the Berkeley Carroll School

Proceedings of the Berkeley Carroll

5TH INDEPENDENT RESEARCH CONFERENCE

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In addition, we would like to acknowledge the support and assistance of the following members of the Berkeley Carroll Administration, without whom this program would not have been possible:

Jane Moore
Director of Upper School

Robert Vitalo
Head of School

Welcome from the Editor

At first glance, the range of topics in this year's journal is literally as wide as it can possibly be. At one end of the spectrum, Aaron Goldin sought to understand how tunneling electrons help us image objects so much smaller than the wavelength of visible light that it makes no sense to talk about "seeing" them. At the other end of the spectrum, Jimmy Council used an understanding of dark matter and dark energy to ask why one Universe isn't big enough. And Michelle Madlansacay looked at an entirely different spectrum as she searched for an empathic bridge between neurotypical and autistic – you'll have to read this journal to see if she found it.

However, on closer examination, many of the questions our students chose to ask this year are not as different as they might first appear. In fact, many of them can be paraphrased as: "How can I make things better?"

Emma Raible, Danielle Cheffo, and Zoe Denckla looked inside the mind and asked how we can learn better and feel better by changing our mindset, our attitude, or our memory, respectively. Tom Shea looked at our brain in an entirely different way by asking whether repeated headers in a soccer match impair neurocognitive ability. And Nadine Khoury examined the electrical impulses in neurons in monkey brains to help pave the way for neuroprosthetic devices.

On a local level, Stephanie Aquino and Camille Johnson asked how teenagers make decisions and form first impressions, and Elias Contrubis looked at an innovative method for reducing stress.

Looking outward, Jacob Justh proposed some dramatic changes in New York City architecture to reduce storm water runoff, while Max Wu and Kirsten Ebenezer examined the respective health issues of addiction and HIV infection on a more global scale.

I'm very proud of the questions our students chose to ask this year – and I know you will enjoy reading their answers as much as I have.

Until next year,
Scott W. Rubin
Upper School Science Chair

Science Research and Design
SENIOR RESEARCHERS

Stephanie Aquino '16

Stephanie Aquino is a senior in the Science Research and Design Program. Her research has centered on the effect of peer groups on decision making.

Danielle Cheffo '16

Danielle Cheffo is a senior in the Science Research and Design Program. She has been studying positive psychology and how that affects human behavior and emotion. At first she was interested in depression, but because that is a very broad topic, she narrowed her focus down to positive psychology. In the spring of her junior year, Danielle conducted her first study investigating the correlation between gratitude and happiness. As a senior, she conducted a second study to examine the correlation between happiness and performance in school. Danielle is most interested in ways positive psychology can help decrease depression and help improve people's lives, especially among high school students. Her paper provides information on positive psychology and happiness and presents her findings on ways to increase people's happiness.

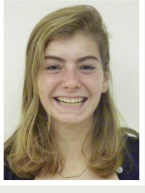
Elias Contrubis '16

Elias is a senior in the Berkeley Carroll Science Research and Design program. After dabbling in topics such as natural disasters and renewable energy during his first year, Elias settled on the study of nonverbal behaviors. His study began late in his junior year when he developed a keen understanding of the nonverbal behaviors in our society as well as those in societies foreign to us. Before the culmination of his junior year, Elias developed an in-house research project investigating the correlation between crossed legs and stress. As a senior Elias began conducting his experiment on fellow members of the Science Research and Design program using a tool that measures skin conductance to quantify stress. After concluding his study, Elias wrote a research paper which outlines the background of nonverbal behaviors before giving an in depth description of his experiment and a thorough examination of its conclusions.

Jimmy Council '16

Jimmy Council is a senior in the Science Research and Design Program. For the past two years, Jimmy has been researching information from numerous scientists about the Multiverse Theory. This theory introduces the idea of an infinite amount of universes; however it does not stop there. Along with this theory are other scientific ideas (String Theory, Theory of Inflation, Dark Energy/Matter) that work together in hopes of explaining an overarching Multiverse Theory. Jimmy has attempted to understand these scientific propositions and has developed a paper that explains the relationship between these studies. The goal of this paper is not to just provide information about the Multiverse, but to introduce a scientific possibility through the aid of widely accepted theories to gain a slight understanding about one of the largest mysteries of our universe.

Zoe Denckla '16



Zoe Denckla has enjoyed learning about various scientific areas such as epigenetics and neuroscience during her three years in the Science Research and Design program. Recently, she has gone in depth looking at the science of memory. Zoe has conducted an independent research project for the past two years investigating a potential positive correlation between music and memory. She is excited to share her findings at the SRD symposium this April.

Kirsten Ebenezer '16

Kirsten Ebenezer is a senior in the Science Research and Design Program. She has been studying the effects of epidemics, specifically the rise of HIV and TB, since sophomore year. She first began her research on the effects of the co-infection of HIV and TB in Southern Africa, and has now transitioned to understanding the diseases on a larger scale—specifically third world countries. Kirsten's

paper concerns the diagnostic tools and therapies that researchers have used to help prevent the spread of infectious diseases like HIV and TB. She also focused on the destruction of the immune system and the unique nature of co-infection and its relation to resistance of drugs. Her primary goal is to show that there are many steps, both epidemiological and economical, that should be taken to effectively address the rise of infectious diseases in third world countries.

Gil Ferguson '16

Gil Ferguson is a senior in the Science Research and Design Program. For the past year and a half, Gil has been researching the ins and outs of the Wim Hof yogic breathing technique. The Wim Hof method is very similar to Tummo Meditation which is a form of breathing meant to attain a mind-body connection. Hof studied yoga and meditation in order to create his own technique. By subjecting himself to the bitter conditions of nature, he learned to withstand the extreme forces of cold and heat. The method claims to make the oxygenation of a subject's blood cells much more efficient. In his experiment, Gil tested one aspect of the Wim Hof method on BC students hoping to determine the validity of Hof's claims. *Gil's final paper is currently in progress.*

Aaron Goldin '16

Aaron Goldin is a senior in Science Research and Design. He has been studying various realms of quantum mechanics over his three years in the program, and settled on the functions and uses of the scanning tunneling microscope (STM). This groundbreaking device is able form an image of the nanoscopic world, allowing scientists to see individual molecules and the geometry of their bonds. In order to demonstrate how the microscope works, Aaron built a "mock" STM: a device that works the same way as an STM, but on a scale large enough to be seen. He is specifically studying how the scanning tunneling microscope can be applied to nanotechnology, such as the use of functional electric "cars" made of single molecules.

Angela Goldshteyn '16

Angela Goldshteyn has devoted a significant amount of time to researching neuroprosthetics, a field of science that uses neural activity to control artificial devices (i.e. prosthetic limbs) and help the paralyzed population regain their motor functions. She is focusing her experiment on figuring out how to make a neuroprosthetic that allows more than one user to control it. She is currently building a brain-computer interface and using a computer program to connect an individual's neural activity to a Hexbug, a small spider-like robot. Hopefully, this process will allow her to gain insight on the process of decoding brain signals as well as making prosthetic devices more universal, therefore increasing their quality and decreasing their cost. *Angela's final paper is currently in progress.*

Camille Johnson '16

Camille Johnson is a senior in the Science Research and Design program at Berkeley Carroll. Since sophomore year, she has been interested in abnormal psychology and, as a sophomore, presented on the relationship between mental illness, genetics and creativity. As a junior she presented on the differences between the brains (using fMRI) of people with and without different mental disorders. During the past few summers she has taken courses at Brown University and Columbia University on psychology and neuroscience. After performing an experiment at Columbia on first impressions of trustworthiness based on appearance, she decided to expand her study to combine her interest of social justice with psychology by observing how things like perceived attractiveness, race, and gender affect subjects' perception of intelligence, trustworthiness, sexual-orientation and socio-economic status.

Jacob Justh '16

Jacob Justh is a senior in the Berkeley Carroll Science Research and Design program. During his sophomore year, he studied hearing technology and the psychosocial effects of hearing loss in children. He also studied climate change and looked into effective ways to sequester carbon dioxide emissions. Continuing on the trend of environmental science, Jacob spent his junior year researching urban agriculture and how it could be

implemented in New York City. His studied how green roofs function as a reservoir for biodiversity as well as New York's capacity for growth in this industry. This past year he studied urban storm water runoff mitigation and combined sewer overflow, and he attempted to create the optimal green roof design for runoff retention.

Nadine Khoury '16

Nadine Khoury researches Neuroprosthetics under the mentorship of renowned researcher, Dr. Beata Jarosiewicz at BrainGate, a Lab based in Brown University pioneering neuroprosthetic research. Nadine decoded one neuron's firing rates to find its preferred direction and then developed codes interpreting multiple neurons at a time to find their collective intended movement velocity. She sat in on brain-control sessions. Her research included courses in bioethical research with Brown University. She shadowed a clinical neurologist from Harvard University at Massachusetts General Hospital, acquiring hands-on exposure to aspects of her research applied in practice. Nadine attended the Yale Young Global Scholars Program (Science, Policy, Innovation) at Yale University where she learned about social, ethical, and political dimensions of scientific breakthroughs. There, she received a Director's Award given to 20 of 220 participants. Nadine plans to continue studying bioengineering at Harvard University next year.

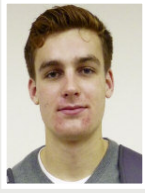
Michelle Madlansacay '16

Michelle Madlansacay is a senior at Berkeley Carroll and her research concerns the autism spectrum disorder and the theory of mind. Since her sophomore year, Michelle has had an interest in studying autism. She began her research by looking into the specific treatments for repetitive behaviors of people with autism. By the end of her first year in the program, she presented a poster presentation on the effects of the drug, fluoxetine, on autistic adults. In her junior year Michelle shifted the focus of her research to the social interactions of people with autism and the function of the theory of mind. Since then, Michelle has written a paper that combines elements of a literature review and an experimental design write-up to answer the question: Is the autism empathy spectrum a continuation of the neurotypical spectrum, or are they two separate spectra?

Emma Raible '16

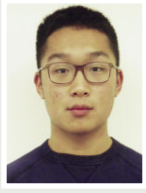
Emma Raible, a senior in the Science Research and Design Program, has always been an observer. She has spent the past two years becoming an expert on physiologist Carol Dweck's mindset theory. Emma is interested in the role that fixed and growth mindsets play in education. She conducted an observational study in school that she hopes will help the English department teach with more of a growth mindset in the future. Emma is looking forward to sharing her results with everyone in the spring at the symposium.

Thomas Shea '16



Tom Shea is a senior in the Science Research and Design Program. For the past two and a half years he has been researching the effects of subconcussive head impacts on the brain. During sophomore and junior year Tom spent his time reading and writing about this topic. He learned that repeatedly heading a soccer ball could affect one's cognitive performance. In fact, in extreme cases, heading a soccer ball can cause one to suffer from Chronic Traumatic Brain Injury. During his senior year, Tom conducted an experiment with the girls' and boys' varsity soccer teams in order to test the effect that heading a soccer ball has on a high school athlete's brain. His paper discusses the risks posed to soccer players throughout the nation.

Max Wu '16



Max Wu is a senior in the Berkeley Carroll Science Research and Design Program. While he explored and presented on a variety of topics during his sophomore year — such as epigenetics, household air pollution, and drug addiction — he decided to pursue the latter, working with two researchers throughout the summer and past year - first, Stanford University researcher Dr. Keith Humphreys, and, second, Dr. John Mariani, director of Columbia University's STARS clinic. His final project is about marijuana dependency's inner workings, a secondary analysis paper he conducted with Dr. Mariani, testing whether higher baseline marijuana use correlated with higher frequencies of depression, anxiety, and Insomnia.

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Peer Influence on Decision Making

by Stephanie Aquino

Abstract

How do people influence our decisions? Why do things like peer pressure exist? Decision-making is something that can be pretty straightforward in certain circumstances, especially ones that are instantaneous and don't leave much room for thinking through consequences. However, there are decisions that we make in our day-to-day lives that are intentional. We even might ask someone for advice on those decisions. The experiment in this paper explores the effect other people have on decision-making.

Background Information

Neurons in our brain are what allow us to think. Neurotransmitters, special chemical compounds, transmit signals or "messages" across a synapse from one neuron to another. This message passes three phases of neurons: sensory neurons, interneurons, and motor neurons. These three phases represent the three stages of our thinking process, where we first gain information, then interpret the information and then properly respond to the information. An example of this would be touching a hot kettle. First, you would touch the hot kettle and sensory neurons in your skin would take that signal and pass it along to the next neuron, until it reached your interneurons at the brain. These neurons are the ones that "think" and determine the response necessary for you to make decisions. In this scenario, the decision is involuntary; your brain knows that you have to pull your hand away from the kettle because if you don't you are in danger. The signal is then carried out as a response—in this case the neuron path goes down your arm that is then told to pull away from the kettle.

That is an example of not only how we think, but also how we make decisions. It is a simplified version, because of how instinctive some choices we encounter are. Some decisions we make are obvious, because we know not to put our body in danger. We pull away when something is too hot, our eyes widen at a sudden noise, and we gain the adrenaline to run when we are in danger. When the decision isn't so straightforward, however, the process of making decisions becomes a lot more difficult, and there are many more factors to consider – especially as we get older.

Method

Do people take greater risks when they are with other people than when they are alone? To answer this question, an experiment was conducted where a survey was handed out to two different groups. The survey was divided into 3 sections: school, health, and online risk. They each have 3-4 questions that ask the participant how willing they would be to take on a certain scenarios, with the response to each question being a) not willing, b) not sure, and c) willing. One of the groups would take the survey without talking to each other, and the other group would take the survey after having five minutes to discuss each section. After they discussed each section, they would then fill out the survey.

AQUINO SRD SURVEY

**Keep in mind while taking the test both the pros and cons that can come from each.*

School

1. How willing would you be to take a class that is acclaimed to be the "best challenging class", but also the hardest grading teacher?
   a. willing
   b. not sure
   c. not willing
2. How willing would you be to cheat on a test you didn't study for, but you might get caught?
   a. willing
   b. not sure
   c. not willing
3. How willing would you be to take a class where you don't know any of the students, and you aren't sure whether or not you will like them but maybe you will make a friend?
   a. willing
   b. not sure
   c. not willing
4. How willing would be to take the elevator from the basement to the fourth floor - but you might get two demerits?
   a. willing
   b. not sure
   c. not willing

Health

1. How willing would you be to try out a gym course proven to show "real results" but whose tactics increase possibility of getting injured?
   a. willing
   b. not sure
   c. not willing
2. How willing would you be to stop eating unhealthy foods, but your health might stay the same?
   a. willing
   b. not sure
   c. not willing

3. How willing would you be, if you were trying to lose weight, to go running everyday, but there might not any results?
   a. willing
   b. not sure
   c. not willing

Online

1. How willing would you be to meet someone you met online in person, alone?
   a. willing
   b. not sure
   c. not willing
2. How willing would you be to message someone you like on social media, not knowing whether or not they will respond to you?
   a. willing
   b. not sure
   c. not willing
3. How willing would you be to post a "funny/weird" picture of yourself on a social media, not knowing whether it will get you more or less likes?
   a. willing
   b. not sure
   c. not willing
4. How willing would you be to friend someone who "intimidates" you on facebook, but they might not add you?
   a. willing
   b. not sure
   c. not willing

Results and Analysis

After collecting answers from both groups, I analyzed their answers by assigning each option a point. If they chose "willing", they would be given 2 points, if they chose "not sure", they would be given 1 point, and if they chose "not willing" they would receive 0 points. Each person was then given a score out of 24 (the highest score one could score on the test), which was then converted to a score out of 100. The average score of each group (A and B) was then taken, with the results being: Group A average – 49.31, Group B average – 40.97.

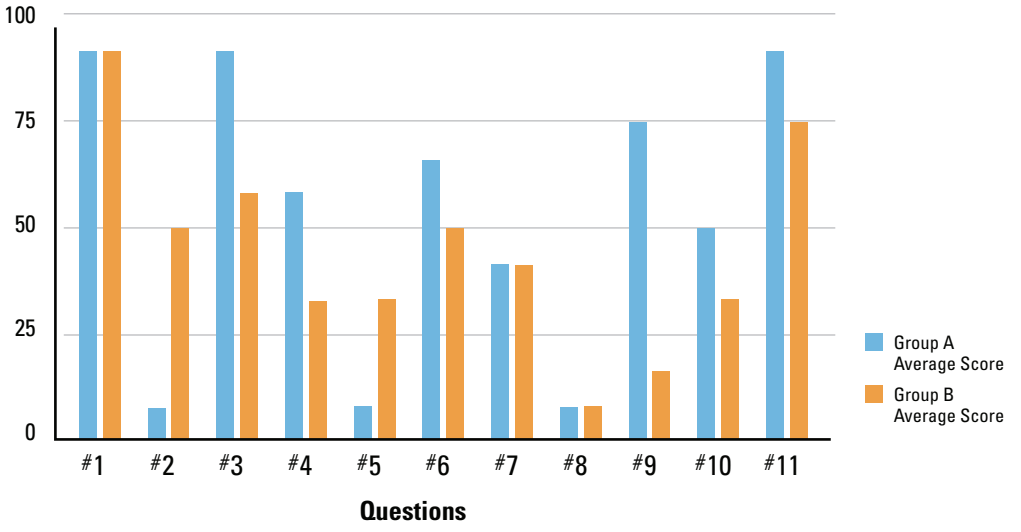
From those results alone, one could say that the answer to this experiments question (Do people take greater risks when they are with other people, and less risks when they are alone?) would be yes, people take greater risks when they are with other people. Group A took the survey while discussing the answers, and scored higher, meaning they were more willing to take risks. Group B, however, took the survey independently without talking to anybody, and scored lower, meaning they were less willing to take risks.

Synesthesia is caused by an interaction between the fusiform gyrus in the pre-frontal cortex of the brain and the retina within the eye. The V4 region of the pre-frontal cortex helps the brain to process colors (Ramachandran). This region for synesthetes is believed to have an excess of neurological connections that was not efficiently pruned during development. These excess connections within the brain cause the involuntary interaction between the senses to

Figure 1

Group A Average Score and Group B Average Score

The graph below compares the average of each group's score for each question, out of 100.



take place. This is known as the neonatal hypothesis (Tomson). This is the leading hypothesis for how synesthesia is acquired. This is the prevailing theory, and as such, the potential causes for synesthesia have been limited.

After conducting a two-tailed independent t-Test, I found that the p value was 0.056. Because of this, the results can't actually be considered statistically significant. Although the results would suggest that people do take greater risks when they are with other people and fewer risks when they are alone, this could only be confirmed if the p value was less than .05, but this experiments value is slightly above it. A .05 p-value means that there is a 95% probability that the difference is not due to chance, and this 95% is the widely accepted cutoff for statistical significance. For this experiment, that would mean that there is a 94.4% chance that the difference is not due to chance, which although not statistically significant, is still a positive direction in answering the experimental question.

Conclusion

The hypothesis for the question "Do people take greater risks when they are with other people, and less risks when they are alone?" was that people who were in group A (the group that discussed the questions before responding), would score higher on their survey. While the difference in scores did not reach the threshold for statistical significance, the results suggest that the hypothesis could be confirmed if the study were slightly altered.

Redoing the experiment, taking into consideration any factors that might have skewed the results, could provide more reliable data. For example, group B, who took the survey without talking to anyone, all took the survey in different places. For the sake of saving time, I emailed the survey to group B over the weekend which could have affected the results because some of them could have been in their room where they felt more comfortable or "brave", and some

might have been somewhere that made them feel uncomfortable. Additionally, only 12 participants were used - 6 in group A and 6 in group B. This is a small pool of participants, so having more people participate in the experiment would help solidify the study. A good direction to take this study would be to redistribute the survey while taking into consideration all of these aspects.

It is interesting to think about how the results would vary when taking into account the gender or socioeconomic status of the participants. This experiment targeted students in the Berkeley Carroll High School, but many previous experiments have been done showing how decision-making in general is shifted between people with different incomes, and between females and males.

Some next steps in studying this topic would be to focus on these different aspects, or perhaps grade level as well. The groups I used were a mix of sophomores, juniors, and one senior, but a new modified experiment could compare the results between the different grades.

Resources

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Positive Psychology: Bringing More Happiness Into People's Lives

by Danielle Cheffo

Abstract

Psychologists researching the field of positive psychology (positive psychologists) have come up with many different experiments to increase people's happiness. Instead of focusing on reducing negative emotions, they use a positive approach to bring more happiness into patients' lives. I designed two studies to answer these experimental questions: how does gratitude affect a person's happiness and how does a person's happiness affect his or her performance in school? In the first study, I split students up in two groups and compared their happiness levels. Those in the experimental group were asked to show extra gratitude for a week by writing down what they were thankful for, while those in the control group were not forced to show any extra gratitude. I concluded that the students that were forced to show extra gratitude were happier than those who didn't. The two-tailed independent t-test yielded a p-value of < 0.001. I conducted a follow up study to answer the second experimental question and concluded that there was no correlation between a student's happiness and their test scores, but the results suggest that another study should be conducted with a larger participant pool.

Background

According to the Center for Disease Control, suicide is the third leading cause of death for youth between the ages of 10 and 24. This statistic can be associated with the fact that twenty percent of youth experience an episode of clinical depression by the end of high school. Depression is one of the most common mental disorders in the United States, affecting one in every ten Americans at some point in their lives. About 18.8 million American adults and 2.6 million American adolescents suffer from a depressive disorder; unfortunately, these numbers are not decreasing[1]. Depression can be debilitating, leading to physical manifestations beyond the mental health issues. Yet many healthcare professionals don't take depression as seriously as they should. Psychologists have tried hard to think of ways to reduce depression. Most of

these ways focus on just reducing negative emotions. However, positive psychologists have shown that just focusing on reducing negative emotions doesn't necessarily increase happiness. This means that reducing negative emotions does not necessarily reduce depression. Positive psychology is the scientific study of the strengths that enable individuals and communities to thrive. Positive psychologists' main aim is to increase their clients' happiness. To understand this field of study, it is important to define what happiness actually means. Happiness can be defined as "subjective well-being," a combination of life satisfaction and having more positive emotions than negative ones[2].

Since happiness is subjective and difficult to measure, positive psychologists have split it up into three groups: the pleasant life, the engaged life, and the meaningful life. The pleasant life concerns positive emotion about the past, present, and future. More specifically, if a person feels content and satisfied by the past, somatic pleasures from the present, and optimism and hope for the future, then they are said to have a pleasant life. The engaged life consists of using positive individual traits, including strengths of character and talents. Some of these strengths include valor, leadership, kindness, integrity, originality, wisdom, and the capacity to love and be loved. A person who leads their life by these traits is considered to be living the "good life," or the engaged life. The third domain of positive psychology is the meaningful life, which entails belonging to and serving positive institutions. Simply, a person belonging to and serving something larger than oneself is living the meaningful life. These three lives are three different roads to happiness and allow positive psychologists to measure happiness in the most objective way possible. One way to measure if a person is living any of these lives is by asking them to fill out a survey[2]. One of the most reliable happiness surveys is called, "The Oxford Happiness Questionnaire (OHQ)." It comprises of 29 items, each presented as a single statement that can be answered on a six-point scale[3]. A sample of the OHQ can be found later in this journal article.

