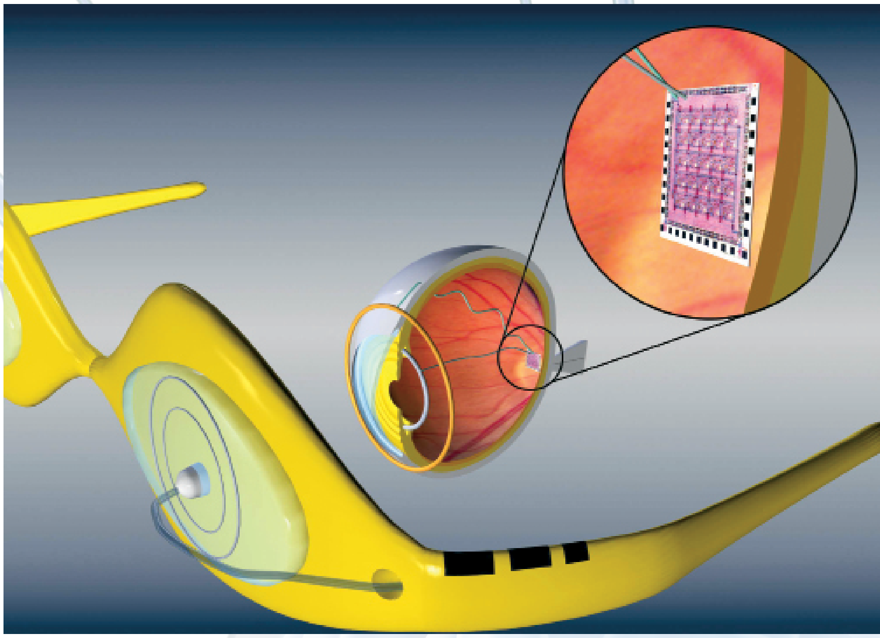
The technology for the BrainPort relies on electrotactile stimulation for sensory substitution. This means replacing one type of signal for another. It consists of a camera connected to a device placed on the tongue. The tongue display is about the size of a postage stamp and is connected to the camera by a cable. The camera is adjustable and mounted onto the head of the user. The BrainPort converts images from the camera into small, controlled, painless currents that are applied to the surface of the tongue.[3] The brain converts the electrical impulses on the tongue given off by the BrainPort into images that the recipient can understand.[2] The user can be trained to interpret them as an image.

The encoded pattern of electrical impulses is representative of the image seen by the camera. It is then turned into a signal for the non-functioning sensory organ, in this instance the visual system, to be received through the skin. BrainPort technology co-inventor and Senior Scientist with the University of Wisconsin, Department of Orthopedics and Rehabilitation Medicine, Dr. Kurt Kaczmarek, explains how the encoded pulses are applied to the tongue. The tongue receives the image data and then "the electric field thus generated in subcutaneous tissue directly excites the afferent nerve fibers responsible for normal, mechanical touch sensations."[3] The image-encoded touch signals are forwarded to the parietal lobe of the brain, which is responsible for integrating the sensory information from the different parts of the body. Arrays of

An Artificial Silicon Retina (ASR) is made up of over three thousand microscopic solar cells that are able to convert light into electrical pulses, mimicking the function of cones and rods found within the eye.



Application of the BrainPort: A small hand- or head-controlled camera records the visual image, which is presented to the user's tongue.



A microchip the size of a match head, embedded with photosensors and electrodes that translate light patterns into electrical currents stimulate the ganglion cells, helping people without sight to see.

electrodes are used within the brain to communicate non-touch information through pathways to the brain normally used for touch-related impulses.[3] In this way, the brain receives information from another sense, touch, and uses it to correspond with a sense that has been damaged or that is not working properly, e.g., vision. Electrotactile stimulation could be used to provide sensory information to the vision impaired, the hearing impaired, and many others in the future.

The artificial retina is a new technology that is being developed as a device that would be implanted into the eyes of patients with seeing disabilities, giving them the ability to see more clearly. An Artificial Silicon Retina (ASR) is made up of over three thousand microscopic solar cells that are able to convert light into electrical pulses, mimicking the function of cones and rods found within the eye.[1] The ASR stimulates the nerve ganglia behind the eye with electrical pulses reactivating lost sight. The ASR is placed behind the retina and obtains its power from the light entering the eye. This is beneficial because it allows the device to operate without any batteries or external power sources. The device is implanted into the eye via surgery in which incisions are made into the white part of the eye. Through these incisions, the surgeons remove the gel in the middle of the eye and replace it with saline. A pinpoint opening made in the retina is used to place the ASR into the sub-retinal space where it is designed to fit.[1] The retina is then resealed back over the ASR.

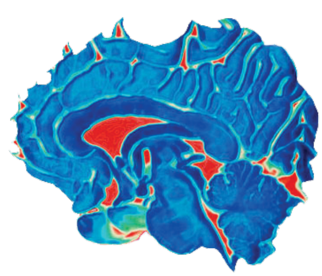
The brain converts the electrical impulses on the tongue given off by the BrainPort into images that the recipient can understand.

In the United States, the Department of Energy has ongoing trials with artificial retinas in patients to improve their eyesight. Retinal diseases like age-related macular degeneration and retinitis pigmentosa destroy vision by eradicating the cells used to convert light signals into electric impulses that are sent to the optic nerve and the brain. The artificial retina device bypasses defunct photoreceptor cells and transmits electrical signals directly to the retina's remaining viable cells. The pulses travel to the optic nerve, and ultimately, to the brain.[4] Adding more electrodes to the retina increases the quality of vision. There is currently testing for an artificial retina that will have over 200 electrodes providing greatly improved vision.[4] This project is a great leap forward in modern technology as it allows us to give sight back to those who have lost it from retinal disease for so many years.

As technology progresses, the ability to aid those who have lost their vision will increase. Already there are viable new ways to regain eyesight for those who have lost that ability. People are being outfitted and taught how to use BrainPort. Advances in technology are allowing for more electrodes on artificial retinas. In the years to come, these technologies will only get better. The goal of fully returning eyesight to those that have lost it, as well as giving it to those that have never seen, is hopefully not too far beyond the horizon.

In the United States, the Department of Energy has ongoing trials with artificial retinas in patients to improve their eyesight.

Walter L. Church is a first year undergraduate student studying computer engineering at NJIT.