An experiment conducted in 2003 by Emmons and McCullough concluded that participants randomly assigned to a gratitude intervention showed increased positive affect relative to the control participants. To come to this conclusion, the researchers split the participants into three groups, the experimental, or gratitude condition and the two control conditions. Those in the gratitude condition were asked to write about five things they were thankful for every week for ten weeks. In one of the control conditions, participants were asked to write about daily hassles and those in the other control condition were asked to write about neutral life events. All participants were asked to complete weekly ratings of how they felt about life as a whole, their expectations for the week to come, and how connected they felt to others. The researchers concluded that relative to the control groups, participants in the gratitude condition reported feeling better about their lives in general, more optimistic about the coming week, and more connected with others[4].

Sample of The Oxford Happiness Questionnaire[4]

Instructions: Below are a number of statements about happiness. Please indicate how much you agree or disagree with each by entering a number in the blank after each statement, according to the following scale:

1 = strongly disagree
2 = moderately disagree
3 = slightly disagree
4 = slightly agree
5 = moderately agree
6 = strongly agree

Please read the statements carefully, because some are phrased positively and others negatively. Don't take too long over individual questions; there are no "right" or "wrong" answers (and no trick questions). The first answer that comes into your head is probably the right one for you. If you find some of the questions difficult, please give the answer that is true for you in general or for most of the time.

The Questionnaire
I don't feel particularly pleased with the way I am. _____
I am intensely interested in other people. _____
I feel that life is very rewarding. _____
I am not particularly optimistic about the future. _____
Life is good. _____
I laugh a lot. _____
I don't think I look attractive. _____
I feel able to take anything on. _____
I don't have a particular sense of meaning and purpose in my life. _____
I don't feel particularly healthy. _____
I don't have particularly happy memories of the past. _____

First Study

In the spring of 2015, I designed and conducted an experiment to see if there was a correlation between being thankful and being happy. I hypothesized that there would be a correlation; that the more gratitude a person shows, the happier they will. In order to answer the experimental question, I recruited nineteen tenth graders to be my participants. I split them into two groups; experimental and the control. To start the experiment, all participants in both groups took the Oxford Happiness Questionnaire, but I called it the "Well-Being Survey" so that they didn't know that I was specifically measuring happiness. Afterwards, the participants in the experimental group wrote four things they were grateful for everyday for five days. Those in the control group were not asked to show any extra gratitude. After the five days, all participants took the "Well-Being Survey" again.

Data

Experimental Group

HAPPINESS AVERAGE BEFORE	HAPPINESS AVERAGE AFTER	HAPPINESS DIFFERENCE
4.2	4.0	-0.3
4.0	4.0	0.0
4.4	4.5	0.01
3.2	2.9	-0.04
4.3	4.5	0.2
4.6	5.0	0.4
4.6	3.8	-0.08
3.8	3.8	0.0
4.4	4.5	0.1
3.7	3.7	0.0
3.0	3.2	0.2

Control Group

HAPPINESS AVERAGE BEFORE	HAPPINESS AVERAGE AFTER	HAPPINESS DIFFERENCE
4.3	3.9	-0.4
3.6	3.4	-0.2
4.8	4.7	-0.1
3.8	3.5	-0.3
4.0	2.9	-1.1
5.3	4.3	-0.9
3.8	3.3	-0.5

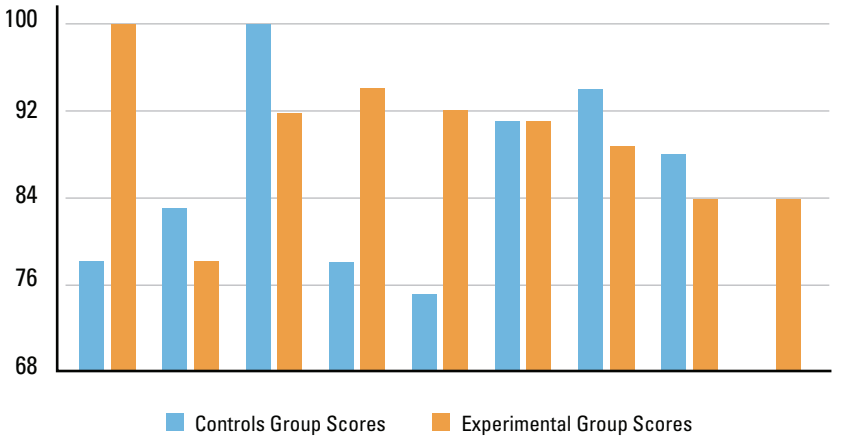
AVERAGE EXPERIMENTAL HAPPINESS BEFORE	AVERAGE EXPERIMENTAL HAPPINESS AFTER	AVERAGE CONTROL HAPPINESS BEFORE	AVERAGE CONTROL HAPPINESS AFTER
4.2	3.99	4.2	3.7

AVERAGE HAPPINESS DIFFERENCE FOR EXPERIMENTAL GROUP	AVERAGE CONTROL HAPPINESS FOR CONTROL GROUP
-0.2	-0.5

Figure 1

Experimental Happiness Difference and Control Happiness Difference

This chart shows the happiness differences between the participants in the experimental group and those in the control group. Since the study took place during finals week, it was expected that the majority of the participants' happiness levels would decrease, but the graph above shows how all those in the control group happiness levels decreased while only three in the experimental group decreased. The average happiness difference for the experimental group is -0.2 and the average happiness difference for the control group is -0.5. The p-value for these numbers is < 0.001, which shows that there is a significant difference between the average happiness difference levels for the control and experimental groups.



Conclusion

This study suggests that there is a significant difference between the scores. This supports the idea that recording things they were thankful for had an effect on the experimental group's happiness. The data shows that the control group's happiness levels before and after the experiment all dropped, while some of the experimental group's happiness levels went up. The average happiness level before the experiment for both the control and experimental group was the same, and although they both decreased (most likely because of the stress from finals), the average happiness level of the control group decreased more than that for the experimental group. That being said, there were many other factors that could have affected the participants' happiness levels outside of the experiment that were not controlled. People could have been happy for many other reasons, so if this study were to be conducted again, more factors would need to be controlled outside of the experiment to get a more accurate conclusion. However, this study does suggest that the gratitude increases happiness, so it definitely wouldn't hurt to be show more gratitude.

Second Study

After the results of the previous study suggested that showing gratitude increases a person's happiness, I wanted to see if there was a way this could help improve students' performance in school. I came up with an experiment to answer the question: how does happiness affect a student's test scores? My participants were students in the eleventh grade Science Research and Design (SRD) class who were learning statistics. The 17 participants were strategically split up by their teacher into two groups to make sure the average skill level in each group was balanced. Two days before the statistics quiz, all the participants were given an envelope with a survey to fill out inside. The 9 students in the experimental group were asked to write down three things that they were thankful for and explain why for one of them. The 8 students in the control group were asked to write down three things they think are important about understanding statistics and to explain why for one of them. Then they put the paper back into the envelope and sealed it. Right before the statistics quiz all the participants were handed back their envelopes and were told to review what they had written for a couple minutes. Then they took the quiz.

Data

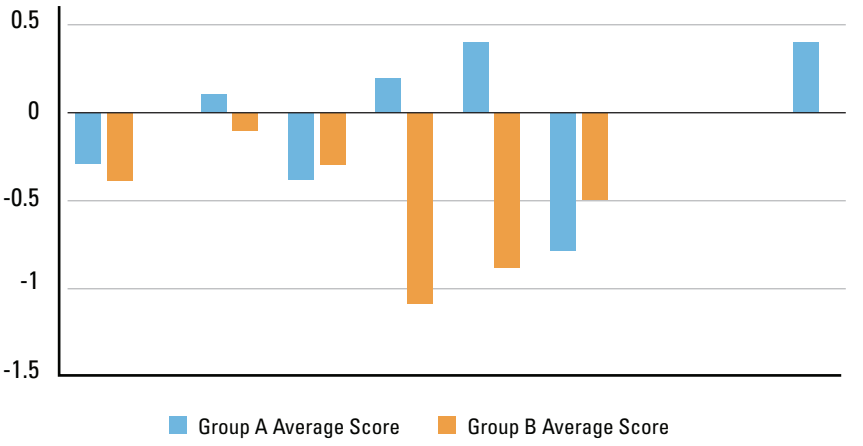
CONTROL GROUP SCORES	EXPERIMENTAL GROUP SCORES
78	100
83	78
100	92
78	94
75	92
91	91
94	89
88	84
	84

CONTROL GROUP AVERAGE SCORE	EXPERIMENTAL GROUP AVERAGE SCORE
85.9	89.3

Figure 2

Control Group Scores and Experimental Group Scores

This graph shows the test scores for the participants in both the control group and the experimental group. The overall average in the experimental group was 89.3 percent and the overall average in the control group was 85.9 percent.



Conclusion

From the data I collected, it is suggested that happiness does not significantly affect a student's performance in school. Although the average for the experimental group is numerically higher, it is not statistically significantly higher. An independent two-tailed t-test yields a p-value of 0.3688. This is suggestive that another study should be done with more participants in order to investigate whether there is a significant difference that was missed due to small sample size. A study similar to this one, but with statistically significant results could positively impact many students in a very simple way. Schools could focus more helping to increase students' happiness levels, which is very important since many high school students experience depression at some point during the four years of high school. With a future study, it might be concluded that happiness does affect a student's performance in school, which would help improve a lot of student's lives.

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The Effects of Leg Asymmetry on Stress in High School Students

by Elias Contrubis

Abstract

A study by Albert Mehrabian shows that people expressing leg asymmetry, otherwise known as sitting with their legs crossed, are more comfortable and relaxed than people with leg symmetry in a one-on-one conversation[1]. Using this research, I planned and conducted an experiment which tests if a person can intentionally decrease their stress level by sitting with leg asymmetry. A Trier Social Stress Test[2] was used to test the participants' stress levels. Stress was recorded using an eSense Skin response, a device that measures the galvanic skin conductance of the middle and index fingers[3]. Results showed that there was no significant difference in stress between those with leg symmetry and those with leg asymmetry ($p = 0.402709$)."

Background

In *The Expression of the Emotion in Man and Animal* Charles Darwin poses the question: "Why do our facial expressions of emotions take the particular forms that they do? Why do we wrinkle our nose when we are disgusted, bare our teeth and narrow our eyes when enraged, and stare wide-eyed when we are transfixed by fear?"[4] Darwin's inquiry is an essential one and widely considered when studying nonverbal behavior. In answering his own question, Darwin proposes that at some point in the evolution of a species it was evolutionarily beneficial to express specific emotions[4]. The raising of skin appendages like hairs or feathers is one such expression which has become beneficial to convey. The raising of skin appendages is usually observed in an animal experiencing fear, panic, or shock and "serves to make the animal appear larger and more frightful to its enemies or rivals"[4]. For example a frightened chicken will ruffle its feathers, spread its wings, raise its tail, and enlarge its collar feathers (figure 2). Furthermore, raising an animal's skin appendages also functions as a warning sign for its own

species. Another example is the "the drawing back and pressure of the ear to the head"[4] which can be seen in animals that fight with their teeth such as dogs and cats. The main purpose of this action is to prevent the ears from being wounded in battle. However, the drawing back of an animal's ears may also serve to communicate a transition to an aggressive mindset[4].

Figure 1

The image gives an example of a dog which has drawn back its ears during a play fight[5].

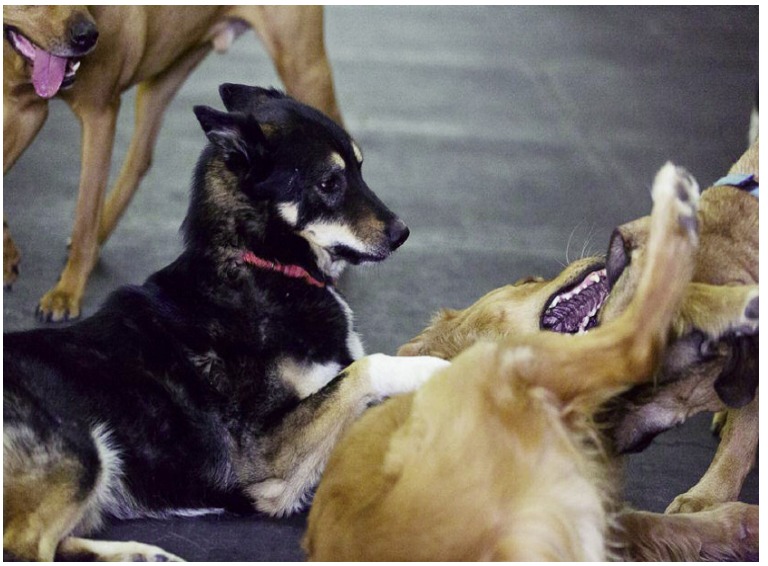


Figure 2

This image shows two chickens who have raised their appendages during a fight[6].

Over the course of evolution, primitive emotions have transformed into human communication. While these emotions have lost some of their initial evolutionary purpose, "They provide others with external evidence of an individual's internal state"[7]. Social psychologists now call these emotions nonverbal behaviors, and have developed two lines of thinking. The first is that they are solely communicative, such as a thumbs up, and the second is that they affect the neurotransmitters linked to emotion[7]. In the case of affecting neurotransmitters, the use of facial expressions could result in the restriction of venous flow to the cerebral cortex affecting the temperature of the blood. This would result in the cooling or warming of the blood which, in turn, would affect the release of the neurotransmitters linked to emotion[7]. An example of a nonverbal behavior specific to humans is the forward lean of seated individuals[1]. In a situation where the distance between people is fixed, such as while sitting on furniture, forward lean can be used to assess the closeness and comfort of the individuals. While a forward lean conveys a positive attitude, a backwards lean conveys a decreased interest[1]. Hand gestures, another example, have been split into two general groups, motor movements and lexical movements[7]. Motor movements are the almost rhythmic hand gestures that don't seem to add to the conversation, and lexical movements are the gestures that seem related to the conversation but are not repeated like the motor movements[7]. In general, the purpose of hand gestures is more to aid in the speech process and lexical recollection rather than convey information in a conversation; these observations seem to support the conclusion that nonverbal behaviors affect neurotransmitters linked with communication[7].

Researchers have also found that an individual's nonverbal behaviors can depend on a person's cultural background[8]. Specifically, distinct gestures such as adapters, emblems, and illustrators were found to vary between cultures[8]. Adapters are unconscious actions such as shaking one's leg or fidgeting; these were found to vary the greatest between cultures. Emblems are culture specific gestures such as the thumbs up or the "okay" sign, and illustrators are gestures used to emphasize words such as cutting a hand through the air. Both of these nonverbal behaviors were found to vary slightly between cultures. Conversely, regulators, which are gestures used to regulate the tempo and content of a conversation, like head nodding, were actually found to be similar throughout the world[8]. Furthermore, the frequency of the nonverbal behaviors was not found to be affected by the cultural background of the individuals.

In a literature review, Albert Mehrabian classifies and quantifies the most common and significant nonverbal behaviors, and defines what they communicate. One way to think of his report would be as a dictionary for nonverbal behaviors. For example, a section of his paper found higher speech rate, higher rates of gesticulation, more pleasant facial expressions, higher rates of rocking, leg asymmetry, and lower rates of trunk swivel to be referents for greater relaxation[1]. The idea that relaxed people act in this way made me curious to see if this process could be reversed to make people feel more relaxed. Specifically, I wanted to see if people purposefully sitting with leg asymmetry (crossed legs) during a stressful situation would experience less stress. I tested this by asking half of my participants to sit with crossed legs during the Trier Social Stress Test and the other half to take the test while sitting with their legs straight then compared the difference in increase of stress.

Trier Social Stress Test

An integral test used in my study of nonverbal behavior is the TSST or Trier Social Stress Test originally invented by Clemens Kirschbaum at the University of Trier[2]. The purpose of this test is to increase a person's stress level in order to study how they may react. This was created as a way to normalize the process of inducing stress in the laboratory. The test usually lasts for approximately 10 to 15 minutes and starts with two minutes of preparation in which the participant is asked to wait in the examination room to create anxious anticipation. Next, the person is asked to give a five-minute speech; this can be about their strengths and weaknesses or can be a made up story. This is followed by an additional five minutes where the participant is asked to solve difficult mental math. The entire test is done in front of a two person interviewing team and is usually videotaped. My experiment used this test because it has been shown to increase cortisol in plasma and saliva, both signs of increased stress levels in a person[2]. During the TSST, an eSense skin response tool created by Mindfield Biosystems was used to measure the stress of each participant[3]. The device uses two small electrodes attached to a subject's middle and index fingers and measures galvanic skin conductance (GSC), which is simply the electrical conductance in skin. Each electrode discharges an unnoticeable amount of voltage on the fingers allowing the device to measure the conductance created in the hand. This particular tool is effective in measuring stress because stress has been shown to induce perspiration in a person's hand, which can be measured through conductance[3]. The units used by the device are μSiemens or the inverse of electrical resistance. Therefore a larger measurement of μSiemens suggests greater current, and hence greater stress levels.

Procedures

TSST's were conducted on 20 randomly selected members of the Science Research and Design class, which includes students from 10th through 12th grades at The Berkeley Carroll School. First, every student's stress level was recorded for five minutes using the eSense skin response and averaged to establish a baseline. Then the participants were separated into two groups to establish a control and an experimental group. The TSST was administered to every participant in the same manner. The first five minutes consisted of asking students to tell a story giving no further instructions (figure 3). The next five minutes consisted of asking the students difficult math problems of which they were only allowed to compute mentally (figure 3). The only difference in how the TSST was conducted is that the control group was asked to keep their feet flat on the ground while the experimental group was asked to maintain leg asymmetry throughout the test.

Figure 3

Trier Social Stress Test

The table shows the exact questions asked during the TSST and why they induced stress.

#	QUESTION	PURPOSE
Q1.	Tell us a story	The broad nature of the question creates nervousness surrounding participant's answer choice
Q2.	Count backwards from 3,000 in intervals of 11	Q2-Q6: The stress of completing complicated math problems is escalated by the pressure of the situation
Q3.	How many factors does 512 have?	
Q4.	List the square roots below 100	
Q5.	Name 5 different ways to split a dollar into change only using one quarter	
Q6.	Count backwards from 2,000 in intervals of 13	

Results

Figure 4

Individual Stress Level Measurements During the Trier Stress Test

The graph represents the measured stress levels of each participant during both the baseline, in blue, and the TSST, in red. The first ten participants expressed leg asymmetry while participants 11-20 expressed leg symmetry.

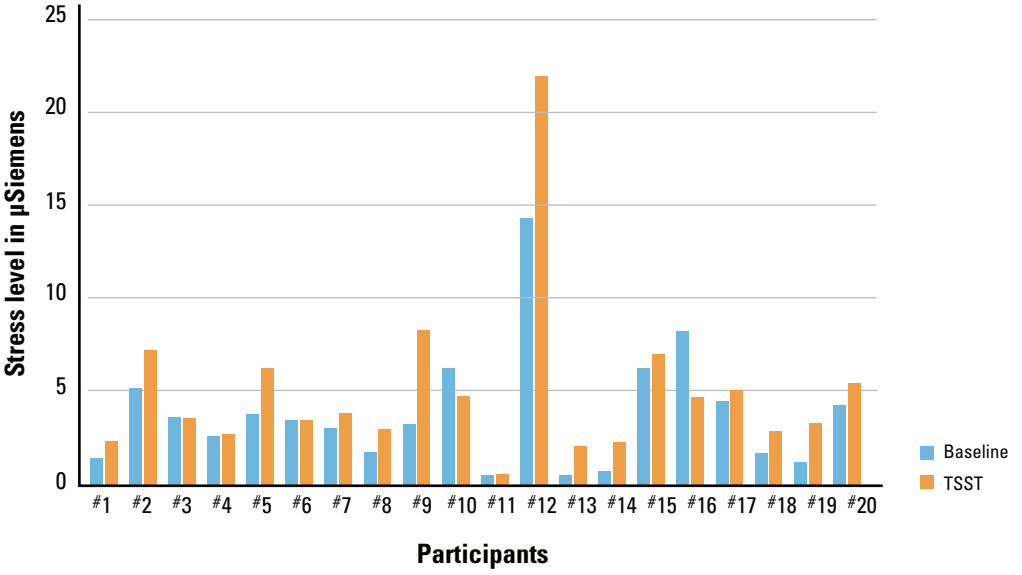


Figure 5

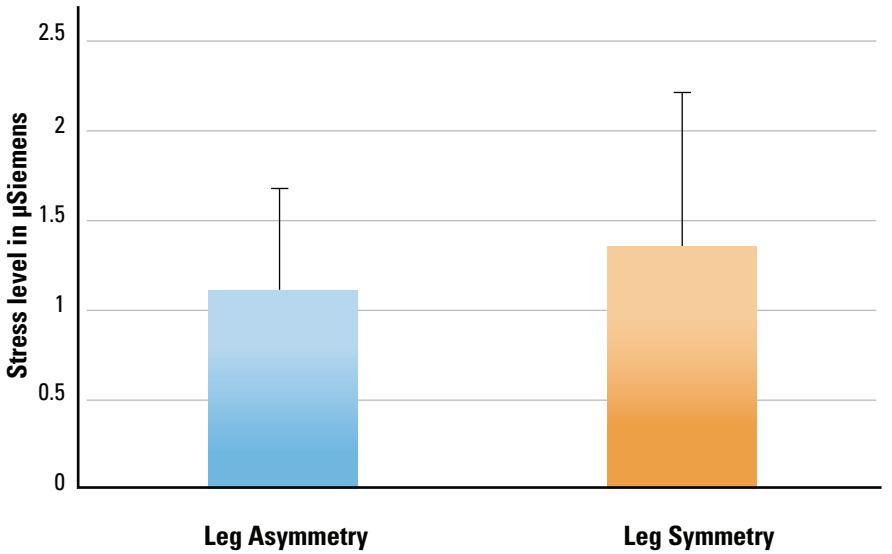
The table below shows the exact questions asked during the TSST and why they induced stress.

LEG ASYMMETERY			LEG SYMMETRY		
#	Change in Stress	Comfort with Math	#	Change in Stress	Comfort With Math
1	0.902	Strong	11	0.028	Strong
2	2.014	Medium	12	7.584	Strong
3	0.018	Strong	13	1.506	Strong
4	0.138	Medium	14	1.607	Medium
5	2.430	Medium	15	0.690	Medium
6	0.000	Medium	16	-3.530	Strong
7	0.839	Medium	17	0.504	Strong
8	1.225	Strong	18	2.171	Medium
9	5.078	Low	19	2.050	Strong
10	-1.495	Medium	20	1.091	Strong

Figure 6

Effects of Leg Asymmetry during a Trier Social Stress Test

The graph shows the average change in stress for participants with leg asymmetry and leg symmetry. The error bars represent the standard error of the mean which shows how the data is distributed around the average.
A One Tailed Independent T-test was used to produce a P value of 0.402709.



The results showed that the stress of those who crossed their legs during the TSST did not increase at a significantly lower rate than those who did not in relation to their baseline (figure 6). On average, those who crossed their legs experienced a stress increase of 1.1 μS while those who did not cross their legs experienced a stress increase of 1.4 μS. Though subjects with leg symmetry did experience slightly more stress, it was not by a statistically significant margin. This conclusion was supported by a one tailed independent t-test completed using each participant's stress increase during the TSST. A t-test produces a p-value which indicates the probability that results are actually different; customarily results in scientific studies are only considered to be statistically different if the p-value is 0.05 or below. The p-value for this test was .403 making the results insignificant.

While the TSST is designed to induce stress in individuals, amongst a majority of the group the test was not effective in causing significantly more stress than the baseline (figure 4). In fact, two participants experienced more stress during their baseline exam than during the TSST. Furthermore, many participants expressed feeling confident with math and only one participant expressed that they were not confident with math. This is made relevant as many of the questions on the TSST were math-related (figure 8).

Discussion

From these results, I was not able to conclude that there is a difference in stress levels as a result of leg asymmetry. The idea was that if people express leg asymmetry when they are relaxed, it may be possible to induce relaxation in stressed individuals by having them sit with their legs crossed. However, according to the findings from this study, those expressing leg asymmetry during the TSST only experienced slightly less stress than the control group and the small difference was not statistically significant.

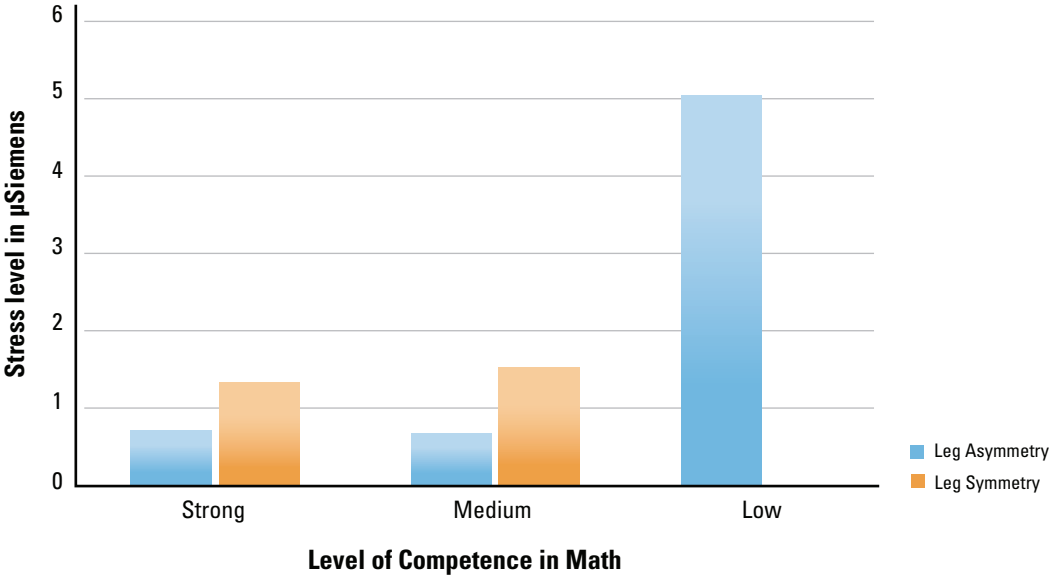
There were three main factors that may have been responsible for the relative ineffectiveness of the TSST. Firstly, students may have experienced stress during the baseline test. The baseline lasted for five minutes and usually consisted of what I would describe as awkward silence and polite conversation. This possibly created an environment where the participants felt stressed or nervous. In future studies, to fix this problem I might ask participants to read a generic article during the baseline to remove the variable of a stressful baseline. I could also record the baseline after the TSST and measure how much their stress decreases by. The second factor is that the two people conducting a TSST are usually actors who are unfamiliar with the participants. However, because of a lack of access to actors unknown to Berkeley Carroll, I conducted the test with another member of the Science Research and Design class. This created the possibility that the participant felt comfortable with me or the other TSST conductor making the test less stressful. On the other hand, the senior-sophomore dynamic present with a majority of the subjects could have had the opposite effect and increased the stress level of the participant. This is especially true because the baselines were conducted at the beginning of the year before the participants became familiar with me through the SRD classroom. Finally, many of the participants self identified as being comfortable with math which would have made the TSST less stressful than intended (figure 7).

Together, these factors may have created a baseline that reflected a greater stress level than intended and a TSST that induced less stress than intended. As a result, the difference between the two stress measurements was very small which made finding results difficult. In the future, besides the changes mentioned above, the experiment could have benefited from a

Figure 7

The Effect of Math Competency in the Trier Social Stress Test

This graphic represents the average stress level relative to a person's ability in math. For example, the change in stress level of those who expressed leg symmetry and are strong math students was 1.3 µSiemens



larger sample size and better overall consistency. For example, if all baselines and TSSTs could have been conducted in the same room with the same temperature, it would have improved the experimental results through a more fastidious control of the variables. Recruiting actors would also be extremely beneficial for this particular experiment and any experiment using a TSST as they improve the quality of the stress test.

In terms of next steps, the fact that the participants with leg asymmetry were on average slightly less stressed is encouraging. I would consider conducting this experiment again with the suggested changes. I would also consider making a slight tweak to the experimental design so that the participants are asked to cross their legs for five minutes before the TSST in case leg asymmetry takes a couple of minutes before effectively decrease a person's stress.

Furthermore, my results support the theory mentioned before that nonverbal behaviors are solely for communication purposes. Because intentionally expressing leg asymmetry was not successful in decreasing a person's stress, this suggests that there is no connection with the neurotransmitters associated with emotion.

Figure 8

The table depicts the distribution of participants who either have strong, medium, or low competence in math for the control and the experimental groups.

LEVEL OF COMPETENCE IN MATH	LEG ASYMMETRY	LEG SYMMETRY
Strong	1, 3, 8, 10	11, 12, 13, 16, 17, 19, 20
Medium	2, 4, 5, 6, 7	14, 15, 18
Low	9	–

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The Multiverse

by Jimmy Council

Questions: *What is the Multiverse and how does the Theory of Inflation, the presence of Dark Energy/Dark Matter, and the String Theory work together to support its existence?*

Abstract

We are individuals. In this universe, the fact you are you and that this is your life cannot change. You are able to make your own decisions and control your movements because you have a mind of your own. Now, imagine the possibility of there being multiple universes–a multiverse–where it is possible that there can be numerous versions of "you". How would scientists be able to determine whether this concept is possible? As you proceed through this paper, you will dive into the world (or many worlds) of the Multiverse and three theories which have been developed to explain the Multiverse hypothesis. Inflation, String Theory, and Dark Energy and Matter are all three independent ideas, each discovered and tested by different scientists that might have a common point to be explored. In this paper I explain the basic concepts that play a role in each of those theories as well as discuss how plausible it really is that we are all living within a Multiverse.

Inflation

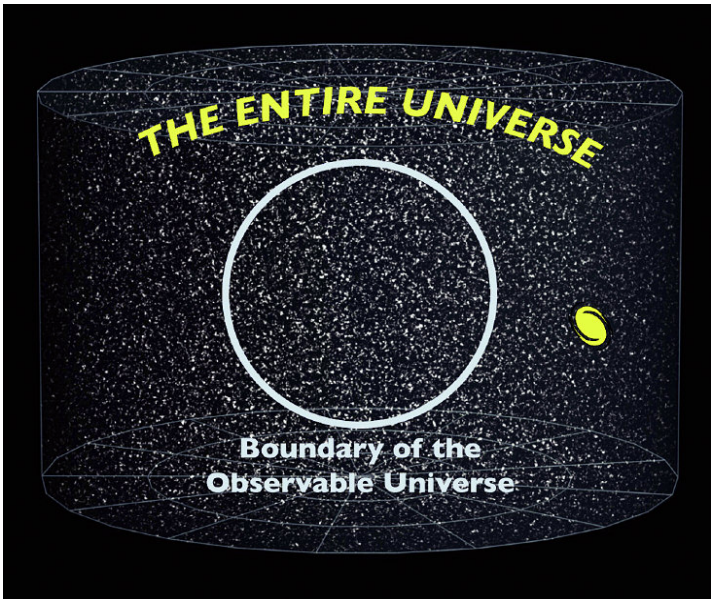
In order to understand a theory of many universes, we first have to understand what a single universe is. Unfortunately, our understanding of the universe is still evolving and changing every moment. This is largely due to the fact that our universe is constantly expanding. It is understood that our universe contains all existing matter. However, a majority of the universe's complexity remains a mystery to scientists. From our understanding, the observable universe is as far as light reaches[1]. To understand this better, let's use an island in the middle of an ocean as an analogy. Standing on this island, you peer through binoculars and observe the horizon. The horizon acts as a boundary and everything within it is your observable universe; you have no knowledge of the universe outside of it.

The Big Bang Theory is recognized as an explanation for the "birth" of our universe and states that the universe constantly expanding[2]. Though this may be a highly supported theory, it also leaves a number of gaps regarding our universe that need some clarification. For instance, as every chemical reaction leaves behind residue or heat, the Big Bang resulted in radiation being left throughout the universe; this is known as the Cosmic Microwave Background (CMB)[3]. Researchers discovered that the CMB was uniform throughout the whole universe; it was the same temperature on all sides surrounding us. How can a point approximately 13.8 billion light years to our east display identical properties to a point 13.8 billion light years to the west? That is almost 28 billion light years in between those two points. There would seem to be no explanation for this observation since the exchange of information between these two points seems to be completely impossible. How can points on completely opposite sides of the universe have identical properties?

It wasn't until 1980 when scientist Alan Guth proposed a new idea that could offer explanations to the questions left from the Big Bang Theory. Studying years of complex mathematical equations, Alan Guth suggested that the early universe went through a large period of accelerated expansion during the first 10^{-35} of a second before the slow rate expansion that we

Figure 1

This graphic displays our observable universe (what scientists can see) in comparison to the rest of the universe which has yet to be discovered.



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[2] "Big Bang Theory." 2002. 7 Feb. 2016 www.big-bang-theory.com/

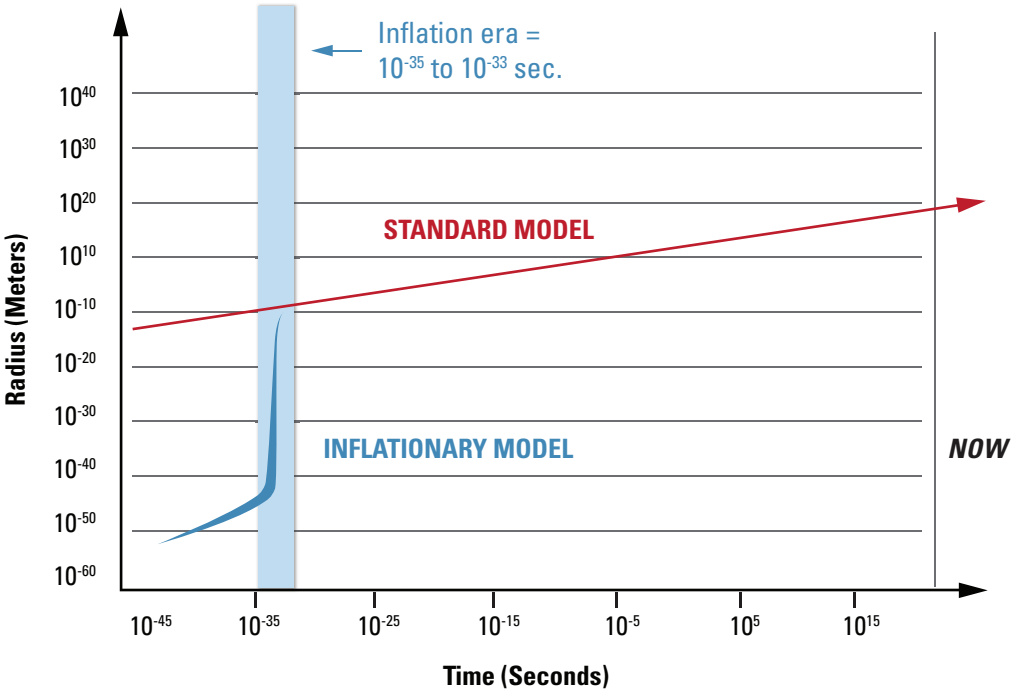
[3] "Cosmic Inflation - The Physics of the Universe." 2009. 7 Feb. 2016 www.physicsoftheuniverse.com/topics_bigbang_inflation.html

are currently experiencing[4]. As shown in figure 2, the standard model created by scientists displayed a constant rate of expansion of the universe. The inflationary model however, suggests an exponential expansion within the first few moments of the Big Bang followed by the constant rate of the standard model. Guth suggests that nuclear forces broke and so opposed gravity and spread the universe apart[5]. When the early universe was a single point all the molecules were homogeneous; they all contained similar if not identical properties (The Horizon Problem). The initial expansion of the universe was indeed so fast that the general homogeneity of the molecules stayed consistent. This gives an explanation for the uniformity that researchers observed through the use of the Hubble (a telescope that scientist launched in space to detect ultraviolet radiation) Telescope's analysis of the CMB. In other words, the general homogeneity remained the same while the space in between them rapidly expanded[6].

Figure 2

Expansion of the Observable Universe

This graphic portrays the original believed rate of expansion of the Standard Model in contrast to the rapid rate of expansion displayed by the inflationary model within the first few stages of the Big Bang. As inflation ended, the expansion rate of the universe followed that of the Standard Model.



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As the inflationary model of our universe gained acceptance in the scientific community, one question still lingered: does inflation ever end? Andre Linde, a theoretical physicist, along with other scientists, believed that though inflation might end, it might not end all at once. They proposed an additional component to inflation called eternal inflation. This idea stated that instead of inflation ending everywhere at once, certain parts of space would continue to expand. This would allow for more space to be available for more nuclear discharges which would then lead to more inflation and more possible universes. To help visualize this concept figure 3 shows an image of Swiss cheese. In this analogy, each individual hole would represent a single universe. Keep in mind that everything in space would be expanding; even the space in between each universe. As the space between each universe increases, the possibility that new universes may be created within that space increases as well, which forms more holes in the Swiss cheese and ultimately many universes within a larger multiverse. The increased possibility of nuclear reactions means that there would be an increase in "Big Bangs", highlighting the possibility that the birth of the universe was just one of many. This highly accepted idea created a completely new pathway in cosmology.

Figure 3

This graphic portrays the basic concept of eternal inflation. Each hole in the swiss cheese may represent an individual universe while the overall block may represent the Multiverse

Dark Matter

Scientists were able to determine that the expansion of space eventually slowed down as gravity aided in the formation of stars and matter as we know it[7]. In fact, it is this gravitational field of stars and planetary structures that cause galaxies to rotate around a central point. Normally, gravity would cause an object much closer to a central point to orbit at a faster rate than objects further out, like the Solar System. As the distance from the center increases, the strength of the force of gravity would decrease. However, data gathered by Vera Rubin in the

[8] "Dark Energy, Dark Matter - NASA Science - Science@NASA." 2010. 7 Feb. 2016 http://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy/

[9] "Dark Energy, Dark Matter - NASA Science - Science@NASA." 2010. 7 Feb. 2016 http://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy/

1960s, and by Jim Peebles and Jerry Ostricker in the 1970s suggested otherwise. Rubin suggested that the stars near the edge of the galaxy were orbiting around the center at the same speed as stars closer in[8]. This then pointed to the fact that the force of gravity did not get weaker the farther a star was from the center of the galaxy. Researchers were only able to see visible matter and the amount of matter they observed did not agree with the supposed mass of the Milky Way; it was much less than predicted[9]. What could account for the addition of density and mass to our universe that would increase the rotation? A possible explanation was that some undetected mass was the source. It was from these observations that scientists suggested the existence of Dark Matter: a kind of matter that does not give off light. Though its origin is unknown, scientists have been able to detect it from the effects that it has on gravitational forces. As galaxies rotate at great speeds, they tend to be torn apart. However, many galaxies are able to withstand this force due to a gravitational pull. The amount of gravity necessary to keep galaxies intact far surpasses the amount calculated by researchers, leading many to speculate that Dark Matter has a strong gravity-like effect on galaxies. Though it is unseen, Dark Matter seems to have a large effect on the maintenance of galaxies throughout the universe.

Dark Energy

According to General Relativity and the inflationary model, the universe is in fact flat which means that it will continue expanding, but will gradually slow down in the future. As scientists observed light emitted from supernovae (exploding stars), however, they noticed something very peculiar about the behavior of the light. Normally, light emitted from supernovae tends to shine brighter than light emitted from galaxies; however scientists observed that as time passed, the light progressively got fainter. A possible explanation for this was that somehow, the stars were moving further and further away.

How could it be possible that these stars were moving away, especially at an accelerating rate? Something must be causing this expansion. Scientists soon concluded that space itself was expanding and like Dark Matter, there must be another kind of invisible force in our universe that does not absorb light. They called this other invisible force Dark Energy. Dark Energy acts as a kind of anti-gravity that causes the universe to not only expand, but to expand at an accelerating rate. Through CMB data from the 2013 Planck satellite, Dark Energy seems to constitute 68% of the universe, compared to Dark Matter with 27% and visible matter with only 5%[10].

How can most of our universe be comprised of matter and energy that we know nothing about and cannot see? One explanation suggested is that Dark Energy is a repulsive force, while Dark Matter is a gravitational-like substance. Although these substances make up most of the mass of our universe, the actual amount of these kinds of particles is very small in comparison to other particles in the universe. In fact, the amount of Dark Energy is so specific to our universe that even a slight increase would increase the repulsive nature of it and cause the universe to expand at an acceleration rate so fast that molecules wouldn't have had time to come together[11]. In contrast, a decrease in the amount of Dark Energy would cause the universe to collapse in on itself. The current balance of the forces in our universe is so finely-tuned to support life and atoms that many scientists wonder: how is it even possible? Scientists have strug-

[10] "The Official String Theory Web Site." 2003. 7 Feb. 2016 www.superstringtheory.com/

[11] "The Official String Theory Web Site." 2003. 7 Feb. 2016 www.superstringtheory.com/

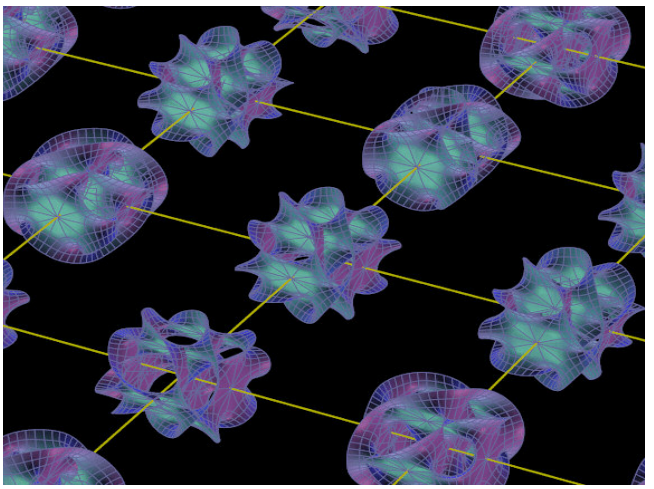
gled to find a rational answer. The multiverse hypothesis offers a possible explanation. To help make sense of this, envision a hotel with an infinite number of floors. Each room on each floor symbolizes a universe while the hotel symbolizes an overall Multiverse. If you were to walk the hallways and take a peek in each room, you would find universes of all kinds; accelerating, collapsing in on themselves and even some like ours. The fact that you would find an ideal universe that supports life is entirely based on chance, which is what scientists believe to be the case in our situation. It is possible that there is no significant reason as to why our universe is able to sustain life. There would be an infinite number in the kinds and combinations of universes that would be possible and our universe might just be one of the lucky picks out that infinite number. The Multiverse is one of the most reasonable explanations to the mystery of why the universe behaves the way it behaves and why it is so precise in the amounts of matter within it.

String Theory/M-Theory

Another theory which has been proposed that also leads to the Multiverse is the String Theory. In an attempt to unify general relativity with quantum physics, scientists developed the String Theory which states that everything in the universe is composed of tiny "strings" that vibrate at different frequencies[12]. The frequencies of the strings' vibrations ultimately determine the molecules that are created and therefore what those molecules make; they are essentially the "DNA" of the universe. The behavior of these strings can be analogous to the behavior of strings on a guitar. As you place your fingers on different frets throughout the instrument, they vibrate differently which ultimately creates different sounds. String theory is similar to this except that the vibrations of the strings determine the molecules they create. It hypothesizes

Figure 4

This graphic shows a Calabi Yau structure. This structure represents possible shapes of the 9 dimensions of space that strings reside in. Each independent structure is a representation of a possible shape of the additional 6 dimensions of space within the standard 3-dimensional plane.



that everything including planets, atoms, and molecules all share one basic fundamental unit; a string[13].

Though this idea has provided a connection between things big and small, scientists observed something very odd while doing mathematical calculations to support the String Theory; they discovered that the math behind the science is only possible with 9 dimensions of space[14]. How can there be more dimensions beyond the standard 4 dimensions (length, width, height and time) that make up of universe? To understand this, imagine a line in between two lamp-posts. From a distance, this line may look like an ordinary one-dimensional line; however, as we move closer to it, the three dimensional make up of this wire reveals itself. Scientists believe that within the three dimensions of our universe, there are an additional 6 dimensions that may be represented by Calabi Yau structures. These structures represent possible shapes of the additional dimensions that strings reside in. There are various possible shapes of the structure and each possible shape means that the strings will behave differently. Essentially, each Calabi Yau structure is a possible blueprint for the universe.

Now, how can a theory of tiny vibrating strings relate to the Multiverse? Though this is theoretical, these ideas seem to be the most logical and reasonable answers to questions that would otherwise remain a mystery.

To explain to connection to the multiverse theory, we must understand that strings can have different shapes. Strings can be either open ended, or they can be formed into a loop, as shown in figure 5.

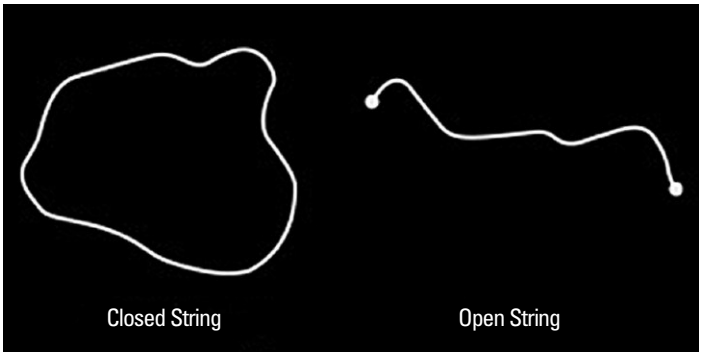
Open-ended strings contribute to the makeup of everything present in our universe, including light and molecules. The closed strings on the other hand are thought to contribute to the makeup of a theoretical particle known as the graviton, which makes up the gravitational force that is present in our universe[15]. The second part that completes the string theory's connection to the multiverse is M-theory. This M-theory states that besides these strings, there is a multi-dimensional "membrane". Membranes are essentially large amounts of energy that move in wave-like motion within multiple dimensions. Researchers hypothesized that the open-ended strings that create molecules are tied down to an individual membrane[16]. If we use a slice of bread to represent a membrane, then this would mean that each "slice of bread" could represent an individual universe while the Multiverse would be represented by the loaf of bread. Since the open ended strings would be tied down to each membrane, contact between these parallel universes would not be possible due to the fact that light along with all matter would not be able to escape the membrane that they reside on. The ends of the strings would be unable to get off the membrane, they would be restricted to that specific one. The only possible way to detect the presence of other membranes would be by the disappearance of gravitons; the closed strings that do not have the ability to be tied to a membrane[17]. This may suggest why the gravitational force seems to be the weakest natural force. Because gravity would be composed of closed strings, it would have the ability to travel from membrane to membrane, but would not be as strong as other forces due to its lack of connection to one specific membrane. String theory introduces the possibility of multiple dimensions which then in turn allows for membranes to come into existence. M-theory helps explain why certain forces are stronger than others while also addressing the question of whether or not contact between universes would be possible. Though it is theoretical as well, these ideas seem to be the most reasonable expla-

[12] "The Official String Theory Web Site." 2003. 7 Feb. 2016 www.superstringtheory.com/

[13] "The Official String Theory Web Site." 2003. 7 Feb. 2016 www.superstringtheory.com/

Figure 5

This graphic shows strings can be either open ended, or they can be formed into a loop



nations to mysteries such as the Horizon Problem, the Dark Energy and Matter conundrum, and other gaps in our understanding of the universe that would otherwise remain a mystery.