Changing Perspective: The Power of Autism

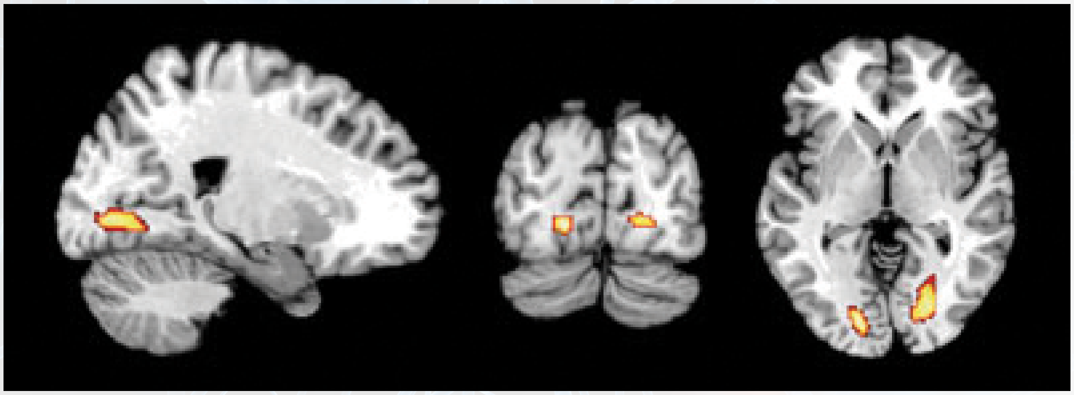
Do we need to challenge our view of autism as singularly debilitating, and embrace the possibility that it comes with its own advantages?

:: BY NICOLE ANTONICELLO ::

Autism is a developmental disorder that appears in the first 3 years of life and affects the brain's normal development, resulting in diminished social and communication skills. It is a physical condition linked to abnormal biology and chemistry in the brain. Recent research has shown the power of autism and how virtual worlds help autistic children develop social skills.

Changing Perspectives: the Power of Autism

"Recent data — and personal experience — suggest that autism can be an advantage in some spheres, including science," says Dr. Laurent Mottron at the University of Montreal's Centre for Excellence in Pervasive Development Disorders. New research suggests that autism, previously regarded as a "devastating" disorder, can be an advantage in scientific research. For the past seven years, Mottron has been a close collaborator of an autistic woman, Michelle Dawson. He states,



Perceptual regions of the brain activated more among autistics than non-autistics during a non-verbal intelligence test.

"…she has shown me that autism, when combined with extreme intelligence and an interest in science, can be an incredible boon to a research lab. I first met Dawson when we were interviewed together for a television documentary about autism. Some time later, after disclosing to her employers that she was autistic, she experienced problems in her job as a postal worker and so had learned everything about how the legal system deals with employees with disabilities. I recognized her skill for learning and asked her to become a research assistant in my lab. When she edited some of my papers, she gave exceptional feedback and it was clear that she had read the entire bibliography. The more she read, the more she learned about the field. Almost ten years ago, I offered her an affiliation to the lab. We've now co-authored 13 papers and several book chapters."[1]

Autism is defined by a suite of negative characteristics, such as language impairment, reduced interpersonal relationships, repetitive behaviors, and restricted interests. Autism's many advantages are not part of the diagnostic criteria. Most educational programs for autistic toddlers aim to suppress autistic behaviors, and make children follow a typical developmental trajectory. None is grounded in the unique ways autistics learn.

Many autistics — not just "savants" — have qualities and abilities that may exceed those of people who do not have the condition, according to Mottron. Mottron's research team has established and replicated the superior abilities of autistics in multiple cognitive operations such as perception and reasoning, as have others. In autistics, there is comparatively more activity in the visual-processing network than in the speech-processing one, and this seems to be a robust characteristic of autism, across a wide array of tasks. This redistribution of brain function may nonetheless be associated with superior performance.

A few years ago, Mottron's team decided to compare how well autistic and non-autistic adults and children performed in two different types of intelligence tests: non-verbal ones, such as Raven's Matrices, that need no verbal instructions to complete, and tests that rely on verbal instructions and answers. They found that non-autistics as a group showed consistent performance in both types of test — if they scored in the 50th percentile in one, they tended to score around the 50th percentile in the other. However, autistics tended to score much higher in the non-verbal test than in the verbal one (see 'Autistic intelligence') — in some cases, as many as 90 percentile points higher.

Virtual worlds help autistic children develop social skills

Additionally, virtual worlds can be used to help autistic children develop social skills, as suggested by early findings from new research called Echoes, funded by the Economic and Social Research Council (ESRC). In their research, children use multi-touch screens to activate virtual characters and experiment with different social scenarios, allowing the researchers to compare their reactions with those they display in real-world situations.

Over a number of sessions, some children demonstrate a better quality of interaction within the virtual environment and an increased ability to manage their own behavior, enabling them to concentrate on following a virtual character's gaze or focus on a pointing gesture, thus developing the skills vital for good communication and effective learning.

The findings could prove useful in helping children with autism to develop skills they normally find difficult. "The beauty of it is that there are no real-world consequences, so children can afford to experiment with different social scenarios without real-world risks," said project leader Dr. Kaska Porayska-Pomsta.[2]