Conclusion

When analyzing all three theories, many gaps come about in the information that cannot be explained using current knowledge of the universe. For instance, before knowledge of inflation, scientists were perplexed by the fact that the universe's molecular makeup is uniform throughout all of space (horizon problem). As scientists accepted ideas that originally seemed absurd, many explanations to these mysteries started to come about; much like how inflation solved the horizon problem. It also introduced a brand new theory, the Multiverse Theory. Inflation set the foundation for other scientists to explore the possibilities of there being a multiverse. Inflation points to the fact that during the birth of the universe, a rapid period of expansion took place that inflated the size of the universe in less than a millionth of a second. Further research into inflation resulted in the idea that because space is expanding, it may be possible for nuclear reactions, like that of the Big Bang, to occur more than once; an increase of space would increase the possibility of this happening. This would ultimately result in many universes within one overall Multiverse. Though this theory may seem a bit irrational to many, its existence does in fact answer some questions held by the scientific community, such as the specificity of dark matter and energy in our universe. Dark Matter's gravitational-like nature helps hold pieces of the universe together, while Dark Energy is able to push the universe apart. However, why do we happen to have just the right proportion of these quantities? Scientists do not have a set answer to the mystery, though the Multiverse does offer one explanation. Instead of zooming in and finding a specific answer as to why the amount of dark energy/matter is what it is, it provides a general approach to the dilemma. Similarly, the Multiverse provides an explanation for why the gravitational force is weaker than the other 3 natural forces by introducing the string theory as well as M-theory into the picture. Though the Multiverse and many of the ideas that lead to it are theoretical, there has been much research to increase the validity of this theory.

[14] "The Basic Elements of String Theory - For Dummies." 2010. 7 Feb. 2016 www.dummies.com/how-to/content/the-basic-elements-of-string-theory.html

[15] "M-Theory: The Mother of all SuperStrings - Dr. Michio Kaku." 2009. 7 Feb. 2016 http://mkaku.org/home/articles/m-theory-the-mother-of-all-superstrings/

[16] "M-theory, the theory formerly known as Strings - damtp." 2009. 7 Feb. 2016 www.damtp.cam.ac.uk/research/gr/public/qg_ss.html

Scientists have been able to use three highly accepted ideas: Inflation, Dark Energy/Matter, and the String Theory to point to one overarching theory. Despite the fact that it may be physically difficult to visualize or experience, there is a substantial amount of data gathered by satellites as well as mathematicians to use as evidence supporting these ideas. The significance of those three theories may be questionable when analyzed individually, but when connected together, they open a brand new understanding to the universe as we know it by introducing the Multiverse. They offer possible explanations to mysteries that would otherwise remain unsolved as well as support an idea that can alter the original thoughts we had about the universe we live in.

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Possible Correlation Between Music and Memory

by Zoe Denckla

Abstract

Have you ever wondered why you can't get that tune out of your head? This experiment explores the relationship between music and memory by looking at the effects of music on studying information. This question was tested by accessing subjects' personal growth (the comparison of an individual's results before and after the experiment in order to access individual change) by means of studying information with flashcards or with music. Although there superficially seemed to be a higher individual growth average when subjects studied through music, this paper is unable to come to a definitive answer on whether or not there is a positive correlation between music and memory based on the insignificant results gathered.

Background

Frontal cortex overlap of Music and Memory Centers of the Brain

According to Lutz Jäncke, the long-term memory part of the brain is located in the frontal lobe, which is the same place that is stimulated when listening to music[1]. Scientists believe there is a direct correlation between music and memory as a result of both neural networks being located in the frontal lobe. In this specific study[1], scientists were testing how well musicians and non-musicians could memorize certain musical pitches. In the experiment performed, scientists took 40 participants and played different musical pieces for them (which were classified as either positive/upbeat or sad) and then tested them afterwards to see which musical pieces they remembered. The researchers found that participants were more likely to memorize songs if they were upbeat, which they justified by talking about how closely intertwined the neurological center for memory and processing music are. Music helps our brain archive memories by using associative memory[2]. If one stimulates their frontal cortex by listening to music, they have a much greater chance of storing that memory[2]. It was shown that even people with Alzheimer's who are unable to recall childhood memories are able to remember childhood tunes and lyrics. This experience of Alzheimer's patients attests to the long term effects music has on memory.

Music Positive Effects on Learning Information

An experiment published in The Frontiers of Psychology journal discusses how musical preference affects one's memory[3]. The study took 73 subjects and played 14 songs for each

subject. Before conducting the study they also indicated whether or not people were musicians. Then each subject identified three of the fourteen songs as positive and three as negative (the other eight songs were considered neutral). From those six chosen songs experimenters randomly chose one positive and one negative song. While listening to music, researchers then gave each subject the task of memorizing 54 Japanese characters. They made them rate their ability to focus while learning and then tested them on what they learned. The researchers concluded that people with musical experience learned the characters better with neutral or negative music as opposed to positive music[3]. These results are inconsistent with previous neuroscience studies done on pleasurable music and memory. This study does not support the commonly accepted idea that learning with positive music helps one remember, but it does draw an interesting distinction between musicians and non-musicians. This study highlights how much disagreement there is in the scientific community regarding the relationship between music and memory. These contrasting ideas inspired me to look deeper into the topic of music and memory.

Chemical Effects of Listening to Positive Music

An NIH study discusses the chemical reasoning behind how positive music helps create strong memories: "dopamine release in the ventral striatum seems to play a major role in the rewarding aspect of music listening"[4]. The release of dopamine contributes to the development of implicit memory while listening to engaging music. Information in songs is embedded in one's explicit and implicit memory through the release of chemicals while listening to music. There just isn't the same neurological reward that your brain experiences when studying normally. This chemically induced implicit memory associated with listening to music as well as the music and memory center location overlap in the brain support the idea that music positively affects memory.

Method

My initial step was to gather a group of subjects to test if memorizing information with a song produces better results than memorizing information with flashcards. I conducted my first trial in April of 2015 on 28 Berkeley Carroll Sophomores. I first administered a blank test where each subject was to write down as many presidents as they could in chronological order. This was necessary in order to test each subject's prior knowledge of the information and use these numbers as a way in which to access the subjects' individual growth. The group was then randomly split into two, where one group studied the information through a song which they replayed for 30 minutes. Simultaneously the other group was given a list of presidents and 44 flashcards which they were given for 30 minutes. After 30 minutes, all 28 subjects were given the same test untimed and were asked to chronologically write as many presidents as they could. The tests were graded and individual growth was assessed by taking the difference of their two tests. The second trial used the same experimental design and 13 new subjects. The results of the second trial were added to the data from the first trial and analyzed.

Results & Analysis

In order to analyze the data I received from my two trials, I conducted a two-tailed independent t-test and created a graph with standard error bars. The result of the t-test was a p-value value was 0.128017. This means that my data does not reach the standard of statistical significance. Although people who listened to music had a higher average score than those with flashcards in this study, it cannot be concluded that music boosts memory test performance.

Figure 1

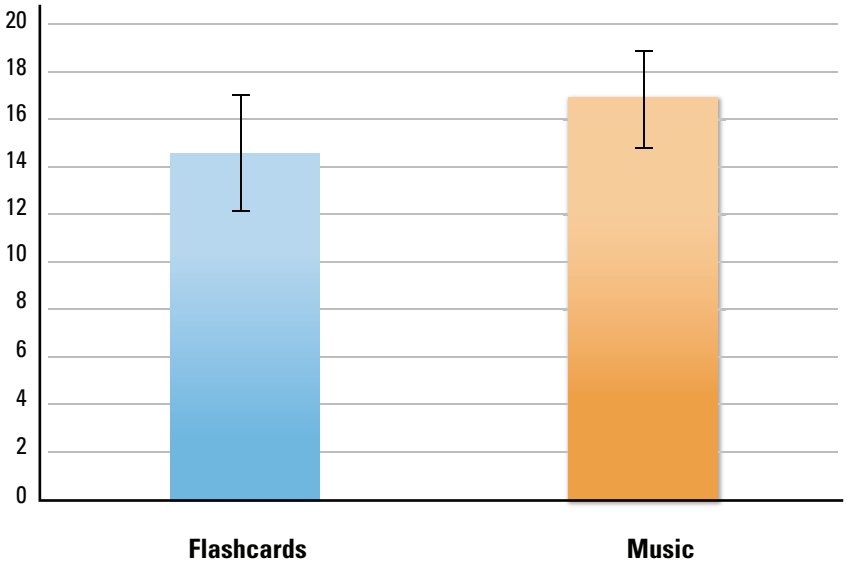
The table below shows the average of the difference between an individual's final and initial test of information with either flashcards or music. The SEM (Standard Error in the Mean) shows the statistical amount of error within the music and flashcard data set.

	AVERAGE	SEM
Flashcard Personal Growth	14.57894737	2.432535502
Music Personal Growth	16.9	1.9

Figure 2

Average Subject Growth

This graph compares the average individual growth of subjects studying with flashcards compared to those studying with music. The error bars on each bar shows the +/- SEM of the data.



In analyzing my data, my insignificant results indicate there is no correlation between music and memory. Due to numerous mistakes in my experimental design, these insignificant results could also incorrectly reflect the effect music has on memory. First, I forgot to tell people with flashcards that they only had to memorize last names of presidents while the group memorizing with the song only memorized last names. This leads to an increase of information for those studying with flashcards which has the possibility of skewing my data. Also, because the two groups were in the same room, music and flashcard subjects were sitting right next to each other so there was a possibility that they could have cheated by looking at each other's tests or overheard music, which could affect the significance of the experiment. Both the test screening for prior knowledge and the test after the study period were supposed to be untimed in order to control for factors like stress of the testing environment affecting subjects' scores. Due to the time restrictions of the class period within which I conducted my experiment, many people had

to rush to finish their second quiz which could have negatively affected their scores because they may have not filled in everything they knew. This also may have caused subjects to experience more stress on the second test which could have incorrectly reflected the actual extent of their knowledge.

Conclusion

Although it is true that a correlation between music and memory cannot be drawn from this data, these results would suggest that there is no advantage gained by learning from music in comparison to learning with flashcards. The multiple errors made while conducting this experiment as well as the small number of subjects made it difficult to receive clear results. Since there is no music and memory connection to be drawn from the original data taken, a second larger experiment should be conducted taking into consideration the errors that negatively affected the previous experiment in order to receive more accurate data. Conducting a second experiment would provide something to compare to the first set of data points making it possible to get significant results and draw further conclusions.

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The Rising Epidemic of HIV and Tuberculosis in Third World Countries

by Kirsten Ebenezer

Introduction: Infectious Diseases and the Effects of HIV & TB

Infectious diseases in developing countries are rampant and the plight of the people is perpetuated due to the lack of treatment available. One of the obstacles for researchers and nonprofits alike is the difficulty of finding cost-effective diagnostic tests that will lead to better remedies. There are thousands upon thousands of individuals who are affected by curable diseases but do not have the appropriate resources and access to medical care[1]. Over one billion people in the world do not have appropriate means to gain health care and more than 8 million children die from malnutrition and preventable diseases every year[2]. Infectious diseases contribute to 16% of the world's total death toll, the majority of which come from developing countries that have an average-to-low income. The main infectious diseases that affect millions of people are lower respiratory tract infections, diarrheal diseases, HIV/AIDS, tuberculosis (TB), and malaria[3].

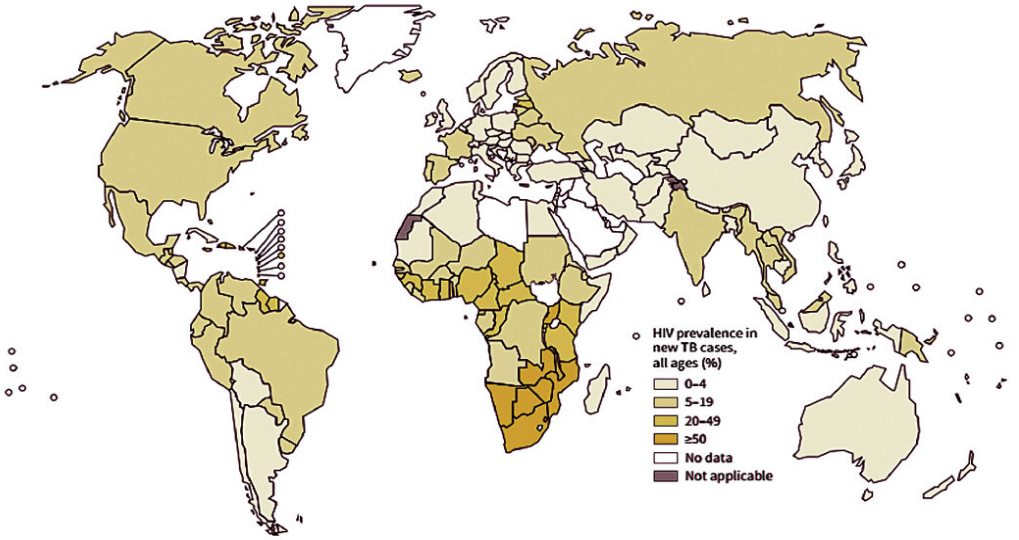
The reason these diseases continue to persist and take lives is due to the lack of available and accessible treatment. The continued prevalence of HIV infection, for instance, demonstrates how difficult, and oftentimes near-impossible, access to treatment is[4]. Today, there are 35 million people who live with HIV/AIDS in the world; 1.5 million died of an AIDS-related illness in 2013[5]. Various studies have shown that 70% of HIV cases are from sub-Saharan Africa, a percentage that is indicative of the developing nature of those countries[6]. Along with HIV/AIDS, TB is one of the largest and most prevalent infectious diseases. In 2014, 9.6 million people worldwide contracted TB, and 1.5 million died from the disease. About 95% of all TB deaths come from low-income and middle-income countries where people don't get the same diagnostic tests and prevention methods as countries in the developed world.

Not only is TB an extremely harmful disease on its own, but it also adversely affects people who have HIV. Unsurprisingly, it is the leading killer of HIV-positive people; TB is present in an estimated one in every three HIV deaths[7]. Since the co-infection of both diseases dramatically increases the mortality rate of individuals researchers must find a better understanding of the fatal connection between HIV and TB. With more information, the scientific and epidemiological community can create more effective and financially sound diagnostic tools that could benefit low-income populations that have a high risk of HIV and TB co-infection.

In this paper, I will be discussing the effects of HIV and TB co-infection and the steps that researchers are taking to find appropriate arenas of diagnosis and therapies to help prevent the spread of these infectious diseases in disadvantaged areas.

Figure 1

Estimated HIV Prevalence in New and Relapse TB Cases, 2013



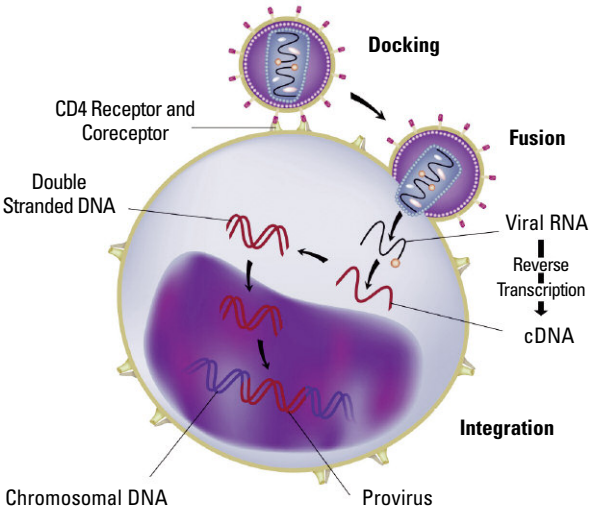
What is HIV? The Phases, Immunology, and Treatments

In 1983, researchers discovered a virus called the human T-cell lymphotropic virus-type III , a virus that destroys the human immune system. The virus was later called the Human Immunodeficiency Virus; it invades the T-cells cells or CD4 cells, which are key white blood cells that fight off infections and diseases. Within the CD4 cell, the virus makes more copies of itself by using the cell's own protein-making machinery, and through cell lysis (breaking), ultimately destroys the cells that are meant to protect the human body[8]. Current drugs that fight against HIV are part of an anti-retroviral therapy (ART) process. These drugs help prevent HIV from making more copies, strengthen the immune system to fight against the viral infection, and decrease the risk of passing it on[9]. But when left untreated, researchers have observed three distinct stages of HIV infection in a human body.

The stages of HIV first begins through exposure and ends with infection. Before the stages of HIV begin, the bodily fluids of an HIV-positive individual must come into contact with the bodily fluids of an uninfected individual; this can occur through sexual transmission as well as through the blood (e.g. blood transfusion or shared needles). The body surfaces that have mucous membranes, which secrete mucus, are more susceptible to getting HIV because they did not have a protective fibrous layers. These mucous membranes are found in the urethra, cervix, vagina, anus, rectum, mouth, and throat.

After exposure to HIV, the virus has to get past a layer of cells called the epithelial cells that cover surfaces in the body. It must then infect the immune cells in the body. These immune cells are called CD4 white blood cells, which, under HIV's influence, are destroyed while the virus multiplies. This molecular entry and lysis have been well documented in scientific literature; the viral package docks at the CD4 membrane receptor, facilitating the entry of its RNA into the target CD4 cell. Through reverse transcription (where the virus' RNA template is used to make DNA inside the target cell and influence gene expression), the new proviral DNA that has been integrated into the CD4 chromosomal DNA, directs the synthesis of more and more

HIV Entry to T Cell



HIV-carrying packages. If HIV makes these copies faster than the CD4 cells are able to direct the killing of the virus, and if HIV passes the mechanical barriers of the epithelium and the cellular barriers of the CD4 cell, it can move from its initial point of infection and travel to any other part of the body[10].

Following the integration of proviral and CD4 chromosomal DNA, the CD4 cell itself is duped into directing the synthesis of new viral packages, which lyse, or break apart, the CD4 cell upon exiting its host. This is the first stage, where an acute HIV infection sets in and weakens the immune system. Individuals might have a flu-like illness within two to four weeks of contracting it. The second stage that follows is clinical latency, or HIV inactivity, where HIV makes copies of itself in lower volumes, but as this phase completes, the viral load of the individual increases and the CD4 count drastically decreases, which leads to the third stage–AIDS. People with AIDS are in the most severe form of their infection and due to their weak immune system are prone to more illnesses[11].

To understand how the immune system is compromised, we must first see how T-cells become depleted due to HIV infection. In a CD4 cell, the kind of white blood T-cell that act as a 'helper" and fights infection, a phenomenon called CD4 down modulation is key to this depletion. Down modulation of CD4 cells occurs when the cells are modulated by genes, disallowing the cells from helping the immune system and therefore forcing them to work at lower levels. Hence, the less-productive CD4 cells regulate the immune system at a lower level, which means that they do not work and help the immune system to their full capabilities.

Researchers at MIT tested this down-modulation during HIV infection, and the resulting low levels of CD4 activity. This lower level was induced by three different types of genes which are thought to be involved in HIV infection. The genes were called *vpu, env,* and *nef* and the researchers studied if the genes could down modulate CD4 cells independently and/or all together and thereby see the effects on HIV Type-1 virus progression. It is important to note here that the Type-1 virus is the predominant HIV virus; there is a relatively uncommon HIV-2 Type found in West Africa as well.

In the MIT study, an immortalized line of human T-cells called Jurkat cells were used to study the CD4 cells in HIV Type-1 Virus. The first step of testing was to see if there was any HIV infection in the absence of the genes *vpu, env,* and *nef;* the researchers discovered that the remaining genes had no apparent impact on the level of CD4 expression. This means that the three genes *vpu, env* and *nef* were required for the depletion of CD4 cells, and their absence did not cause a decrease in CD4 helper T-cell activity. Then, the researchers tested the effect of only *nef* on CD4 down modulation, followed by *env and vpu,* which were both done independently. These independent tests showed that each gene individually can effectively down modulate the activity of the CD4 cell. Finally, the combination of the CD4 modulatory genes of *vpu, env,* and *nef* was tested. The researchers discovered that together the genes can eliminate the bulk of the cell surface CD4 cells. This is what causes HIV infection and slowly diminishes the immune system.

HIV has evolved 3 independent mechanisms, (i.e. the genes *vpu, env* and *nef*), to ensure that CD4 levels in infected cells are efficiently reduced, accelerating the progression of HIV. This leads to a virtually complete depletion of CD4 receptor and cell surface[12]. From this seminal study, researchers now know what genes are involved in the down-modulation of the T-helper cell and with more information can create better diagnostic tests and treatments that increase, and not decrease or down-modulate, the healthy immune activity of CD4 cells.

In regards to current treatment for HIV/AIDS, there is no primary cure, although there are ways to manage the infection. The treatment of HIV can be done through antiretroviral therapy and through pre-exposure prophylaxis (or PrEP) where people who have a higher risk of getting HIV can take medication to lower their chances of infection. PrEP uses the drugs tenofovir and emtricitabine, which become present in the bloodstream and help HIV-negative people who live in an HIV-susceptible environment receive first-hand treatment[13]. HIV has many debilitating effects, and several socio-economic factors impact the contraction of the virus. HIV/AIDS can also take a greater control over the body with associated infections, since the body becomes more susceptible to other diseases due to an overall weak immune system. The disease that wreaks a considerable amount of havoc on HIV-positive individuals, especially in disadvantaged, third-world areas, is TB[14].

What is TB? The Disease, Its Resistance, and Diagnostic Tests

Mycobacterium tuberculosis is the organism that causes the bacterial infection TB; the disease has figured in human history for more than 20,000 years. The prevalence of HIV, however, has brought about a dramatic new wave of TB as millions are infected and die annually through co-infection. The bacteria from TB usually attacks the lungs, but the kidney, spine, and brain can be infected as well. TB can be spread through the air from one person to the other, and can be contracted more easily if the immune system is already weakened by another disease. For people with HIV, the risk of developing TB is much higher than for people with normal immune systems.

There are two types of TB: Latent TB Infection and TB Disease. The first can exist in the human body without making someone ill; it is not infectious, and cannot be spread. However, if the TB bacteria multiplies, a person can have TB disease. When the bacteria is inhaled, the infection remains in the lungs (pulmonary) but can move into the bloodstream and to other parts of the body (extrapulmonary). When the immune system cannot stop the growth of the TB bacteria, the disease comes into full infective force, and can be spread[15].