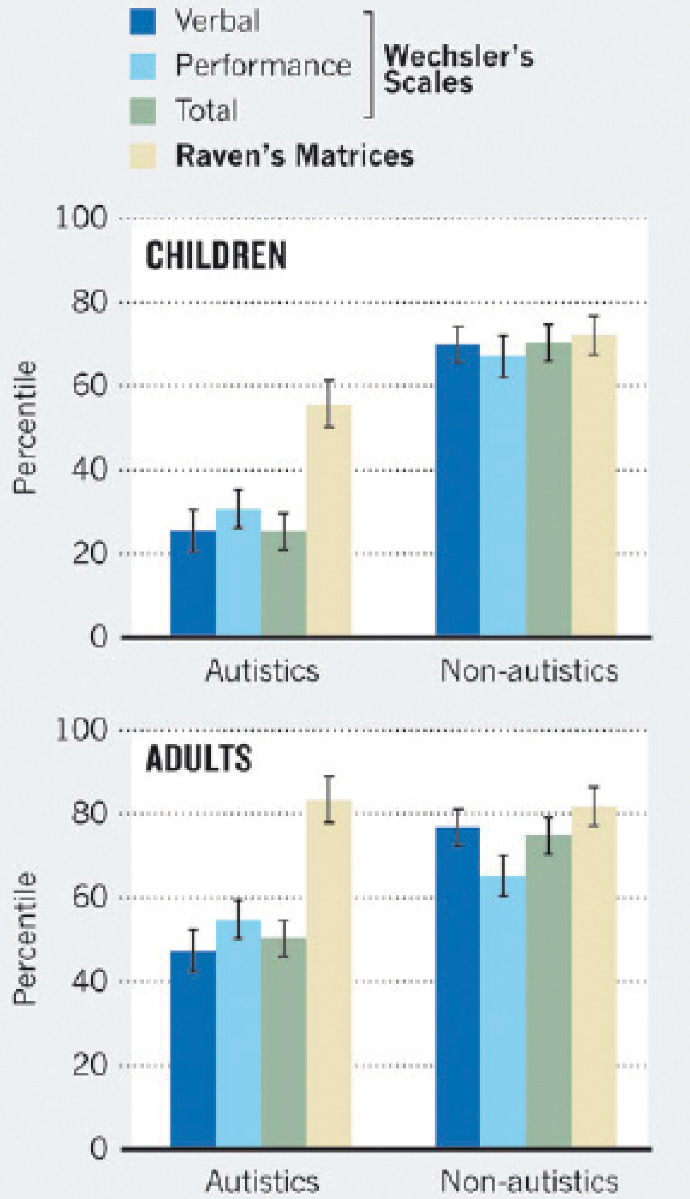
Conclusion

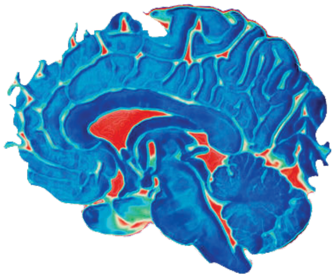
Evidence from Dr. Mottron's studies suggests autism should be viewed from a new perspective. Additionally, autistics' superior abilities due to brain organization prove they have an advantage in non-verbal intelligence over the average individual. Similarly, Dr. Kaska Porayska-Pornsta's work on the Echo project allows autistic children to develop social skills beyond their anticipated levels. Both of these research efforts hope to promote learning and social environments that will enhance autistics' careers as well as their academic futures.

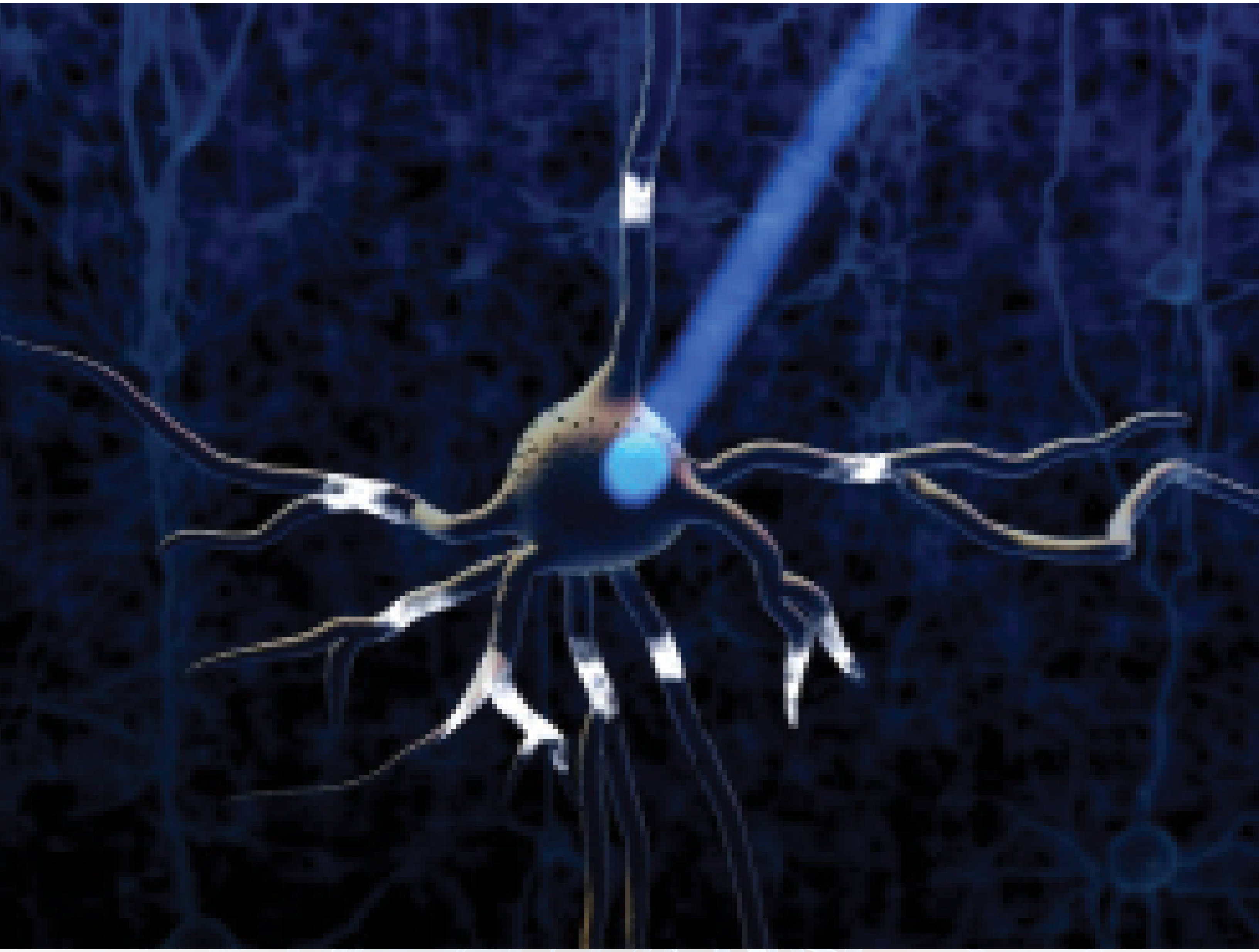
Nicole Antonicello is a fourth year undergraduate student studying biomedical engineering at NJIT.

AUTISTIC INTELLIGENCE

Non-autistics typically perform equally well in tests of verbal and non-verbal intelligence. Autistics, however, score much higher in non-verbal tests, such as Raven's Matrices, than in verbal ones, such as Wechsler's Scales.





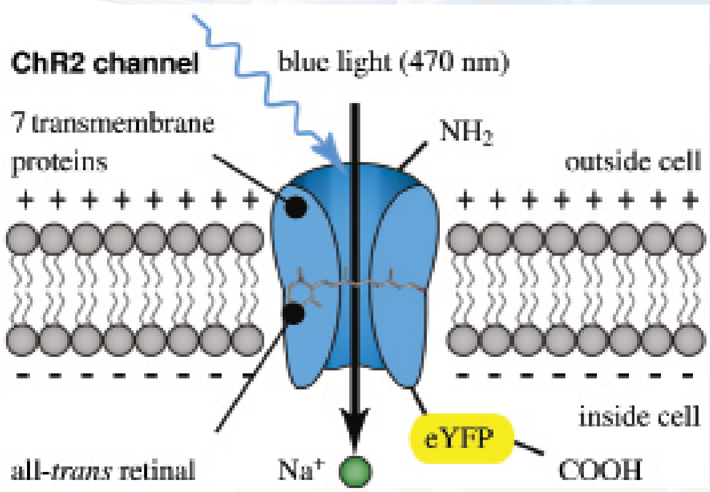


Shedding Light in the Field of Neuroscience

An exciting new technology derived from work on jellyfish allows scientists to activate and deactivate individually selected neurons in functioning tissue, opening new avenues of research and suggesting potential treatments for brain disorders.

:: BY FATIMA ALI ::

Optogenetics, the use of light to control the behavior of cells, is causing great excitement in the field of neuroscience. Over 6 million people in the United States suffer from some kind of degenerative neurological condition.[2] Many neurological diseases affect the quality of life and health of the sufferer. However, there is still much that we have yet to discover about our brain. The brain is much more than just gray matter; it is an intricate web of billions of neurons, many with distinct characteristics and wiring. The brain is extremely complex and contains many different pathways, determined by thousands of different types of nerve cells. This complexity limits neuroscientists in their understanding of how activities within specific brain cells give rise to various brain functions such as thoughts, feelings, and memories. This is the missing piece of the puzzle in the treatments of many distinct psychological disorders such as schizophrenia and depression.



Channelrhodopsin-2 (ChR2) is a light-gated cation channel native to the green alga C. reinhardtii. It consists of seven transmembrane proteins and absorbs light through its interaction with retinal. Here, scientists induce channelrhodopsin coupled to enhanced yellow fluorescent protein (eYFP) into undifferentiated human embryonic stem cells via a lentiviral vector and differentiate these cells into cardiomyocytes.

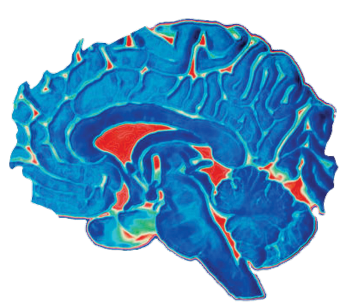
Current treatments for such disorders are very nonspecific and most are not actually cures, i.e., they only aim to alleviate symptoms.[6] Pharmaceutical treatments bathe the entire brain in chemicals. The body's reaction to these chemicals is very slow and leads to a multitude of side effects. Another treatment method, commonly used in patients with Parkinson's disease, is the use of electric stimuli via electrodes. Electric stimuli do not have high specificity because the electric current follows the path of least resistance, affecting normal circuits as well as abnormal ones.[2]

Further development in neuroscience requires more precise control. The ideal way to accomplish this task would be to target a specific cell, turn it on or off, and see what the result is. This is what inspired Ed Boyden, who was trained as an electrical engineer and a physicist, to make the conjecture that if neurons are just electrical devices, then we may be able to develop a way to stimulate them to turn on or off from a distance.[1] This is what led to the discovery of Optogenetics.

The brain is extremely complex and contains thousands of different pathways, determined by thousands of different types of nerve cells.

Research performed on algae found a light-sensitive channel that allows the algae to swim towards or away from light. The channel protein, Channelrhodopsin (ChR2), opens when exposed to blue light, triggering the influx of positive ions that allow electrical messages to pass through the cell. This mechanism is similar to that which causes nerve cells to fire. Years later, neuroscientists realized that if they manipulated these channels to work in mammalian nerve cells, then it would allow them to have very precise control over the nerve activity of the brain. This treatment would potentially have instantaneous results and be more precise than pharmaceuticals and electrical stimulation. Other ion channels activated by the light of different colors have since been developed, including Halorhodopsin, which inhibits instead of stimulates the cell. All of these photosensitive channel proteins are called Opsins.[2]

To test this process, scientists took the gene that encodes for the ChR2 protein and its associated promoter and inserted it into a virus. The virus infects the neurons of the brain and releases the gene. The CH2 gene was developed in such a way that only a subset of the infected neurons would have the correct machinery to activate the gene, allowing specificity which was unattainable before. In these cells, the Channelrhodopsin protein is expressed and embedded in the cell membrane. Next, the final component of a fiber optic cable, similar to those used for internet and television, delivers a blue light that activates the gene. Based on its simplicity and effectiveness, the probability for optogenetics to develop into human clinical use seems very high.[2] The insertion of the Opsins into the body via viruses is relatively easy. There is already a multitude of other gene therapy methods that use the same



viruses as Optogenetics with no known adverse effects, such as AAV's (Adeno Associated Viruses). In addition, we have seen that this optic stimulation does not produce any significant effects on other cells or their functionality.[1]

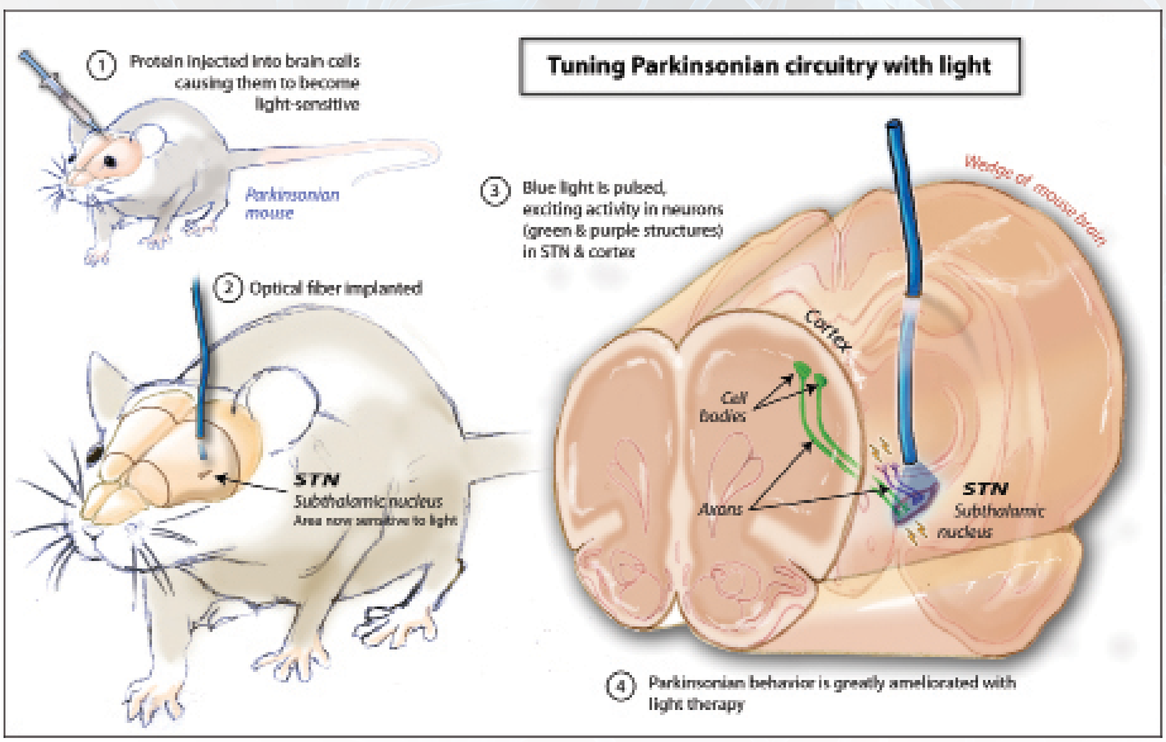
There is a great deal of speculation about which particular brain regions are responsible for different actions and pathways. However, in most cases, their functional role in behavior and local processing is unknown. The regions may be distinguished based on their molecular identity or anatomic projection patterns, but without Optogenetics, it is not possible to target these specific neural elements. Optogenetics offers a means to target specific neurons by providing the ability to:

- manipulate the rate of neural firing with high precision during specific time periods
- direct manipulations to particular subclasses of neurons based on brain region or cell types
- identify specific cell types using extracellular recordings
- map the detailed connectivity of defined inputs to cells in a given brain region.[6]

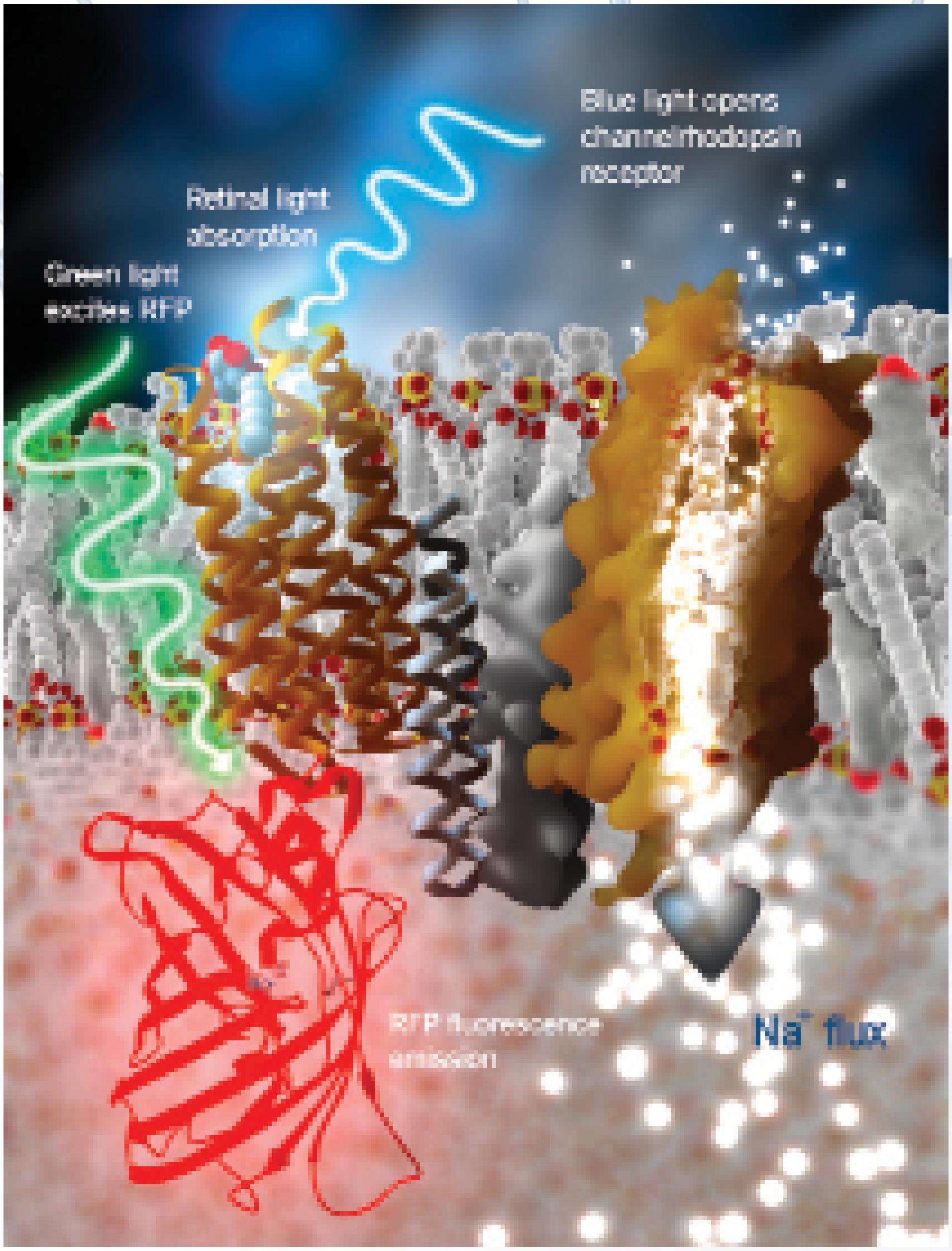
One study uses Optogenetics to target the sense of fear. The traditional method of Pavlovian fear conditioning was used on mice. Pavlovian fear conditioning associates fear with a sensual stimulus. In this experiment, mice were given a shock concurrent with the sounding of a tone. After some time these mice were conditioned to freeze, similar to a deer in headlights, when the tone was sounded, even without a shock. The researchers wanted to see what pathway of the brain allows one to overcome fear. In experimental trials, the researchers targeted particular parts of the brain to see if it stimulated the mouse to overcome its fear. The conditioned mouse was given a flash of blue light through a fiber optic cable after the tone. The medial sector of the central nucleus (CeM) is the output region that contributes most amygdala projections to brainstem fear effectors. By targeting the expression of Channelrhodopsin in basal amygdala projection to CeM, it was shown that stimulating this exact region reduced anxiety-driven behavior (e.g. freezing), and the inhibition of the same terminals increased stress-related fear. This has many implications for treating people with conditions such as severe anxiety and post-traumatic stress disorder.[3]

> Degeneration of photoreceptors is found in many types of inherited as well as non-heritable blindness.