Table 1

Mutations in rpoB in 125 Multidrug-Resistant Strains from the 2009 Survey Regarding Tuberculosis-Drug Resistance in Swaziland.*

MUTATION	STRAINS WITH MUTATION	MUTATION IN *rpoB* HOT-SPOT REGION†
	no. (%)	
D435F	1 (0.8)	Yes
D435F, N437D	3 (2.4)	D435F, Yes; N437D, Yes
D435V	1 (0.8)	Yes
G442R,‡ 1491F	1 (0.8)	G442R, Yes; 1491F, No
H445D	7 (5.6)	Yes
H445L	6 (4.8)	Yes
H445Y	6 (4.8)	Yes
1491F, R552C	1 (0.8)	1491F, No: R552C, No
1491F	38 (30.4)	No
QF432-433del	1 (0.8)	Yes
S450L	58 (46.4)	Yes
S450W	1 (0.8)	Yes
Unmutated	1 (0.8)	No

In most cases, there are two antibiotics that are taken for people who have TB; they are called called isoniazid and rifampin. However, there is a type of TB that is resistant to the treatment that scientists and researchers have created. It is called Multidrug Resistant TB (MDR-TB) and is caused by a bacteria that is unaffected by isoniazid and rifampin, the two most potent TB drugs. These two drugs are used to treat all persons with the disease[16]. In a study conducted in Swaziland, researchers were trying to understand the diagnostic test– Xpert MTB/RIF–and see how it identifies the TB drug rifampin's mutations and its resistance. Xpert MTB/RIF is a cartridge-based point-of-care assay, which is a diagnostic test that is designed to identify rifampin resistance in *rpoB* mutations. This specific *rpoB* mutation is found in 96.1% of people who have rifampin resistance and the mutation is found in a region called 81-bp in the *rpoB* gene mutation. 38 out of 125 multidrug resistant strains (30%) that were isolated during a survey carried the *ropB* mutation which has resistance to rifampin. The data was presented in the form of a table that showed mutations in *rpoB* in 125 multidrug resistant strains from the 2009 survey regarding the TB drug resistance in Swaziland.

While very helpful as a diagnostic tool, the sensitivity of Xpert MTB/RIF based diagnosis is reduced substantially by the circulations of strain with the *rpoB* mutation in Swaziland and sometimes results in underdiagnosis and potentially inadequate treatment. This is problematic because 26% of adults are affected with HIV and 80% of patients with TB are co-infected with HIV. In Swaziland there is a high prevalence of TB, with 945 cases for every 100,000 people or 1%. The results show that scientists still have to find easier, and more economical methods of

identifying the *rpoB* strain that is present in many populations, especially in populations with low-incomes and in third world countries.

The following two research conclusions discuss the use of diagnostic tests for TB and treatments for HIV infection. Both are focused on the improvement of access to medical care in third world countries.

Combined Use of Serum and Urinary Antibody for Diagnosis of TB[17]

In this study, researchers from the NYU School of Medicine were trying to determine whether urinary anti-*Mycobacterium tuberculosis* antibodies are present in patients with TB. They evaluated the feasibility of developing a urine antibody-based diagnostic test that could help developing countries with diagnosis. Immunoassays, quick and accurate tests that can be used on-site and in the laboratory to detect specific molecules, were used in this study. They rely on the inherent ability of an antibody to bind to the specific structure of a molecule. The researchers used ELISA (enzyme-linked immunosorbent assay: a test that uses antibodies and color change to identify a substance) for the detection of antibodies.

The researchers examined results of serum and urine tests from an assortment of subjects around the world. While the data and the article concludes that the current sensitivity of detection of antibodies in proteins is too low to be useful for devising a urinary antibody-based diagnostic test, they did show that the combined use of serum and urinary antibodies was extremely useful for the diagnosis of TB.

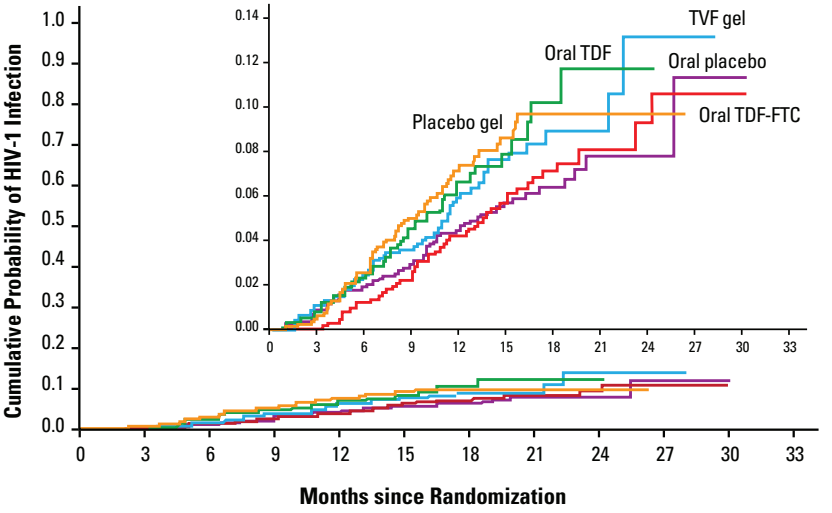
Due to the current HIV epidemic in developing countries, a urine antibody-based diagnostic test would be an important contribution to TB control programs. Therefore, the difficulties in diagnosis in third world countries could be resolved if an antibody-detection diagnostic test based on the use of bodily fluids such as urine, stool, or saliva could be developed. This is a preliminary study that provides the foundation for further studies of a urine antibody-based immunoassay that could provide the on-the-spot diagnosis that is critical for TB control in developing countries.

Tenofovir-Based Pre Exposure Prophylaxis for HIV Infection Among African Women[18]

In this study, the researchers were trying to find out ways to prevent HIV infection among reproductive-age African women who are at risk of getting the infection. They used oral medication or gels as treatment methods. There were three different kinds of tenofovir, which was an antiretroviral treatment drug that was used in this study. The researchers were trying to find out if the daily treatment of HIV Type-1 by using oral tenofovir disoproxil fumarate (TDF), oral tenofovir–emtricitabine (TDF-FTC), or 1% tenofovir (TFV) vaginal gel, (which are all tenofovir based antiretroviral treatments) could be used as preexposure prophylaxis (PrEP) against HIV-1 infection in women in South Africa, Uganda, and Zimbabwe.

PrEP is a way for people who do not have HIV, but who are at substantial risk of getting it, to prevent HIV infection by taking a pill every day. Tenofovir treats HIV infection and the hepatitis B virus. This medicine does not cure HIV or AIDS, but combinations of drugs (often called a 'cocktail') may slow the progress of the disease.

In a randomized trial that was controlled by placebos, researchers assessed the daily



Number at Risk

Oral TDF	1002	966	752	504	309	155	72	23	2	0	0
Oral TDF-FTC994		971	953	931	802	467	271	143	71	22	2
Oral placebo1008		982	966	943	818	485	281	152	72	22	1
TFV gel	1003	973	944	702	486	288	154	64	14	1	0
Placebo gel	1000	985	952	699	493	278	145	64	16	0	0

treatment of TDF, TDF-FTC, or TFV. They also had HIV-1 testing once a month to see if women had the virus or not. Of the 12,320 women who were screened, 5,029 were enrolled. The graph showed the cumulative probability of HIV-1 infection according to the participants in the study group. In the intention-to-treat analysis, none of the treatments demonstrated a statistically significant benefit. In a random sample, TFV was detected in the plasma samples of 30%, 29%, and 25% of participants randomly assigned to receive TDF, TDF-FTC, and TFV gel, in that order.

The conclusion stated that none of the drugs/medications provided reduced the prevalence of HIV-1. The adherence to the medication provided in the study was low. The results show that there is still a need for effective and acceptable prevention interventions for women at a high-risk for acquiring HIV-1. There need to be more accurate treatments to get better results in HIV-1 prevention trials.

From these studies, we can note that the mitigation of the HIV and TB epidemic is of prime importance to researchers and they are taking steps, along with antiretroviral treatment, to stop the perpetuation of the co-infection and disease in third world countries.

Conclusion: Where Do We Go From Here?

The research shows that there is still more that can be done by the scientific and epidemiological community to respond to the growing HIV/AIDS epidemic and the threat of TB and MDR-TB. These multiple studies show that it is still difficult to find appropriate treatment and diagnostic tests for people in the third world countries affected by infectious diseases. Resources are scarce, the infections continue to take more lives, and most treatments are not economically viable. The HIV epidemic in Africa has led to the rise of TB and drug-resistant TB. Now, the rates of co-infection for these two diseases have increased.

To further improve the lives of people affected by the disease, governments are searching for cost-effective and urgent ways to mitigate infectious diseases. In 2012, the South African National Department of Health estimated the financial capabilities of having Xpert MTB/RIF diagnostic tests throughout their country[19]. This is an impactful step to stop the spread of infection in underserved communities in South Africa and other communities like it all over the continent. At the 8th International AIDS Society Conference on HIV Pathogenesis, Treatment, and Prevention in 2015, researchers also decided that there was a great opportunity to provide antiretroviral treatment that would be cost-effective and would further prevent the spread of HIV[20].

Ultimately, as noted in this paper, there are treatments and diagnostic tests available, but the statistics show that inadequate access is given to infected individuals in the developing world. There must be a greater collective effort to improve diagnostic tests like the Xpert MTB/RIF and drugs like tenofovir, rifampin, and isoniazid, for a faster, easier, and cheaper way to stop the spread of HIV and TB in areas most in need of treatment.

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The Quantum Mechanical Scanning Tunneling Microscope as Applied to Nanotechnology

by Aaron Goldin

Abstract

The invention of the Scanning Tunneling Microscope (STM) in 1981 by Gerd Binnig and Heinrich Rohrer has given scientists the closest ever look at the nanoscopic world. The STM is a microscope accurate enough to image both the relative depth and the intricate geometric structure of individual molecules and offers promise in the construction of nanotechnology—devices even smaller than microtechnology. As technology becomes smaller, conventional machinery will lack the precision required to accurately build tiny devices like quantum dots: circular lights 4-6 nanometers in radius. Using both its ability to push atoms to specific locations and its capability to send electrons to desired locations, the STM has the capability to design, build, and test nanotechnology smaller and more powerful than could any machine previously developed possibly could.

Background

Overview

This paper will largely cover the inner workings of the Scanning Tunneling Microscope (STM), including the quantum mechanical properties that allow the device to work, various applications of the machine, and how the STM could be applied to the production of nanotechnology in the near future. This paper will also demonstrate how the STM works through the explanation of a "mock" STM—a device that functions exactly like a real STM, but on a scale large enough to be seen. An image of a Scanning Tunneling Microscope is shown on the left of Figure 1, and the image it produces is shown on the right. Each blue mound represents a single atom.

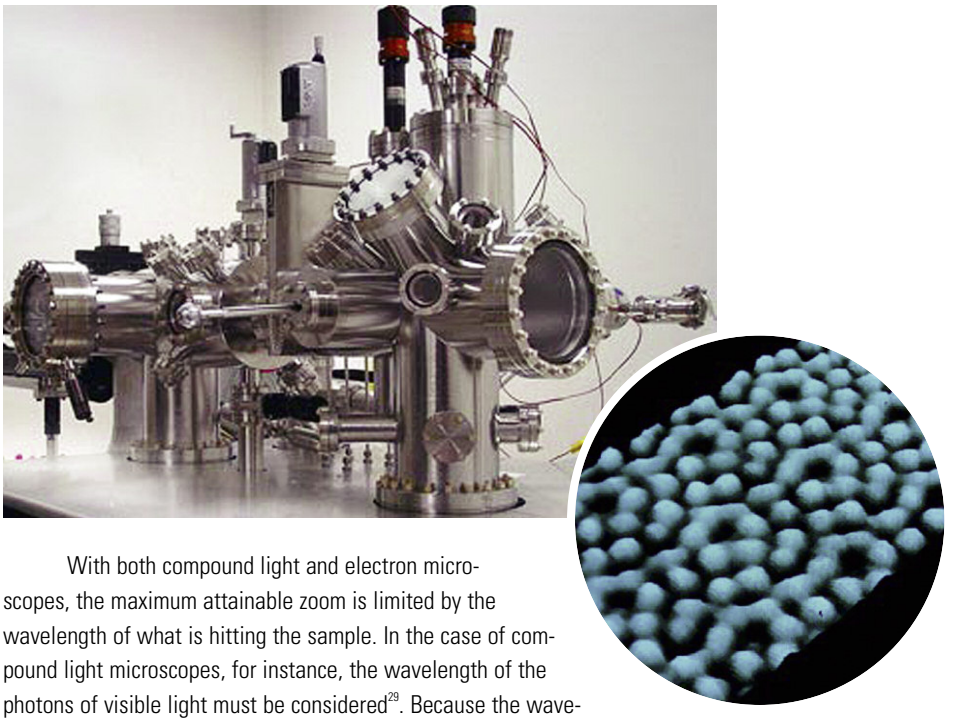
The ability to view molecular bonds is huge in the study of chemistry; without a visual representation of the scanned subject, its geometric structure can at best be inferred through experimentation. The STM, rather, provides a concrete look at the nanoscopic world.

Compound Light Microscopes

In order to understand the necessity of the STM, the limitations of a compound light microscope must be discussed. Figure 2 shows an image of a typical compound light microscope. This type of microscope is not usually able to magnify the sample more than 2000-3000 times larger than normal vision. It works by using a light to illuminate the sample, and then using curved lenses to collect this light, thereby bringing an image into view.[9]

Figure 1

A Scanning Tunneling Microscope and the image it produces.[43,44]



With both compound light and electron microscopes, the maximum attainable zoom is limited by the wavelength of what is hitting the sample. In the case of compound light microscopes, for instance, the wavelength of the photons of visible light must be considered[29]. Because the wavelength of visible light is, at the smallest, 400nm, and atoms are typically (classically speaking) 0.5nm to 1.0nm in diameter, compound light microscopes are simply unable to bring a clear image of a single molecule into view, regardless of how the lenses are adjusted

The Scanning Tunneling Microscope

The Scanning Tunneling Microscope (STM) is a powerful tool which allows scientists to take pictures of the nanoscopic world using properties of quantum mechanics. The STM's instruments are so precise they allow the user to visualize individual molecules and the geometry of their bonds. The STM is just one in a family of electron microscopes, including the Atomic Force Microscope and the Transmission Electron Microscope. These other devices are similar to the STM in that they can take pictures of molecules, but they will not be discussed in depth in this paper.

Rather than designing experiments simply to infer the structure of molecules, such as how Rosalind Franklin used X-ray diffraction (a technique that involves shooting X-rays at the sample to determine the structure of the DNA molecule), it is possible to capture an image of the molecule with an STM.[6] As shown in Figure 3, it is much easier to interpret the double-helix structure of DNA from an STM image than from an X-ray diffraction image.

Quantum Mechanics

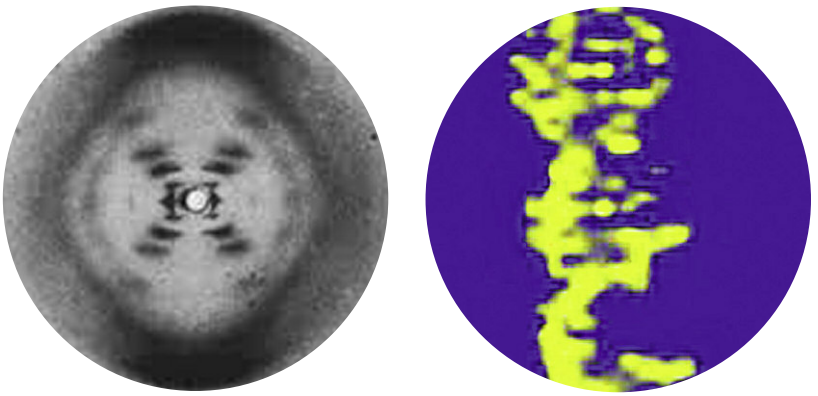
In order to understand how a Scanning Tunneling Microscope works, a few concepts from quantum mechanics must be understood.

Figure 2

A Compound Light Microscope and a typical image produced.

Figure 3

A typical interpretation of the double-helix structure of DNA from a Scanning Tunneling Microscope (STM) image



Quantum mechanics is the field of physics concerned with the properties of tiny particles like electrons, photons, and quarks—it is the study of the behavior of particles at the nanoscale. Although relatively large bodies like humans, rocks, or the Earth act according to the more familiar laws of physics (known as classical mechanics), everything in the universe is made of smaller particles. In other words, although classical mechanics classifies the behavior of large objects, these large objects are actually made of particles like atoms that behave according to the principles of quantum mechanics[2].

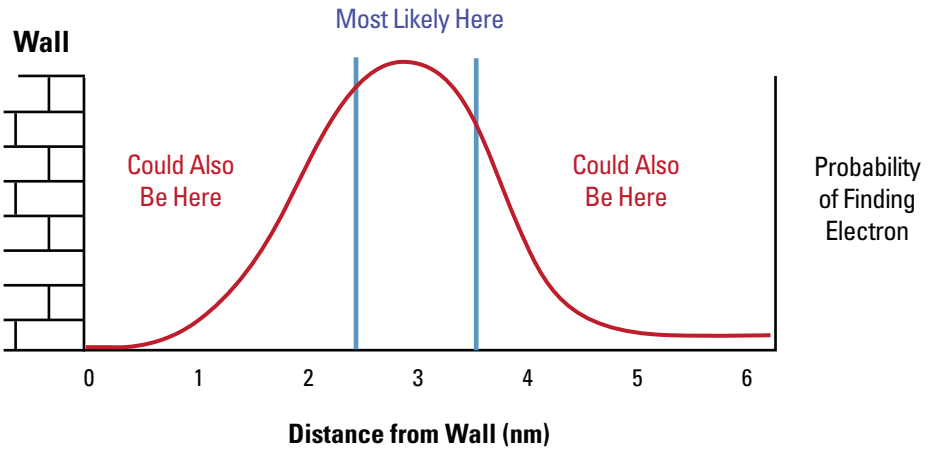
If the nanoscopic world can be better understood, scientists will better understand *why* larger objects function the way they do. For example, it is known that gravity is a fundamental

property of the universe, but scientists do not known why gravity exists. The future of quantum mechanics research seeks to answer, or at least explore, this question of *why*[5].

Position for Particles in Quantum Mechanics

When an object in the macroscopic world, like a basketball, is examined, it appears to exist in one position. When it is thrown at a wall, it will always bounce off, eventually coming to rest somewhere on the ground. The reason for this predictable behavior is that the ball is composed of many atoms, and so acts according to classical mechanics. If instead, the ball were just a single electron, it would behave in a completely different manner. Electrons do not exist at discrete positions, rather, as waves of probability[15]. This concept is shown in Figure 4.

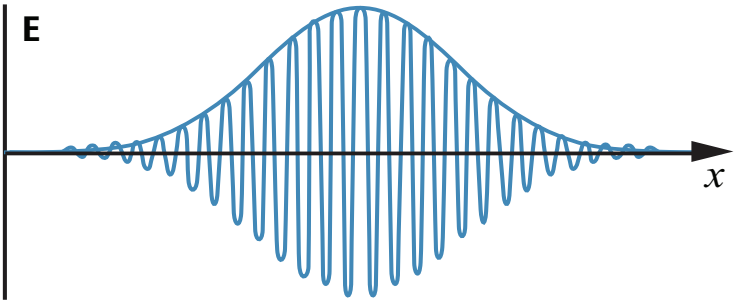
Figure 4[28]



In this diagram, the X-axis represents the position of the particle, and the Y-axis represents the likelihood of finding the electron at each given point. Because the maximum of this graph is at 3 nanometers from a wall, the best way to think of it is that the electron is *most likely* 3 nanometers from the wall, but it also exists in many other positions, only with lower probabilities. In this sense, the electron is not a ball, but a wave of probability[15]. The electron is not somewhere inside the wave; it *is* the wave—everywhere within the curve at once.

A graph like the one shown in Figure 5 shows more properties of the particle than the graph from Figure 4. The fluctuating curve is a graph of the particle's wave function (Ψ-function or wave equation, among other names), which provides a mathematical definition for a particle's properties in quantum mechanics. The amplitude (Ψ-value, which is the height) of the wave squared represents the probability of finding the electron at that given point. The distance between each wave in the function represents the energy of the particle, so in Figure 5, the particle has the same energy no matter where it is found.

Figure 5[17]



In this example, the object is most likely to be found in the middle where the amplitude (and therefore the square of the amplitude) is greatest.

In quantum mechanics, tiny particles behave as waves, that is, until they are somehow forced to interact with another material. Interacting with a particle behaving like a wave collapses its wave function, meaning it starts acting as a point-like particle. "Finding" the electron at the middle of the curve means that upon measuring its location, the wave function was collapsed to that single point, in which a discrete position *does* exist. It is not that the electron "stopped." It was not moving to begin with, per se; rather, the electron was at every point in the curve simultaneously, right up until measurement[23]. This concept is called wave-particle duality, and currently lacks a proven explanation; it is a fundamental property of quantum mechanics.

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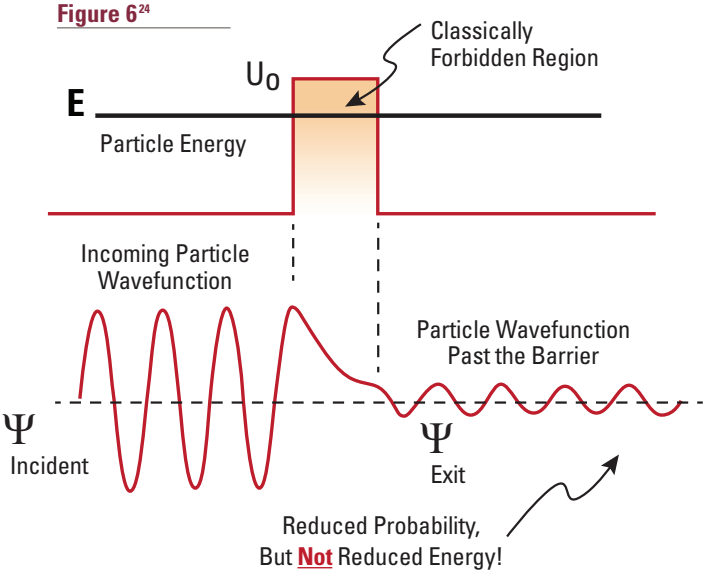
Quantum Tunneling

Quantum mechanics predicts that if a barrier, like a thin wall (known as an energy barrier), is located somewhere in the electron's wave of probability, the electron may be found on *either* side of the wall through a process called quantum tunneling. If the electron is placed, classically speaking, on the left side of the wall in Figure 6, for example, it may actually be observed on either the left or the right side of the wall. Inside the wall, the electron's wave function exponentially decays toward zero, but never actually reaches zero probability. By this logic, the thinner the wall, the more likely it is for the electron to be found on the far side[24].

As indicated by the wave function's amplitude, the electron is most likely on the left side of the classically forbidden region (the wall), but it also exists on the right side. Note that the period of the curve, which is directly proportional to the energy, is the same on both sides of the wall. This means that the electron does not expend any energy when it quantum tunnels[24].

Figure 6[24]

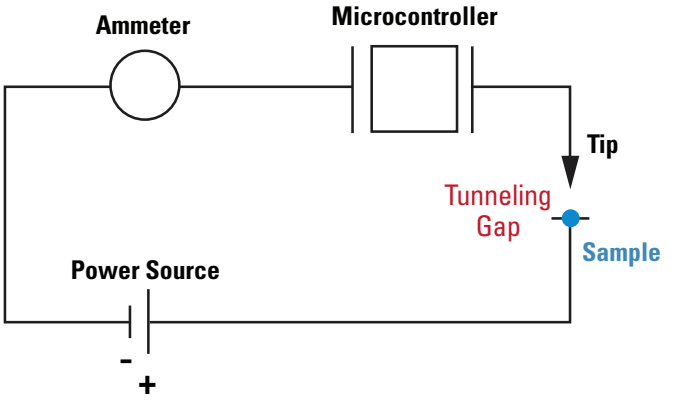


Components of an STM

THE CIRCUIT

At its most basic level, the STM is nothing more than an electric circuit with six components, each of which will be explained: the power source, the ammeter, the sample, the microcontroller, the tunneling gap, and the tip[3]. The circuit diagram is shown in Figure 7.