Another study of Optogenetics was focused on learning and addictions. In this case, scientists were looking for the exact signals that cause the sense of reward, thus promoting learning. This research is associated with the field of drug and alcohol addictions. The scientists imbedded ChR2 into particular neurons of a mouse's brain. The animal was then put in a box with a blue light at one end that could be turned on if the mouse tapped the light. If the region with ChR2 was linked with pleasure, the mouse would continuously hit the light, becoming "addicted" to the feeling it triggered. Unsurprisingly, the dopamine receptors of the brain were the most significant in triggering this response.[5]



Casting light on diseased circuitry: optogenetics helps identify cellular targets of deep brain stimulation. First, specific cells are treated in a way that makes them sensitive to stimulation by blue light. Then an optical fiber is implanted in the subthalamic nucleus (STN) region of the brain. Treating the brain with rapid flashes of blue light activates neurons (green and purple structures) in the STN and cortex, which improves disease symptoms. This optogenetic result provides important scientific insight into the affected brain circuits.



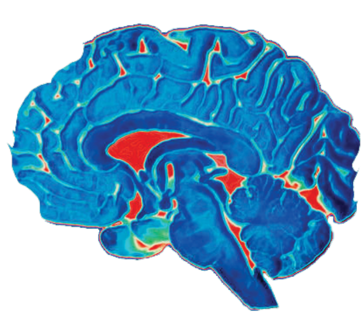
Operating Mechanism Optogenetics—Receptors expressed in neurons light when excited by light of a particular wavelength, in this case blue. This makes it open to the flow of Na+ ions, the pore that are capable of forming, depolarizing the neuron. The inserted gene causes the neuron is expressed with the marker protein called RFP (Red Fluorescence Protein). RFP fluoresce red when excited with green light.

Further research is being conducted to incorporate Optogenetics into different subfields of neuroscience. One area of interest may be treating severe epilepsy. One current treatment involves removing parts of the brain prone to seizures. This method is risky and has many side effects.[6] With Optogenetics, one simply turns off the region that is overacting during the seizure using Halorhodopsin or other Opsins, which inhibit the cells.

An exciting future application is the restoration of sight for the blind. Degeneration of photoreceptors is found in many types of inherited as well as non-heritable blindness. Drugs cannot address this issue because there is nothing in the retina onto which the drug can bind. However, many of the other retinal neurons remain functional. If alternate photoreceptors (i.e., an Opsin) could bind to the retinal cells downstream in the retinal sight mechanism, these replacements could restore vision. There is great potential in one strategy that targets the ganglion cell of the retina. It is easy to transfer Channelrhodpsin genes into these cells via a single intravitreal (directly into the eye) injection of AAV2/2: a viral vector carrying the Channelrhodopsin gene. Studies at The Royal College of Surgeons were conducted on rats with established inherited retinal degeneration. These rats, blind after the age of 3 months, had their vision restored by a single intravitreal injection of AAV-ChR2. However, the degree of vision restored by ChR2-expressing retinal ganglion cells is unknown.[4]

The discovery of Optogenetics shows that innovation is usually found in places that have been explored for years. The researchers of algae could not have guessed the implications their observations would have for humans. It is looking at a dilemma from a multifocal perspective that allows us to make progress. This story of Optogenetics is just the beginning; we do not know exactly how it will play out, but there is hope that this great technological discovery in neurology will shed light on the mysteries of the human brain.

Fatima Ali is a first year student studying biomedical engineering at NJIT.



Power Dreaming: A New Hope for Veterans with PTSD

A new treatment for post-traumatic stress disorder uses computer imaging to relax sufferers.

:: BY LOGAN HAINE ::

In the distance, Private Smith hears the all too familiar sound of Apache helicopters roaring overhead and the guns firing their venom. Fearing for his life, he grips his rifle, peering through his night-vision goggles to the wasteland that lies around him. He gets the command to move ahead and follows his war-time friend. Unbeknownst to them, the field is home to dozens of landmines. The soldier watches as his friend takes a step and…Smith wakes up, drenched in sweat. The soldier realizes that he has just endured another nightmare reliving the scenes of that horrible day. He, like so many soldiers, suffers from Post-Traumatic Stress Disorder, or PTSD. PTSD is an anxiety disorder in which people who experienced a past life-threatening event suffer from anxiety-related symptoms. Symptoms of PTSD include increased arousal, such as outbursts of anger, as well as avoidance of situations that may remind one of the event, and flashbacks of the event through hallucinations or nightmares. The most common victims of PTSD are military veterans who suffer from nightmares rehashing their tragic experiences in war. Currently, the only treatment is to help sufferers cope with their symptoms.[4] Fortunately, the US Army is working on an experimental procedure called "Power Dreaming," which aims to treat the disease.

The basis of Power Dreaming lies in Biofeedback therapy. Biofeedback therapy is the process of conditioning one's brain patterns to more desirable functions. To do this, an electroencephalogram is used.[6] This is a test in which electrodes are placed on the scalp to measure the electrical activity of the brain.[2] By using this test, patients are monitored and taught to control themselves when awakened. Unfortunately, when patients are awakened, they have difficulty creating soothing scenes that are vivid enough to calm them down.[6] This is where Power Dreaming comes in. Using Second Life, an on-line video game where players create avatars to explore a virtual world, soldiers will be able to create their own specific animated scenes and avatars. Essentially, soldiers will make their own cartoon shows which are both detailed and soothing. Then, after waking up from a nightmare, soldiers will simply put on their 3D goggles and watch their therapeutic scenes, which will enable them to relax.[1] Imagine waking up from a horrific nightmare confused and scared. After watching a soothing cartoon, both reality and a sense of safety are restored. This is exactly what Power Dreaming aims to do for sufferers of PTSD.