Figure 7[28]



THE PARTS[3]

- **Tip**

The tip is a needle-like piece of metal (such as Tungsten) that scans across the surface of the sample, indirectly measuring the height of the sample below (as explained below). Ideally, it is only 1 atom thick at the end, which can be achieved by submerging the tungsten wire into a solution of NaOH (for example) and applying a current until the tip breaks off[25]. The tip is able to pass electrons through the tunneling gap and into the sample when it is close enough.

- **Tunneling Gap**

The tunneling gap is a space between the tip and the sample which allows electrons to quantum tunnel, as explained above. Ideally there would be no particles inside the gap to prevent contamination of the sample. That said, the STM still functions without being fully evacuated. The size of the gap can be altered by applying an electric voltage to the piezoelectric elements attached to the tip (explained below), but it will never be larger than a few nanometers[3].

- **Sample**

The sample is the object being imaged. This could be a metallically bonded surface, a molecule, or even a single atom.

- **Power Source**

The power source provides power to the circuit. The electrons moving as the current are ultimately used to quantum tunnel through the tunneling gap.

- **Ammeter**

The ammeter measures the current through the circuit.

- **Microcontroller**

The microcontroller, such as an Arduino (a relatively simple microcontroller which can receive and send electric current as dictated by a computer program), sends the reading from the ammeter to a computer. It also controls the moving parts of the STM.

How the STM works

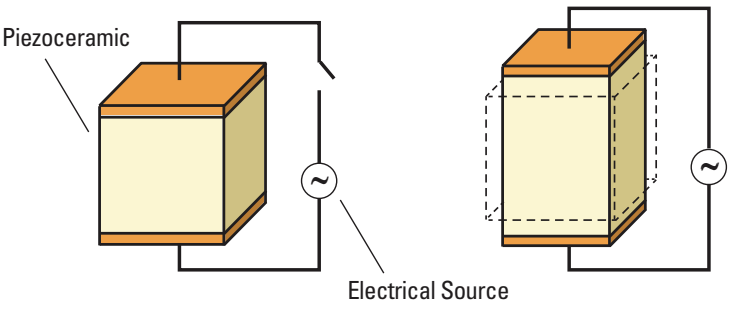
First, a voltage is activated in the circuit using the power supply. Normally, a circuit will only work if it forms a complete loop. Logically then, because the circuit loop of the STM is incomplete, current should not flow. Even so, when the gap is small enough (within nanometers), though it should classically be impossible, some electrons jump the gap. This is a form of quantum tunneling, only instead of tunneling through a wall they tunnel through the gap consisting of empty space[3]. STMs produce the clearest images when the gap truly is empty, but it can still work in a non-evacuated chamber.

The thinner the gap, the more likely it is for the electrons to quantum tunnel. This means that the thinner the gap, the more current in the circuit. In other words, the current measured by the ammeter is directly proportional to the size of the gap, which is equivalent to the height of the sample at that given point. A computer records the measured height[3].

XYZ Movement of the Tip using Piezoelectric Materials

The previous section discussed finding the height of the sample at one point, but that information alone is not enough to get a picture of the sample. Instead, the STM must scan across the entire surface, point by point, until the height of the sample is known at every location. This tiny amount of movement required by the STM can be accomplished using a piezoelectric material. A piezoelectric material is any material that changes shape, though only very slightly, when a voltage is applied, or the reverse process[18]. This concept is illustrated in Figure 8.

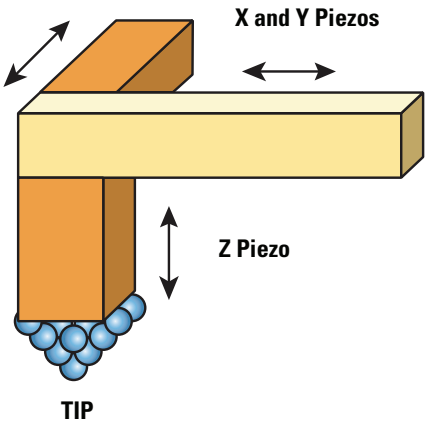
Figure 8[26]



As shown by the figure, when the electrical source is connected to the piezoceramic (a type of piezoelectric material), it expands slightly.

STMs are able to take advantage of this slight motion. The tip is actually controlled by a piezoelectric material, often in the shape of a tripod (shown in Figure 9), that can stretch when a voltage is applied. Electrodes are placed in strategic locations around the ceramic. Depending on which electrodes are activated by the circuit, the tip can be moved in the X, Y, or Z directions by increments smaller than the width of an atom if the scientist so desires[3]. As shown in Figure 9, the tip and piezoelectric material are oriented in a "tripod" shape, such that an electric current through a given piezo will move the tip slightly in the corresponding direction. For example, if a current is passed through the z-piezo, the tip will move slightly upward.

Figure 9[19]



THE COMPUTER PROGRAM

The final aspect of the Scanning Tunneling Microscope is a computer program that tells the piezoelectric material to scan back and forth across the surface of the sample. After scanning over the entire sample, the computer compiles the height at each point and an image of the geometric structure of the sample is formed. STMs can form images like that in Figure 10, which shows small mounds (representing atoms) arranged in rows of three distinct heights.

Figure 10[40]

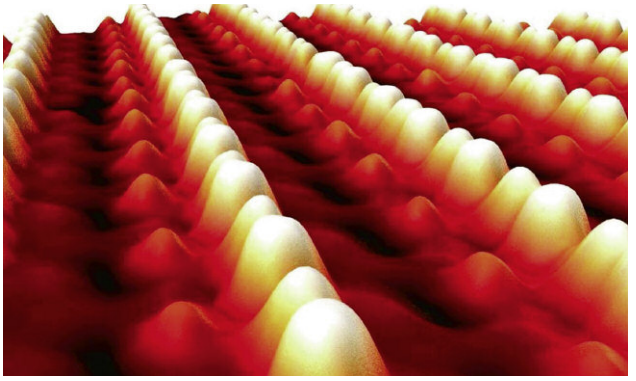
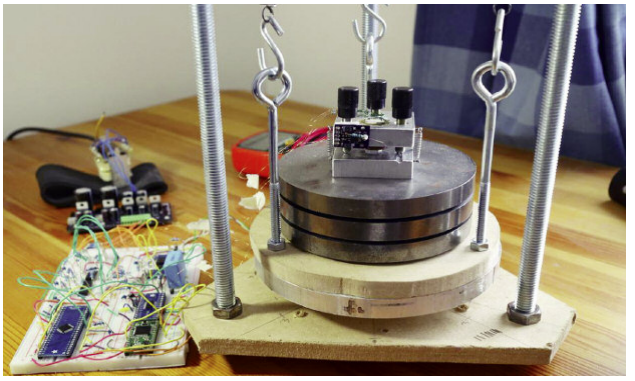


Figure 11[27]



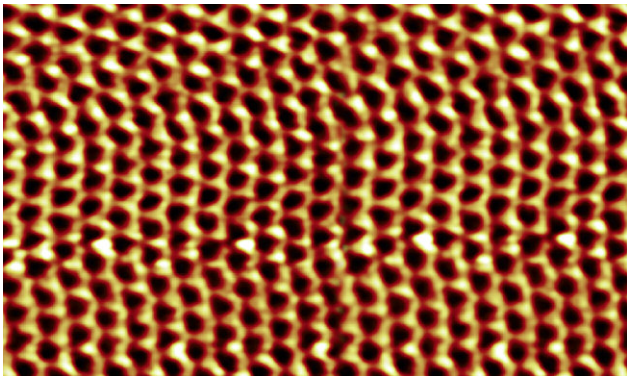
A Simple STM

Figure 11 shows a simpler version of an STM. It was designed by Dan Berard in January 2015, and was inspired by John Alexander's "Simple STM project."

In this specific STM, a piezoelectric material called a unimorph disk scanner was used to control the tip's motion. Because of its simplicity, this STM was able to produce only a basic image of a metallically bonded surface of copper atoms, as shown in Figure 12. That said, one can still observe the hexagonal structure of the atoms—a property that could only be inferred indirectly through experimentation before the invention of the STM. Unlike such inferences, the STM directly images the sample[3].

Figure 12

A surface of copper atoms in metallic bonds up close. Notice the hexagonal structure of the bonds[10].



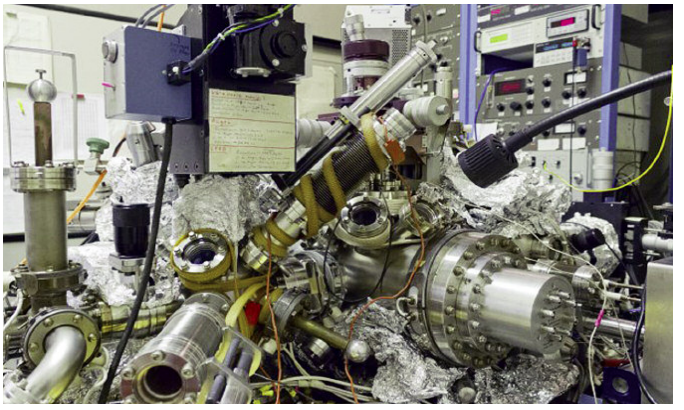
A More Complicated STM

To obtain a higher quality image of the sample than that in Figure 12, a more complex STM must be used. Figure 13 shows what a more complicated STM typically looks like.

Aside from its auxiliary features, as will be explained shortly, the primary difference between a basic and complex STM is how much of the environment it is exposed to. In Dan Berard's simple STM, for example, the device is vulnerable to the air and vibrations of the Earth. For simple projects, like taking a picture of a surface of atoms, such disturbances make immaterial differences. But when looking at structures that can be contaminated by particles in the air, it becomes important to eliminate any background interferences.

Figure 13

A complex STM[42]



More complicated STMs take the following precautions to avoid outside disturbances:

No exposure to air

The molecular structures to be scanned can be contaminated by particles in the air. For this reason, the more complicated STMs operate under a vacuum to remove as many particles in the device as possible. After a week-long evacuation of air, the scanning chamber has a particle density of approximately 4 atoms per cubic centimeter[3]. That is, for a randomly selected cubic centimeter, there are 4 atoms (the rest of the space would be completely void of particles). For comparison, one atmosphere of air (101.325 kPa) contains on average 10^{19} atoms per cubic centimeter[47], and space has an average particle density of 1 atom per cubic centimeter[4].

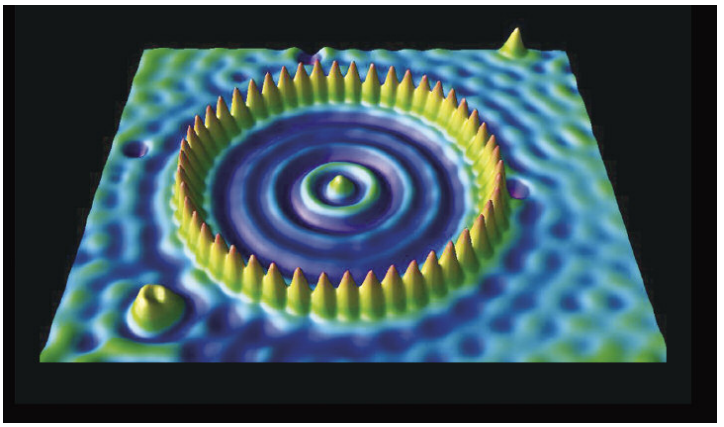
Extremely Low Temperature

The warmer an object is, the more kinetic energy in the form of vibrating it experiences. Though in the macroscopic world, the vibration of particles makes an immaterial influence on measurements, when trying to observe individual molecules, the STM cannot form a clear image unless it remains still.

The solution is to cool the STM to near-absolute zero. As the temperature approaches zero degrees Kelvin (absolute zero), the motion of the particles slows down enough to image them[21].

Using these precautions together, higher quality STMs can produce pictures like that in Figure 14, which show a three-dimensional image of the surface of atoms. In this case, the atoms were arranged in a circle, which is called a quantum corral. The wave-like ripples in the middle of the circle represent the wave function of the electrons in the surface; the electrons are most likely to be found where the waves are highest[3].

Figure 14[45]



There are limitations to the functions of the STM in addition to the simpler logistical difficulties such as constructing the tip to be exactly 1 atom thick.

Specifically, STMs function best when the sample is highly conductive. The device is at a significant disadvantage when trying to scan biological surfaces, for example. Although con-

ductive substrates can be added to non-conductive surfaces, such that electrons can tunnel into the sample more easily, it may be easier not to use the STM at all[46]. If the sample is electrically charged, for instance, the Atomic Force Microscope, which measures miniscule amounts of electric repulsion, may be the best option.

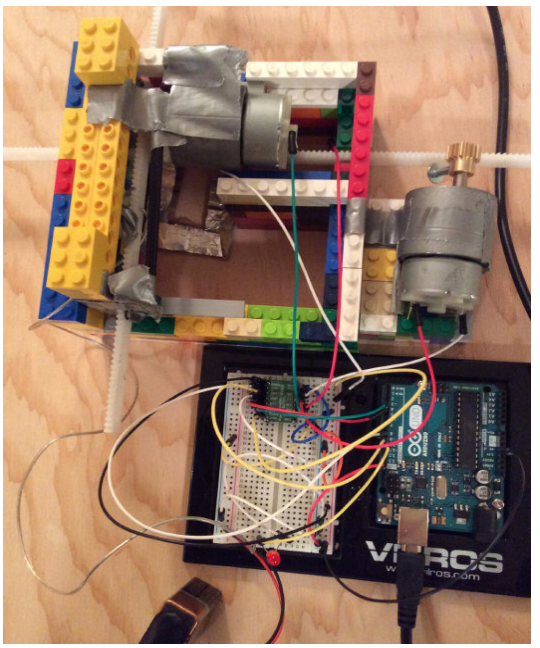
Methods

In this section, the process used to demonstrate how an STM works will be explained.

In demonstrating why STMs will be instrumental in the creation of nanotechnology in the future, the function of an STM must be explained in such a way that non-quantum physicists can understand it. If investment firms are to put money into the STM's construction and use, for instance, they must know exactly what they are giving money to.

Hence, a "mock" STM was created that is capable of scanning across a surface to image the surface below it. Unlike a real STM, the mock STM functions on the macroscopic level

Figure 15



(scanning across 5cm^2) so that viewers can fully see and comprehend what it is doing. Figure 15 shows an image of the device.

The mock STM consists of a tip and a scanning surface, but rather than using quantum tunneling to detect the sample's presence, the tip simply makes contact with the sample, and applies an electric current. Also, instead of recording the exact height of the sample, it uses boolean variables 0 and 1 to indicate a connection, transforming this information into a graph, shown in Figure 19.

Table 1

This table shows the materials used to create the mock STM and each part's purpose.

Part (amount used)	Purpose
Motor (2)	Gives angular momentum to pinion gear, which in turn controls the position of the tip. One controls X motion, the other controls Y Motion. These require at least 9V to run.
Rack gear (2)	Connected to the tip and pinion gear. Converts the motors' angular velocity into linear motion. One is oriented on the X axis, the other on the Y axis.
Pinion gear (2)	Connected to motors and controls the motion of the rack gears.
Metal brush (1)	Creates a conductive connection to the image to be scanned.
Arduino Uno (1) (Microcontroller)	Tells motors when to move, receives the signal that a connection is present, and connects to a computer to transmit the information.
Sample (1)	The sample is what will be imaged. In a real STM, the sample could be of any material, but for the mock STM, it must be conductive so that electricity can easily flow through it.
LED (1)	Signals that there is a connection between the tip and sample.
Motor driver (1)	Controls the motors. The motor driver can tell the motors to spin in either direction, and can change their angular velocity.
9V battery	Provides external power to the motors. This is necessary because the Arduino cannot provide more than 5V.
Computer	The computer receives the information from the mock STM and translates it into a graph, shown in Figure 19, as explained later.

Figure 16

A Complete Circuit Diagram of the Mock STM

This figure shows a circuit diagram of the device. The most salient information from the diagram will be explained in greater detail.

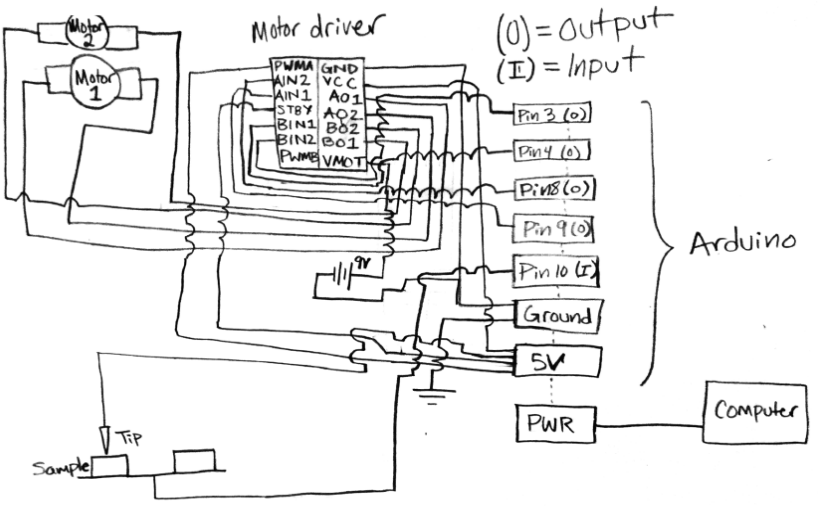
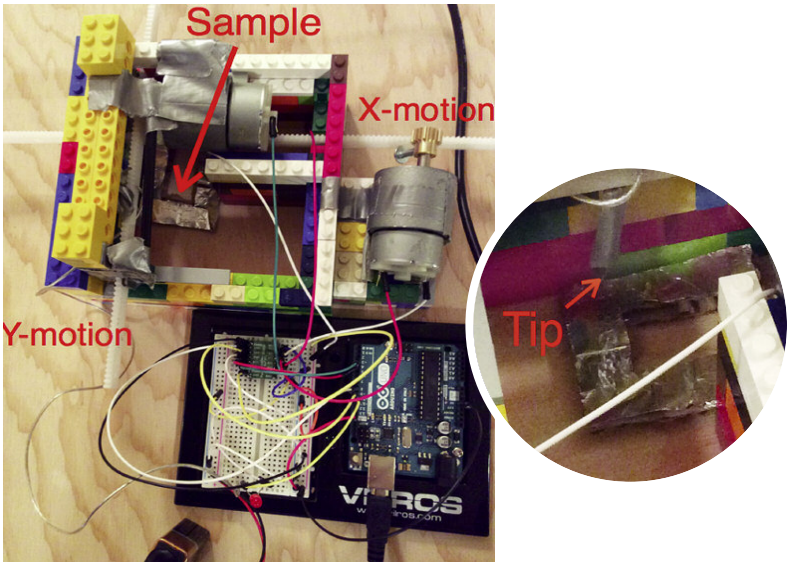


Figure 17



How the Mock STM Works

The sample to scan is a plate with a layer of aluminum foil attached. The sample is placed inside the mock STM as shown in both sides of Figure 17. The two rack gears in Figure 17 each control the motion of the tip, shown in more detail in the second image of Figure 17.

The motor driver has two pins labeled "in" (as in input) and two labeled "o" (as in output). The "o" pins are attached to the motor. When a voltage is applied to one of the "in" pins, the motor spins one direction, and when a voltage is applied to the other "in" pin, the motor spins the other way. If both, or neither, pin is activated, the motor will not move.

When both motors are controlled by this method, the tip can be maneuvered to any position desired using the rack gears. If, at any point, the tip is touching the conductive surface, a message is sent to the Arduino, which tells the computer to shade the spot corresponding to its current location. This concept is illustrated in Figure 18.

Figure 18 [28]

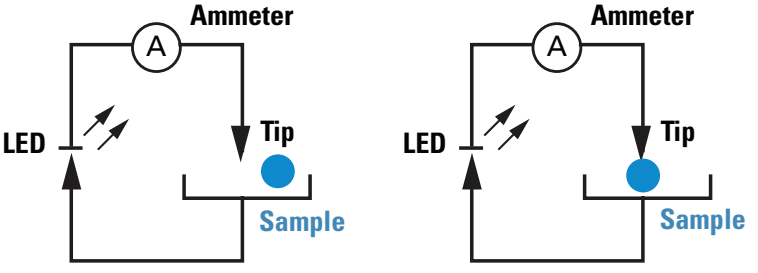
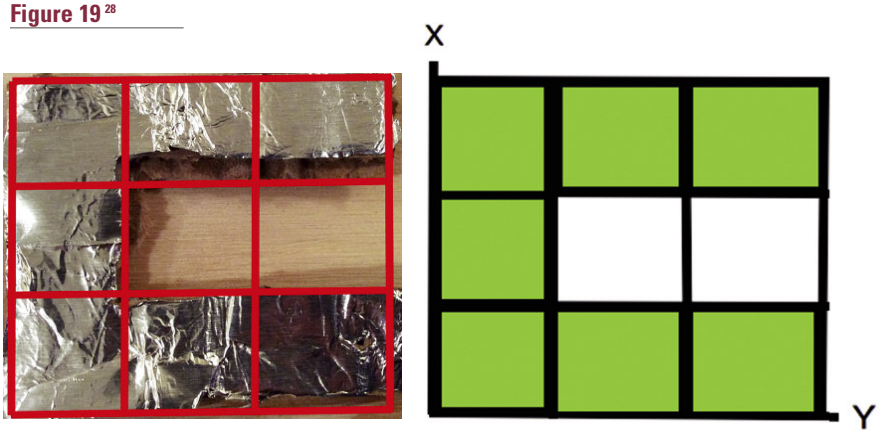


Figure 19 [28]



Using this capability, the tip is moved to touch each of the 9 sections shown in the left side of Figure 19. This particular sample will produce the graph shown in the right half of Figure 19.

In short, the Mock STM works as follows: when the tip is touching the sample at a given point, it shades a section of a graph, and when the tip is not touching the sample, it does not shade that point.

Although this technology is not useful at the macroscopic level, with new technology being built smaller and smaller, such a device may be the only way for engineers to actually see the nanotechnology that they are designing.

Applications of the STM

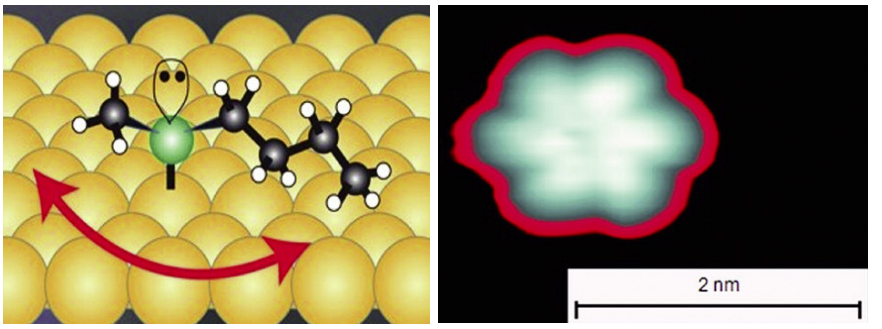
The following section of this paper will explore a few of the possible technologies the STM has already been instrumental in both designing and building, and some future applications.

As time has passed, the physical size of new technologies has diminished to being much smaller than the human eye can detect. To continue this trend of decreasing product size, new machines will have to be built that can handle technology no more than a few molecules across, and STMs will have an instrumental part in their creation.

The Single-Molecule Motor

A recent example involves a single-molecule motor—that is, when electrons are passed through the molecule, it rotates. More specifically, when electrons are sent from an STM's tip to interact with the free pair of electrons on the butyl methyl sulphide (BuSMe) molecule, the BuSMe shifts into the next of six positions permitted by the hexagonal geometric structure of the copper surface beneath it. Ideally, after six applications of the electric current, the BuSMe will be back in its original position[31]. Figure 20 shows the structure of a BuSMe molecule; the two black dots above the central green sulfide ion represent the free electrons, and the yellow structure beneath it shows the hexagonally oriented copper surface. Figure 21 shows an image of the single-molecule motor as it shifts through the six positions, creating a flower-like shape. Note that if the surface did not have a hexagonal structure, Figure 21 would show a "flower" with a different number of "petals" (where the petals represent the stable positions)[32].

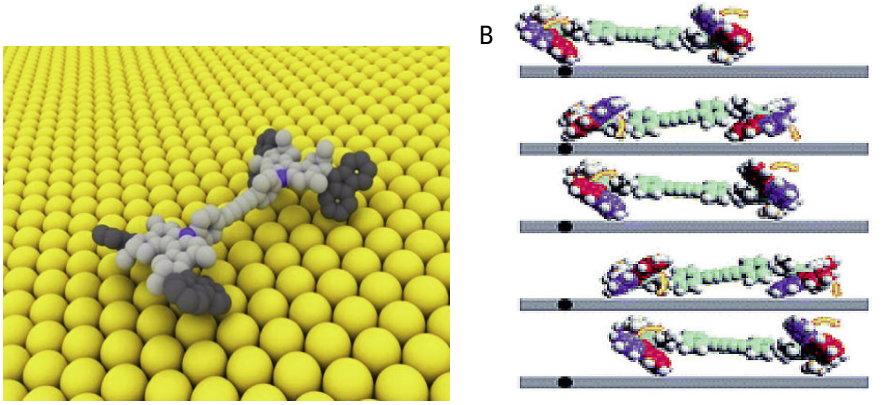
Figure 20[31] & Figure 21[31]



The Single-Molecule Vehicle

A second example of nanotechnology made possible by STMs is single-molecule vehicles. In addition to rotating, certain molecules are able to physically move forward by a specific amount by applying an electric voltage. These work in much the same way as single-molecule motors. The meso-(R,S-R,S) isomer is one such molecule. Each application of electric voltage moves the "wheels" of the molecule one half of a rotation such that after ten bursts of voltage from the STM, the molecule will have traveled generally forward about 6nm. Figures 22 and 23 show computer-generated diagrams of the meso- (R,S-R,S) isomer in motion[32].

Figure 22[32] & Figure 23[32]



STM Movies

A limitation of simple STMs is that they are only capable of taking static images of the sample. In 2005, quantum physicists built an STM that could scan the entire surface at one frame per second—fast enough to visualize changes in the sample over time in a stop-motion video. STMs today can scan even faster[35].

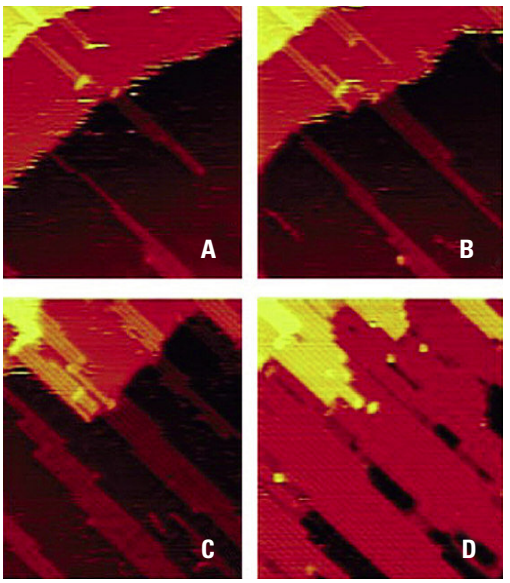
The aforementioned 2005 1fps STM was used to visualize the reconstruction of Cu(110) through the adsorption of oxygen. It had been known for around 25 years that oxygen molecules

dissociate into individual atoms before adsorbing into the Cu(110) surface[34]. In doing so, it would double the size of the Cu(110)'s unit cell—the smallest repeating pattern in its structure.

It was believed prior to the STM's use that new "steps" (the color bands found in Figure 24) were being formed by the adsorption of oxygen atoms. "New steps" refers to the doubling of the unit cell. This hypothesis was disproven by an STM movie. Figure 24 shows four images from this STM movie, taken 1 second apart. The stripes of color each represent a single band of molecules referred to as steps. As it turned out, the doubling was not new steps being formed, but old rows of steps being torn away to reveal the new ones which were beneath the surface. As shown by Figure 24, the black step in box A becomes jagged in boxes B and C before completely breaking down in D. Without the STM movie, this mechanism was unknown[35].

Figure 24

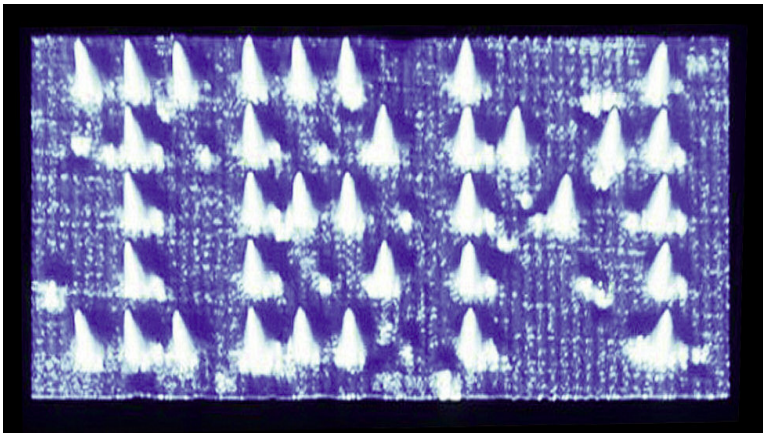
An STM Movie of O2 molecules dissociatively adsorbing onto a Cu(110) surface



Pushing Atoms

Using electric repulsion, the STM is capable of manipulating atomic surfaces into any shape desired. As a recreational use of this technology, Figure 25 shows the smallest company logo in the world, made by IBM, a prominent technology company, using an STM. The 35 larger bumps in the image are individual xenon atoms, each of which rest on a copper substrate surface[22].

Figure 25



As a much more practical example, the ability to push atoms around is the STM's key to its usefulness in the mass-produced nanotechnology of the future. One modern-day example is the Quantum Dot. These tiny circular devices have a cross-sectional area of just .16μm^2, and are designed to hold 200 electrons at any given time, and emit a specific frequency of light when electrons are passed through them[36]. Because Quantum Dots are very efficient in their use of energy, they are an excellent candidate to replace television displays, producing ultra-high definition images without the excessive energy cost from alternative options. Sony was the first television manufacturing company to actually use this method, and in 2013, they produced the world's first commercially available Quantum Dot television. It used the Quantum Dots to enhance the picture quality, though it did not completely replace the conventional display[37].

While these quantum dots did not require STMs, if television companies wanted to further increase the quality of the images, they may have to reduce the size of Quantum Dots—perhaps to the size of individual molecules. If so, the STM will become instrumental in constructing these devices.

Conclusion

In the near future, STMs will serve as invaluable tools for quantum mechanics research. The device gives scientists a more intimate look at the world of molecules and atoms than ever before, revealing previously unexplainable properties of matter.

In addition, as technology continues to shrink, the precision of the machines used to build them must increase. The STM is the perfect candidate to build these devices, and their precedence may increase dramatically once their value is fully recognized.

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Are There Patterns of Judgements that We Make Based on First Appearance?

by Camille Johnson

Abstract

To discover people's hidden biases and pre-judgments from appearance, subjects sat in a room and filled out five questions about 15 pictures in a slideshow projected on the board. Each picture was of a different high school senior in matching formalwear. Subjects had to rate each student in the slideshow from 1-15 on their attractiveness, trustworthiness and intelligence, based solely on the picture. They also guessed each student's sexual orientation and socio-economic status. First, it was found that subjects almost always rated themselves higher than the people in the picture. Also, on average, subjects rated the attractiveness of white people significantly higher than they did black, latino, asian or racially ambiguous people. There was also a correlation between trustworthiness and intelligence, so the more intelligent subjects believed a person to be, the more trustworthy they also found that person. Lastly, there was also a weak correlation between the mean attractiveness that subjects rated a person and how many subjects thought that the person was straight.

Background

First impressions are an enormous part of our lives. They determine how we interact with others, and the pre-judgments that we make about people. Every day humans decide how trustworthy people are, how intelligent people are, how much money people have, what sexual orientation people are just from first glance. We decide how we interact with others depending on the assumptions we make at first glance. I am looking to see what could possibly cause or correlate with these assumptions. I'm seeing how one's perception of another's attractiveness affects their other assumptions about him/her, and whether their gender and race play a part in the assumptions as well.

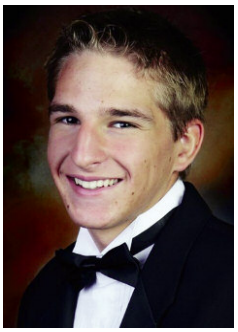
In one study, researchers looked at how a person's first impression of another's attractiveness affects the perception of their academic and intellectual achievements. After looking at pictures of men and women and rating their attractiveness and achievement levels, the researchers found that the more attractive subjects found a man, the more successful they found him. But, the more attractive they found a woman, the less successful they found her (Chia, Allred, Grossnickle, Lee).

Another study asked people to choose between pictures of people whose faces were either manipulated to look more like them, or manipulated to look like another. It was shown that people trust others more if they look more like themselves (DeBruine). Studies of trustworthiness have shown that first impressions are actually very much related to the brain, and one even states that the, "amygdala automatically categorizes faces according to face properties commonly perceived to signal untrustworthiness" (Haxby, J. V., & Gobbini, M. I).

No studies have really been done to see how gender and race play into these impressions, and whether these observations can be made about other traits as well, so I'm also looking to observe what correlations occur.

Methods

The purpose of this experiment was to see if there were correlations between people's perceived view of others' socio economic status, intelligence, sexual orientation, and trustworthiness, based on their appearance. Using an online survey, students first filled out their gender and their own attractiveness on a 1-15 scale (1 being the least and 15 being the most).

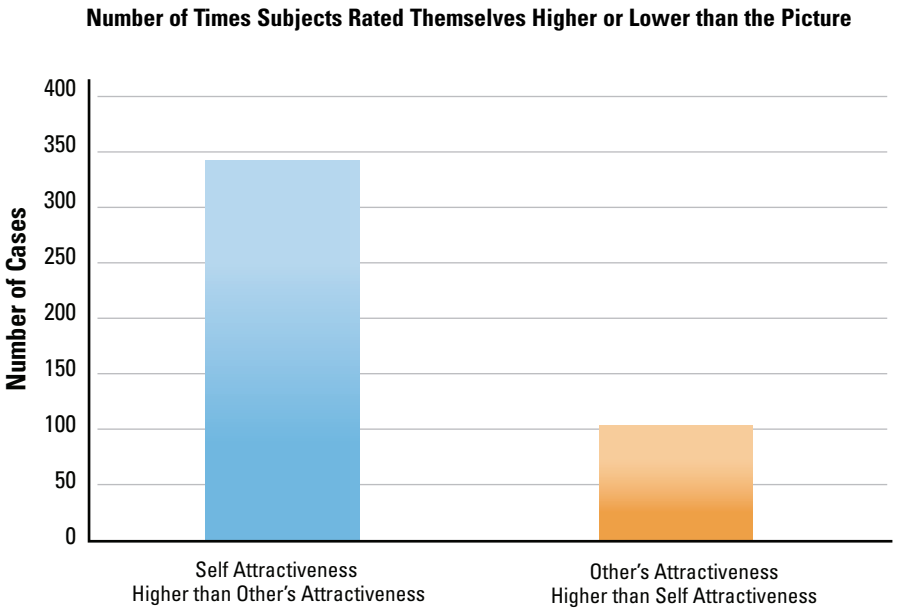


The facilitator then showed the group of subjects a slide show containing 15 high school senior pictures (all wearing the same formal outfit).

The experimenter stayed on each picture for 30 seconds while the students filled out how attractive, intelligent and trustworthy each person was on a 1-15 scale, and what their socio-economic class and sexual orientation were based on the one picture. After the 30 seconds on that slide, the experimenter then switched to the next slide and the subjects answered the same questions over again. After the experiment was completed, correlations were tested using race, gender, or attractiveness as the independent variable, and looking to see their effect on the subjects' perception of students' sexual orientation, trustworthiness, or socioeconomic status.

Figure 1

In this study, 30 subjects rated 15 people, so there were 450 responses in total. This graph shows that out of these 450 responses, in only 102 of them did subjects find the person in the photo more attractive than themselves. In 348 responses, subjects rated themselves higher than the person in the picture.



Results

Figure 2

Perceptions of Trustworthiness vs. Intelligence

In this graph, it's clear that there is a slightly weak correlation between the subjects' perception of students' trustworthiness and intelligence with an R-squared value of .31. The more intelligent they think a person is based on his or her appearance, the more trustworthy they also think that person is.

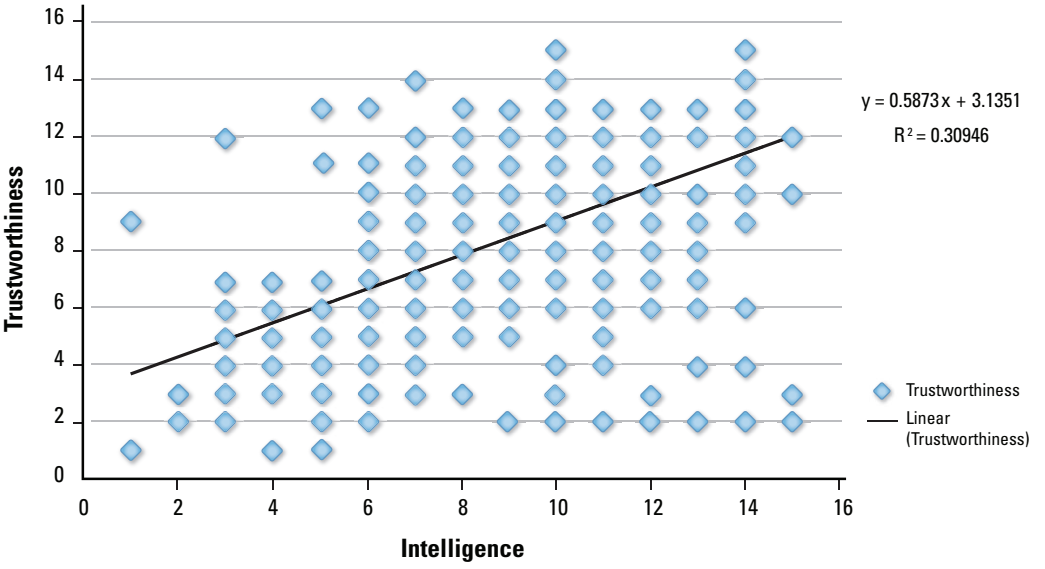


Figure 3

Mean Average vs Percentage of those who think the person is straight

This graph illustrates that there is a very weak correlation between the subjects' perception of a student's likelihood to be straight and his/herthe mean attractiveness rating.

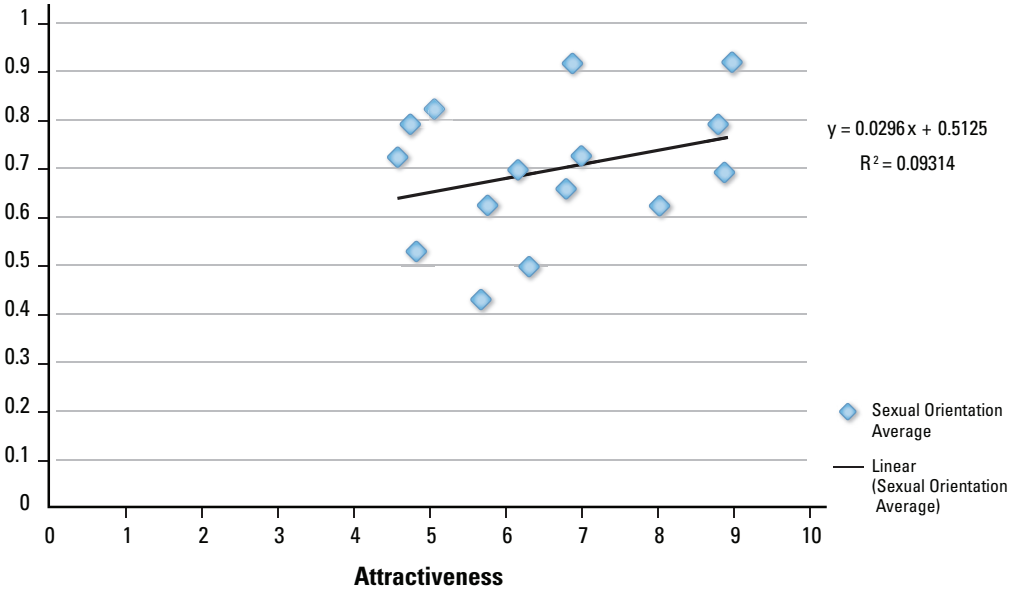
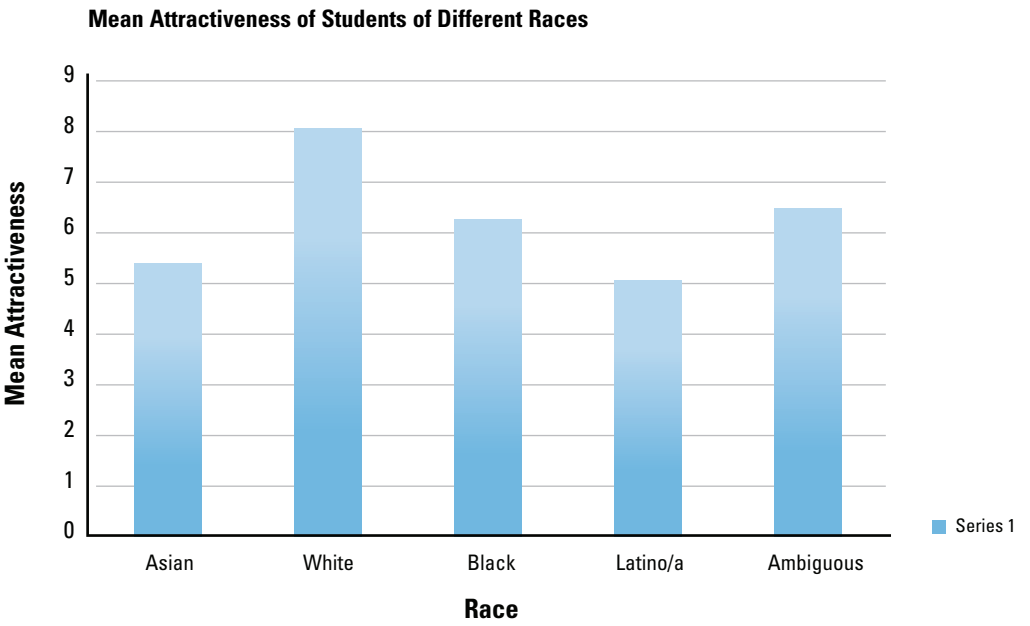


Figure 4

This graph displays the mean attractiveness that subjects rated students of different races. Based on an independent sample Analysis of Variation (ANOVA), there was a significant difference, with a p-value of .015 between people's rating of the attractiveness of white, black, asian, latino/latina and ambiguous people. The average attractiveness of white students was 8.08, that of black students was 6.25, that of asian students was 5.42, that of latino/latina students was 5.07 and that of racially ambiguous students was 6.5. Overall, people rated the attractiveness of white students significantly higher than they did people of color.



Conclusion

Overall, not many correlations were able to be detected, especially considering the number of correlations that the experimenter tested for. First, there was a tendency to rate oneself as more attractive than others which was interesting, because there have been many studies that show that people always consider themselves to be above average at almost everything (even though obviously not everyone can be above average, or it wouldn't be the average. This phenomenon is considered the Superiority Illusion (Ghose)). Subjects almost always rated themselves as more attractive than others, despite the statistical truth that not all of them are more attractive than every single person shown. There was also a correlation between rated trustworthiness and intelligence which was interesting and very much unexpected. Also there was a significant tendency to rate the attractiveness of white students above students of color. This related to the Clark Doll Experiment, where white and black girls had to choose between a white and black doll and identify which one was bad, good, pretty, ugly, nice, mean etc. Children almost always connected the white doll with the good traits, and the black doll with the negative one (NAACP Legal Defense Fund). Like that study, this experiment shows that in general, people find white skin more attractive, supporting the concept of white privilege, especially in terms of attractiveness. Lastly, there was a correlation between attractiveness and straightness.

Of course, there are multiple sources of error and a few things that could have been improved in this experiment. First, there should have been more pictures in the slideshow, so there could be a wider variety of people of different races, because with only 15 pictures, there couldn't be many pictures show for each race and more pictures could give a more accurate vision or people's first perception of people based on race. Also, one of the main difficulties was that people don't want to admit their biases about race or gender, so they might not want to put down what they really think, in fear of sounding or feeling racist or sexist. Even though this was anonymous, there might be a feeling of guilt if subjects admitted racist biases in their surveys. Also, this data definitely cannot be applicable to the rest of the population of the US because subjects were restricted to students at the Berkeley Carroll School, in one of the most liberal and diverse cities in the world, New York City. The lack of strong correlations could just show that Berkeley Carroll students don't have such strong biases in their first impressions.

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Urban Stormwater Management: The Potential Role of Green Roofs in Brooklyn

by Jacob Justh

Abstract

Combined sewer overflow occurs when New York City's sewage system experiences excess stress due to storm water runoff. One potential solution for managing this storm water is through the implementation of green roofs across the city. This paper will combine research on different subjects to create a green roof design optimized for storm water retention. It will also analyze the feasibility of implementing green roof technology and estimate the quantity of water that can be retained through the creation of this infrastructure.