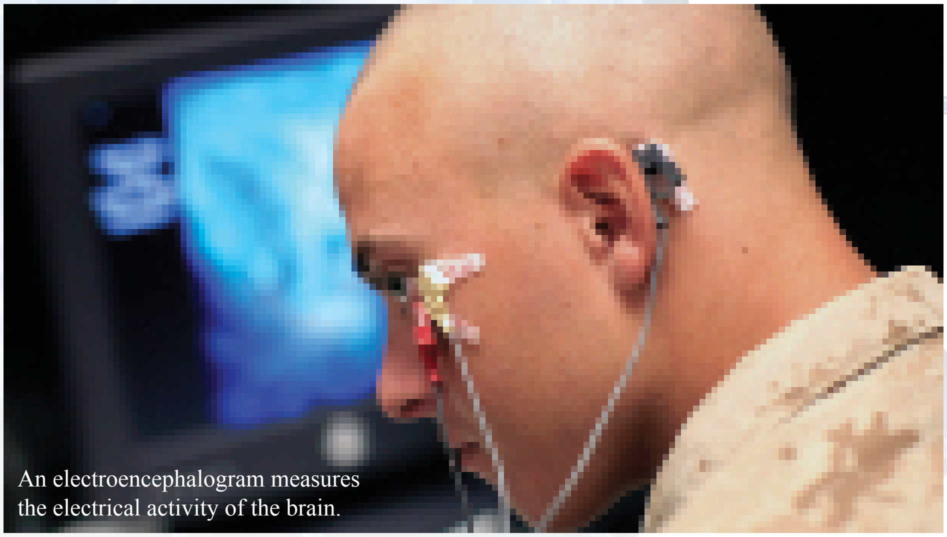
To ensure that the experiment is successful, soldiers will have their vital signs, such as heart rate and brain-wave activity, measured during the experiment. Power Dreaming will be successful if it decreases the increased brain-wave activity associated with nightmares.[1] After the experiment is completed, the army will also know what scenes are most effective at decreasing the awakenings of soldiers.[3] Until then, the soldiers will be encouraged to make their scenes as soothing as possible, while still being 'neurologically distracting' enough to trigger a relaxation response. For example, if a soldier likes sea life, they will create a therapeutic scene where they are exploring the sea creatures of a coral reef. The more "neurologically distracting" a scene is, the better it will be at reducing awakenings.[1] Therefore, it is hoped that Power Dreaming will be effective in treating PTSD if it successfully treats awakenings.

A common indication of PTSD is the activation of the sympathetic nervous system during nightmares. When confronted with a threat, the sympathetic nervous system releases hormones, such as noradrenalin. The hormones then cause heightened arousal and physical symptoms, such as elevated heart rate and blood pressure. To reverse this heightened arousal, a soldier would simply play their pre-designed scenario on their goggles, and their parasympathetic nervous system would be activated. The parasympathetic nervous system is essentially the complete opposite of its sympathetic counterpart because it decreases one's arousal.[5]

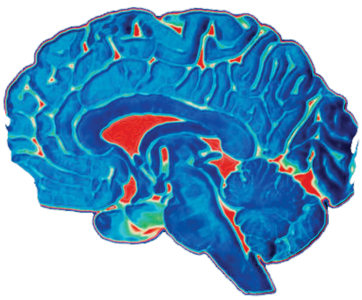
…the Power Dreaming experiment will successfully find out which scenes are most effective at activating the parasympathetic nervous system.

However, the parasympathetic nervous system will only be activated if the Power Dreaming scenes are distracting enough for a soldier to forget about their nightmare. Optimistically, the Power Dreaming experiment will successfully find out which scenes are most effective at activating the parasympathetic nervous system. If so, the benefits of Power Dreaming will be enormous.

Intended to assist soldiers, Power Dreaming will hopefully be an effective way of treating PTSD. Soldiers suffering from PTSD will finally have relief in the knowledge that, if they experience a nightmare while sleeping, help is right next to them, on the bedstand. If successful, Power Dreaming may be used to treat civilians who suffer from PTSD as well. Imagine how happy people will be to eliminate such a detrimental condition. Until then, it will be used to cure America's brave war veterans who suffer from the disease. Due to Power Dreaming, one day Private Smith, or any veteran like him, will no longer have to fear going to sleep.


An electroencephalogram measures the electrical activity of the brain.

Logan K. Haine is a first year undergraduate student studying actuarial science at NJIT.



New Jersey Institute of Technology in Action

Photographer: Guillaume Lanteri

NJIT lives up to its designation as New Jersey's Science and Technology University in the classroom as well as the laboratory. Cutting-edge projects carried out by NJIT faculty in support of these initiatives is at its highest level ever. In fact, total research expenditures for this fiscal year are expected to top $100 million. The success in the laboratory is translated to the classroom by the faculty to the students in real time, benefitting the entire learning community on campus. NJIT, reports *The Princeton Review*, "stands today as one of the nation's most prominent research schools, specializing in nanotechnology, solar physics, and polymer science...and retains its reputation as New Jersey's top choice for the hard sciences." NJIT has seen the benefits of its commitment to establishing successful departments in the fields of engineering, management, biological sciences, and mathematics. The fruits of this labor can be seen in the faculty mentioned below.

Using Biophysics to Improve Treatment of Hydrocephalus

:: BY ANDREW J. HELBERS ::

Dr. Gordon A. Thomas
Professor of Physics
Department of Physics and Biomedical Engineering

Walking through the entrance of Dr. Gordon Thomas' lab, you might not notice anything out of the ordinary compared to what you might see in any other physics laboratory at NJIT. But, in some ways, it is very different. Dr. Thomas is unusual in that he switched fields from basic physics to biophysics after a change in his worldview. He saw people dying of cancer and other medical tragedies, and questioned how much good he was doing for people in non-financial terms. This led him to pursue a field that would use his existing knowledge in order to work on problems in medicine. This means that much of his research focuses on using physics and related sciences to create potentially useful medical devices. His work is often the result of collaborations with a number of other experts, reflecting the multidisciplinary nature of this type of research.

A particular device I elected to discuss was meant to work as an improvement on a surgically installed tube to correct symptoms of a condition called hydrocephalus. The brain is submerged in cerebrospinal fluid which is continually replaced with new fluid. Hydrocephalus results when this fluid does not properly drain or is overproduced, resulting in an increase in pressure.[1] With the exception of injury, its root causes are not well understood. It causes headaches and migraines, and can also result in brain damage.[3] This is commonly treated by installing a drainage tube into a patient's body to allow extra fluid to drain from a catheter inserted into this fluid bath, through the tube, and to elsewhere in the body, where the fluid will not do harm. A valve maintains one-way flow. Many variations on the specifics of this technique exist. This device is called a shunt. The problem is that the shunt can become clogged or break, or the catheter can become dislodged, and the flow rate of the fluid is so low that it is very difficult to detect without performing additional surgery. This may exacerbate the problem by allowing for another clog.[3] A less invasive method for measuring flow rate would be desirable, and Dr. Thomas may have a solution. Developed at NJIT, Thomas' recently patented Smart Shunt includes a microcircuit that has a resonance frequency in the microwave spectrum that varies with pressure.[2][3] This is accomplished by a capacitor whose plate separation is changed by pressure. In a manner similar to how you might tune a radio, this change produces a change in the resonance. Then, as pressure and fluid flow are related, one can indirectly measure flow rate by using an external device to find the resonance without having to perform surgery.[3] The challenge in creating such a device is that this circuitry must be made on a micro-scale level. The next major step, being undertaken now, is testing and improvement.

In order to do this, Thomas joined forces with the Infoscitex company and the Harvard Medical School and succeeded in winning a sought-after National Institutes of Health grant. The NJIT group will continue lab testing, Harvard will work on testing in sheep (with induced hydrocephalus) and the company will work toward a product.[2][3] These grants are typically awarded in phases, so that one must produce some sort of promising research in an early round in order to be awarded a second phase of such a grant, which was achieved in this case.[3] One of the exciting things about this device is that it will make measurements of fluid pressure in the brain that have not been made in a convenient, nearly constant manner before. This alone may provide some insight into studying hydrocephalus, apart from the likelihood of improving the shunt treatment.[3] There may even be improvements in treating other ailments. For instance, in principle, glaucoma is a similar problem in the eye, and creating such a shunt using micro-scale fabrication might be considered as a possible treatment for that problem as well.[3]

The research being conducted here reflects considerations from many angles and viewpoints. Jim Goldie and Thieu Truong work at Infoscitex, which is a company trying to make the product into something marketable and economically realistic. Dr. Joseph Madson is a medical doctor at the Harvard Medical School and Children's Hospital, Boston, who considers the problem from the viewpoint of working with a patient. Dr. Alokik Kanwal, and Dr. Reginald Farrow, NJIT Research Professors, work on the microfabrication and testing processes with Dr. Thomas. Dr. Donald Sebastian is the Senior Vice President for Research & Development at New Jersey Institute of Technology, and Dr. Thomas gives him much credit for helping to initiate the project.

Biophysics is rather intriguing in that it has so many direct applications to the quality of human life, and the Smart Shunt is only one of many such devices being developed at NJIT. As an Applied Physics major bound for graduate school, I only hope that something to which I contribute will have the same level of impact as saving someone from the threat of potential brain damage or numerous minor surgeries.

How Forces Affect the Nervous System

:: BY BASIM EL-TOUKHY ::

Bryan J. Pfister, Ph.D
Interim Chair Department of Biomedical Engineering
Associate Professor

In every action and thought we may take for granted, the brain is in constant communication with the entire body. Just consider that every move that you make requires cell signaling. If just one part of the nervous system is damaged, it could hinder daily activity. Scientists like Dr. Bryan Pfister at New Jersey Institute of Technology are studying ways to regenerate nerve tissue by examining the effects of injuries and stretching on nerve cells. Many neurological disorders, diseases, and traumatic brain injuries have the potential to be better understood, and perhaps better remedied, with research, as the nervous system is a complex system about which many things are not well known.

This complexity requires deeper understanding. Dr. Pfister's research focuses on understanding how mechanical forces affect the nervous system and the biological results of these forces. Dr. Pfister received his BS in Interdisciplinary Engineering from Clarkson University, his MS in Mechanical Engineering from Johns Hopkins University, and his PhD in Material Science and Engineering, also from John Hopkins University, for work on in vitro analysis of the stretching of axons and deformation from injury to the axons. Dr. Pfister did postdoctoral research at University of Pennsylvania's Department of Neurosurgery, where he used his diverse background in engineering to approach problems in neural biology and the nervous system.

Dr. Pfister's research deals with injury of the nervous system and how the system repairs itself. This information is then used to develop therapies. In order to injure the axons in a controlled way, Dr. Pfister designed and built a new bioreactor, a chamber in which experiments can be performed on cells in a controlled environment, to enable different rates of stretching. Several new devices were developed to study a standard model of brain injury, the effects of various rates of stretching on nerve cells, and the effects of sudden injury on nerve tissue.

The highlight of Dr. Pfister's research examines cell growth that occurs in response to mechanical deformation. Dr. Pfister discovered two kinds of growth resulting from slow and fast stretching. When a neuron is stretched quickly, it results in damage, while slow stretching causes it to grow physiologically. This revealed that slow stretching is ideal for repair of the nervous system. Dr. Pfister found that slow stretching was a small injury in itself, or rather, it is a sub-threshold injury, where the minor stretching does not kill the neuron, but acts as a signal to the nerve that it must now grow to compensate for this minor stretch. This stretch growth enables it to grow about 5mm a day, as opposed to unstretched nerves, which grow 1-3mm per day. Dr. Pfister emphasizes the importance of work being done in vitro. This enables him to look at the cells under a microscope and injure the cells to observe their reaction and growth. Dr. Pfister explains, "if you [were] to apply an injury to a lab animal you would not be able to see the effects on the cells right away[,] as opposed to [observing] the same effect in vitro." By understanding how nerves react to stretching Dr. Pfister leads the way in activating nerve generation.

Dr. Pfister is well loved by the department and has a variety of students he oversees in research, both undergraduates and graduates. He has been the recipient of many prestigious honors and grants, including the National Science Foundation (NSF) Career Award, an invitation to serve on the New Jersey Commission on Brain Injury Research, and more recently, a "Research Experience for Undergraduates" from the NSF which funds 10 undergraduate students to do research. Dr. Pfister takes pride in the fun he has doing his research, comparing his research and excitement to that of the Discovery Channel's *Mythbusters*. Dr. Pfister has provided the field of neuroscience a great deal of knowledge and information. Within the next ten years, he hopes to see collaboration between all of New Jersey's health and science and engineering schools for bigger questions in brain injury research to be solved.

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Cover Artist
Designed by Melissa Schwartz

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Image of hands on sun
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Editorial Note
Image of Peter Besada
Photographed by Andrew B. Hanna

About NJIT and the Albert Dorman Honors College
Image of two students
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A letter from the Dean
Image of Dr. Dhawan Atwan
New Jersey Institute of Technology
<http://www.njit.edu>

Back Cover
Designed by Peter Besada
Image of eye. < desktop.freewallpaper4.me>

Fellows of the Honors College
Declan Tonna
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Neuroimaging: Gateway to Our Brains
David Thompson
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x11 Image of MRI machine
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Pooja Banginwar
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x12 Image of working brain
Courtesy of Fernando Correia de Oliveira

x14 Image of Dr. Adamovich amd Dr. Foulds
Courtesy of NJIT Strategic Communications

x15 Image of HapticMASTER
Photographed by Pooja Banginwar

x16 Image of Soha Saleh and Qinyin Qiu
Photographed by Peter Besada

Cause of Consciousness
Jeremy Jen
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x24 Image of the Joker
Courtesy to creators of Joker DC Comics, movie made by Warner Bros.

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Fatima Ali

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Power Dreaming: A New Hope for Veterans with PTSD

Logan Hanie

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x40 Image of Eberhardt Hall, Photographed by Guillaume Lanteri

x40 Image of Dr. Thomas Gordon Courtesy of Dr. Thomas Gordon

x41 Image of Dr. Bryan Pfister <www.njit.edu>

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