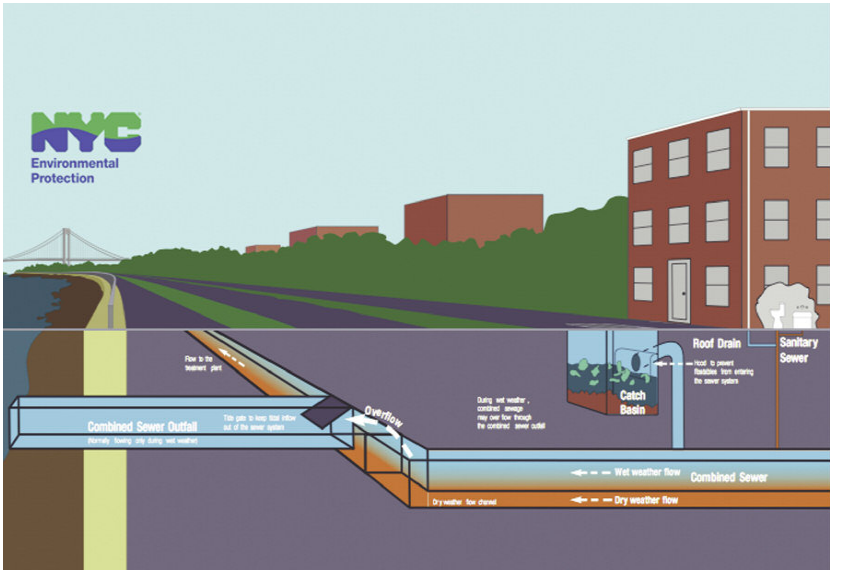
Introduction

By the year 2050, researchers predict that the global population will have risen from its current 7.2 billion to around 9.6 billion (Kochhar, 2014). In the same time period, the percentage of people living in cities globally is expected to rise from 54% to 66% (UN). One of the costs of urbanization is the increase of impermeable surfaces. As a result of this increase, urban storm water runoff has no place to go and causes combined sewer overflow (CSO) into city waterways. It is estimated that the 772 combined sewer systems in the U.S. discharge around 850 billion gallons of storm water and sewage waste into waterways every year (Levy, 2014).

This is one of the most important environmental issues that New York currently faces because most of New York City's sewer system is combined, meaning that the system that treats sanitation is the same that manages storm water runoff. When there is too much stress on the system due to excessive storm water, the system will discharge directly into one of the city's waterways to prevent upstream flooding. As a result, polluted and otherwise dirty water is injected into our waterways, impacting water quality and recreational use (New York City Environmental Protection).

Figure 2

New York City's Combined Water System



New York's Combined Sewer System

One potential solution to this problem is to increase porous surface area (surfaces that absorb water) through the development of green roofs. A green roof is a roof of a building that is covered by a plant layer, growing medium, and multiple insulation layers. There are many studies that have been performed that prove the storm water management capabilities of green roofs (VanWoert, 2005) (Uhl, 2008). However, in a city as complex and developed as New York City, extensive planning towards the optimization of green roofs and the feasibility of their implementation on a large scale is necessary before new infrastructure can be added. The purpose of this study is to examine the variables that affect green roof water retention in order to determine an optimal green roof design as well as to study the amount of available roof space and the potential water capture rates.

Materials and Methods

For this study, I analyzed how the different components of a green roof can be customized to optimize water retention as well as the total acreage of potential green roof sites in Brooklyn.

According to Conservation Technology, a typical green roof has around eight layers—roof structure, waterproofing membrane, root-barrier/ponding membrane, protection fabric, water-storing drainage layer, non-clogging separation fabric, soil, and vegetation (Conservation Technology, 2008). However, there are three main variables to consider when constructing a green roof for the purpose of storm water retention—surface medium (the plant life that exists on the roof), media depth (the depth of the soil layer), and slope (the pitch of the green roof). Another prospect to consider is whether an intensive or extensive green roof would fit Brooklyn the best.

Figure 2

An example of a green roof on Chicago's City Hall

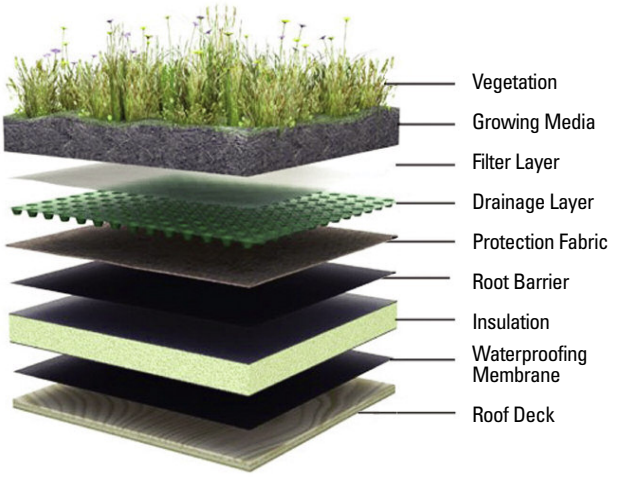
Results

Slope

In 2007, researchers at Michigan State University performed a study to quantify the effect of roof slope on green roof storm water retention. In the study, they constructed 12 different green roofs with varying degrees of slope (2%, 7%, 15%, and 25%) and measured the runoff on each slope in varying rain events. Rain events were classified by varying intensities such as light (<2.0mm), medium (2.0-10.0mm), or heavy (>10.0mm). They concluded that the greatest retention was found at the 2% slope (85.6%), the lowest at the 25% slope (76.45%), and that mean retention was 80.0%. In addition, the researchers assigned Curve numbers, a unit of measurement for runoff (0 being all water retained, 100 being all precipitation resulting in runoff)(NRCS, 2004). The curve number for a traditional concrete surface is 98. The slopes of 2%, 7%, 15%, and 25% received curve numbers of 84, 87, 89, and 90 respectively. The retention percentage (85.6%) and curve number (84) clearly suggest that a 2% slope retains storm water most effectively (Getter, 2004).

Figure 3

Anatomy of a green roof



Media Depth

In 2005, researchers performed a study to test the effect of media depth on storm water retention rates. In this study, twelve different green roofs were created, 6 at a 2% slope and 6 at a 6.5% slope. Media depths of 2.5 cm and 4 cm were used for the 2% slope roofs and media depths of 4 cm and 6 cm were used for the 6.5% slope roofs. While researchers observed a greater retention in the roofs that had larger media depths for both slopes, the 4 cm roof at a 2% slope had the greatest retention rates over different intensities of rain. From this they concluded that increasing media depth usually increases retention (VanWoert, 2005).

Still, while the media depth is proven to be the most important factor in determining runoff, even a thin layer substantially reduces peak runoff (Uhl, 2008).

Surface Material

Studies have found that the role vegetation plays in water retention varies based on the season. During periods of low water availability, such as summer, vegetation plays an important role in retaining and detaining water. However, during other periods where water is more readily available, studies have shown that the role of vegetation on water retention is insignificant (Berndtsson, 2009). Still, other research suggests that varying plant life increases biodiversity which improves the water retention rate and health of the green roof system (MacIvor, 2011).

Intensive vs. Extensive

Green roofs are often separated into two different categories—intensive and extensive. Intensive green roofs have deeper layers of soil (>10 cm), host larger plant life, and require more maintenance. Extensive green roofs have thin layers of soil (<10 cm), small vegetation cover, and are often intended to be maintenance free (Berndtsson, 2009). Each has its own benefits and drawbacks. Extensive green roofs are much cheaper and easier to install than intensive green roofs because they require less labor, weigh less (12 to 50 lb weight at full soil saturation per square foot compared to 80 to 120 lb weight of intensive roofs), and can be more easily customized to specific buildings (Zimmerman, 2008). Perhaps the most important difference between the two is that extensive roofs detain water whereas intensive roofs retain it. This means that an extensive roof will capture storm water and release it slowly over time. This still mitigates peak runoff and reduces stress on the sewer system. However, an intensive roof would retain the storm water in its deep soil and not release it as run off. This completely eliminates stress on the sewer system that would occur from that area.

Available Land in Brooklyn

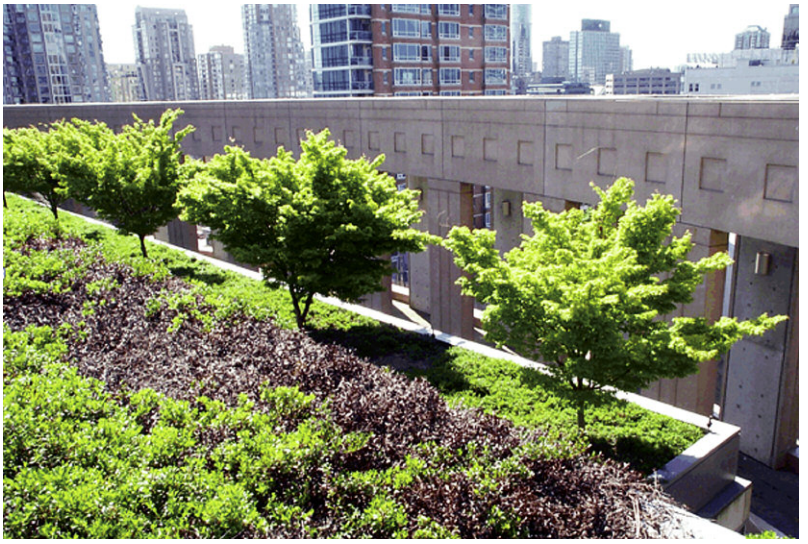
In 2011, a group of researchers at Columbia University's Urban Design Lab performed a survey of New York City in which they sought out the vacant land New York City had to offer for urban agriculture. As a part of this study, they found data on the potential for rooftop farming in NYC. The buildings they chose had to meet a specific set of criteria that had to do with size, height, and structure. In Brooklyn they found 1,670 private buildings offering 848 acres and 117 public buildings offering 92 acres (Plunz 2012).

Figure 4

An intensive green roof

Figure 5

An extensive green roof



Discussion

Optimal Roof Structure

The collaborative data suggests that an extensive green roof with a slope of 2% and media depth of 4 cm would be most effective in storm water management. The slope and depth were chosen based on their observed storm water retention properties and an extensive system is favored due to the difficulty of implementing intensive green roofs on pre-developed spaces. Vegetation can be used or disregarded based on the intended aesthetic or budget.

Implications in Brooklyn

The NYC Green Infrastructure plan has a goal of reducing CSO volumes by an additional 3.8 billion gallons per year (Plunz 2012), in part through capturing 10% of rainfall in the combined sewage watersheds citywide (CSW, areas whose runoff drains into combined sewage systems). A Columbia University study estimated there to be around 3970 acres of land in CSWs citywide. Covering all 940 acres of vacant rooftop land found in Brooklyn with green roofs would reduce CSWs by about 24%. The same study estimated that 25% of CSWs would need to be made impervious in order to reach the city's 10% capture rate. This means that adding green roof infrastructure to possible green roof locations in Brooklyn would play a huge role in reducing CSO volumes, and nearly meet the citywide reduction goal.

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Neural Decoding for the Brain Machine Interface

by Nadine Khoury

Abstract

Whenever an individual performs any motor function, his/her neurons are at work. The motor cortex, an important area of the brain involved in motor function, generates neural impulses that control the execution of voluntary movement. These electric patterns travel throughout the neurons, from the cerebral cortex to the spinal cord to the peripheral nerves, transmitting a command that will conduct the contraction of a muscle within the body[1,2]. In the field of neuroprosthetics, a subject can control an external device using his motor cortical spike activity (the neural impulses). The Brain Machine Interface (BMI) serves as the principal link between the motor cortex and the prosthetic device[2,3]. Small microelectrode arrays implanted in the brain read the neural signals and transmit them to a computer, which interprets the signals and converts them into movement commands[4]. These commands are then transmitted to the external device where they are executed. This research aims to bypass spinal cord injuries and peripheral nerve damage to restore limb function for amputees or paralyzed individuals.

The most important part of a BMI is the computer decoder, an algorithm that estimates movement intention from neural activity. This paper will discuss the first steps in "calibrating" this decoder for a specific user. In an experiment conducted by Jarosiewicz et al. (2008), monkeys used a BMI to move a cursor in 3D virtual reality to one of eight targets arranged in the corners of a cube. The data collected in this lab consisted of neural firing rates and the target directions from each trial. These two sets of data were used to create a cosine-tuning curve in order to find the preferred direction of each recorded neuron in the motor cortex[5]. The next step was the decoding, which was done by generating a so-called "population vector" by summing the individual "votes" of all neurons in their preferred directions. Decoding neural activity using methods similar to this in real time allows neuroprosthetic devices to restore motor function in paralyzed individuals.

Background

In this section, I outline two parts of neuroprosthetic devices: the electrodes/electrode arrays which detect neural signals, and the Brain-Computer Interface, which involves a computer translating the signals detected in the electrodes from neural to electrical commands.

I. ELECTRODES: WHAT IS A NEURAL IMPULSE? HOW ARE WE ABLE TO MEASURE NEURAL ACTIVITY?

The neuron consists of dendrites, a cell body, an axon, and an axon terminal. On the axon terminal there are many neurotransmitters specific to certain instructions. When a person wants to move or when any function is performed, the instruction to do so is generated in the nucleus (in the cell body) of one or more neurons. What's also important to know is that the electrical charge of a neuron is negative relative to the surroundings when it is at rest. The way it makes itself negative is that an enzyme on the membrane called Na+/K+ ATPase (aka sodium potassium pump) on the membrane of the neuron lets out three molecules of Na+ and potassium leak channels let in 2 molecules of K+ regardless of the concentration gradient (particles tend to move from high to low concentration). This action makes the neuron lose charge because you have a net loss (-3+2=-1). So essentially, neural activity is the movement of K and Na + ions inside and outside of the membrane of the neuron. This happens until the inside of the neuron reaches -70 millivolts relative to the outside of the cell. When an action potential/instruction is set off, the instruction/electrical signal transmitted is called an "active potential." An active potential is more like an event. It is only set off in the neuron when the potential difference is -50 millivolts. When the neuron reaches -50, Na+ voltage gated channels on the membrane of the neuron open and let in sodium according to their concentration gradient (because there is more Na outside the neuron, opening the gate makes sodium enter the cell to equalize concentration on the inside and outside of the neuron). The influx of Na+ ions raises the charge inside the neuron and when the potential difference reaches 35 millivolts, Potassium voltage gated channels open and let out Potassium according to its gradient. This causes charge to be lost in the neuron because positive particles are being let out. When the neuron reaches -90 millivolts, the gated channels close and the Na/K ATPase and the K leak channels open and stabilize the neuron back to -70 millivolts. While all this exchange is happening, some Na+ slides down the axon causing the charge to increase in that specific area of the neuron. This creates another action potential and the series is begun again.

But this is all in one neuron. Neural signals are passed from neuron to neuron. At the end of the axon of the first neuron, the dendrites from a neighboring neuron lie near it. The gap between the axon terminal and the dendrites is called synaptic cleft. When the action potential I described reaches the end of the axon, a neurotransmitter on the axon terminal essentially carries this potential and brings it to the dendrite of the next cell. Certain channels open on the dendrite allowing Na to flow in. If there is enough Na transmitted to the second neuron that the potential changes to -50 millivolts, the action potential will be set off again and will be passed down to the end of the neuron and so on. EEG measures this action potential.

Therefore, the strength of the signal is not based on voltage. The set off voltage is -50 millivolts each time and the maximum voltage is always 35mV. The intensity depends on the *frequency* at which the action potential is set out. This is why EEG measurements are in hertz. Because it is a frequency, strong brain activity is a high frequency of action potentials. Electrodes are thus implanted into the grey matter of the brain where they measure the frequency of action potentials.

II. BRAIN-MACHINE INTERFACE

The Brain Machine Interface (BMI) serves as the link between neural activity and the external device. The electrodes that detect the neural firing rates transmit the tracings to a computer. Algorithms within the computer compute and interpret the firing rates into commands that can be executed by a mechanical device such as a prosthetic limb. The BMI is therefore what allows the neuroprosthetic devices to bypass the spinal cord. While a natural limb functions by means of signals passing from the brain through the spinal cord to the peripheral nerve, the BMI bypasses the spinal cord (and in turn any spinal cord injuries that could inhibit signal movement) by taking brain activity, interpreting it, and transmitting it to a bionic device. Thus, an amputee, or patient with a spinal cord injury can function without employing their spine.

Procedure

I have furthered my research in neuroprosthetics through mentorship by Dr. Beata Jarosiewicz at the BrainGate Lab in Brown University. Most of my work dealt with data analysis and decoding neural activity collected in trials conducted in Jarosiewicz et al. (2008)[6].

In the experiment, an electrode array was implanted into the motor cortices of monkeys, enabling them to control a bionic limb.

Each electrode in the electrode array recorded a particular action potential from each neuron and transmitted the readings to a computer. This technique is also called electroencephalography (EEG). The frequency of the action potential determined how frequently the neuron fired. The monkeys had to move the robotic arm to a particular target (there were 8 arranged in a circle each 45 degrees from the next). While the monkey was moving the arm to a particular target, the EEG profiled a group of target neurons in the motor cortex and the array measured how frequently each neuron in the group fired during each trial. The placement of the target was also recorded with each trial.

Data

The data tables provided are shown below.

Data Table A

Cartesian Coordinates of Target Directions for 99 Trials

-0.7071	0.7071	-0.7071	0.7071	-0.7071	0.7071	-0.7071	0.7071	-0.7071	0.7071
0.7071	-0.7071	-0.7071	0.7071	-0.7071	0.7071	-0.7071	-0.7071	-0.7071	-0.7071
-0.7071	-0.7071	0.7071	0.7071	0.7071	-0.7071	-0.7071	0.7071	0.7071	-0.7071
-0.7071	0.7071	-0.7071	0.7071	-0.7071	0.7071	0.7071	0.7071	-0.7071	0.7071
0.7071	0.7071	0.7071	0.7071	0.7071	0.7071	-0.7071	-0.7071	0.7071	-0.7071
0.7071	-0.7071	-0.7071	0.7071	0.7071	0.7071	0.7071	-0.7071	-0.7071	0.7071
-0.7071	0.7071	-0.7071	-0.7071	0.7071	-0.7071	-0.7071	-0.7071	0.7071	0.7071
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-0.7071	-0.7071	0.7071	-0.7071	-0.7071	-0.7071	-0.7071	0.7071	-0.7071	0.7071
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-0.7071	0.7071	-0.7071	0.7071	-0.7071	-0.7071	0.7071	0.7071	-0.7071	-0.7071
0.7071	0.7071	-0.7071	0.7071	0.7071	0.7071	-0.7071	-0.7071	0.7071	-0.7071
-0.7071	-0.7071			0.7071	-0.7071	-0.7071	0.7071	-0.7071	-0.7071

PROJECT I

Data Table A represents the target directions for each trial. It consists of 99 rows of two columns. This means that there were 99 trials and each column represents an axis, x or y. For example, in the first trial, the monkey had to move the arm from the center of the circle of targets -.7071 horizontally (assuming 0,0 is in the center) and .7071 vertically. This is equivalent to the vector coordinates $(-\sqrt{2}/2, \sqrt{2}/2)$. Later, in analyzing this data, each x, y direction was turned into an angle. For example, the Cartesian coordinates of the first trial $(-\sqrt{2}/2, \sqrt{2}/2)$ were converted to the equivalent polar coordinates $3\pi/4$ (This explains why the x axis in Graphs A and B are in radians).

Data Table B represents a 99-row, 1-column matrix and communicates the firing rate of the profiled neuron over the 99 trials.

Data Table B

Firing Rates of Profiled Neuron Over 99 Trials

80.7985	20.5835	11.6279	34.5299	31.5664	
14.8810	24.7703	20.5671	13.5837	17.0000	
31.2500	60.7012	72.5300	30.3479	25.7889	
15.1848	62.3441	7.0578	42.6254	22.1956	
55.1576	41.4250	31.9672	29.7158	36.7680	
26.0839	49.5901	19.7044	10.5960	58.4448	
19.7802	30.1075	23.6742	11.1955	19.0476	
38.9610	51.9760	29.6221	55.0880	15.7811	
17.4197	18.9772	54.9964	9.9548	38.0678	
32.9378	25.8558	16.9830	22.3577	45.3499	
53.5679	12.6354	24.1952	15.1848	14.1044	
14.4731	16.4690	19.1655	16.3705	17.0394	
54.6397	26.0102	29.4118	46.4720	17.7680	
24.9053	50.1792	18.8889	41.3163	16.1467	
23.5690	22.4033	65.8142	28.8210	27.9570	
30.5970	26.7957	57.8394	26.2541	13.1429	14.3942
42.1950	60.2931	11.9893	25.1620	11.4068	49.7069
26.3043	18.7850	17.3965	54.8327	24.0058	16.1806
11.6794	15.7748	15.5969	17.0482	29.6779	63.5478

PROJECT II

Analysis

The first step in analyzing the data above was to decode the preferred angular direction of one neuron. After the coordinates of Table A were converted to angles, a scatter plot was generated by mapping the firing rates v. target location (the angles determined) per trial shown in Graph A.

I reiterate that these were the firing rates of only one neuron over the 99 trials. A multivariate regression was then performed and a cosine-tuning curve was fit to the data collected in the lab. As a result, it can be concluded that the peak/highest point on the cosine curve was the *preferred direction* of the neuron because at a particular target direction (x) the neuron fired the most (y). This depiction is shown in Graph B below. In other words, the neuron prefers to fire the most at the specific direction specified by the x value at the peak. For this

reason, this point represents the one specific neuron's preferred direction. Because the neuron fires the most at this point, then this is the direction that the neuron is specialized in controlling. This is how the BMI enables researchers to see preferred "thoughts" and "instructions" of each neuron.

Data Table C

Neural Firing Rates of 49 Neurons over 121 Trials

This Data Table is too large to include. It is similar to Table B except it is inverted and instead of 1 column there are 49 rows (to represent the 49 neurons), and instead of 99 rows there are 121 columns to represent the 121 trials.

Data Table D

Target Locations in Cartesian Coordinates for 122 Trials

The Data Table below consists of two rows representing the two dimensions of the Cartesian plane and 122 columns representing the 122 trials. When converted to angles, the target locations here become similar to those of Table A: multiples of $\pi/4$. This is because the experiment consisted of eight targets arranged in a circle, each $\pi/4$ radians from its neighbors. However, the difference between Tables A and D are the magnitudes - Table A represents components of a unit vector where the sum of the two components is one. Table D involves the magnitude of $55\sqrt{2}$ because each target was spatially located $55\sqrt{2}$ units from the center.

-55	55	55	-55	-55	55	55	55	-55	-55	55	55	55	55	-55	-55	-55	55	-55	-55	-55	55	-55	55	55	55	55	-55	55	55	55	-55
55	-55	55	55	-55	-55	55	55	55	-55	55	-55	55	55	-55	55	55	-55	-55	-55	55	-55	-55	-55	-55	55	-55	55	55	55	-55	55	55	-55

55	-55	-55	55	55	55	-55	55	-55	55	55	-55	55	55	-55	55	55	55	55	-55	55	-55	-55	-55	55	-55	-55	-55	55	55	-55	-55
-55	55	55	55	55	55	-55	55	55	-55	-55	-55	-55	55	55	55	-55	-55	55	55	-55	55	55	-55	55	-55	-55	55	55	-55	-55	-55

-55	55	-55	55	55	55	55	55	-55	-55	55	55	-55	-55	55	55	55	55	55	-55	55	55	-55	55	-55	-55	-55	55	-55	55	55	55	-55	-55
-55	-55	-55	55	55	55	55	55	55	-55	-55	-55	-55	55	55	55	-55	-55	-55	55	55	-55	55	-55	-55	-55	55	-55	-55	-55	55	-55	-55	-55

-55	55	55	55	-55	55	-55	-55	55	55	-55	-55	-55	-55	55	-55	55	-55	55	55	-55	55	-55	55	-55	-55	55	-55	-55	-55	-55	-55	55	-55
-55	-55	-55	55	-55	-55	55	55	-55	55	55	-55	-55	55	55	-55	55	-55	-55	55	-55	-55	-55	55	-55	-55	-55	-55	55	-55	-55	-55	-55	55

A necessary part of generating a tuning curve is determining regression coefficients, which provide a baseline, x component, and y component according to the data, and act as an intermediate between the data and the tuning curve. The equation for the regression coefficients in for neural decoding is shown below.

$$Regression\ Coefficients = B = (X^T X)^{-1} X^T y$$

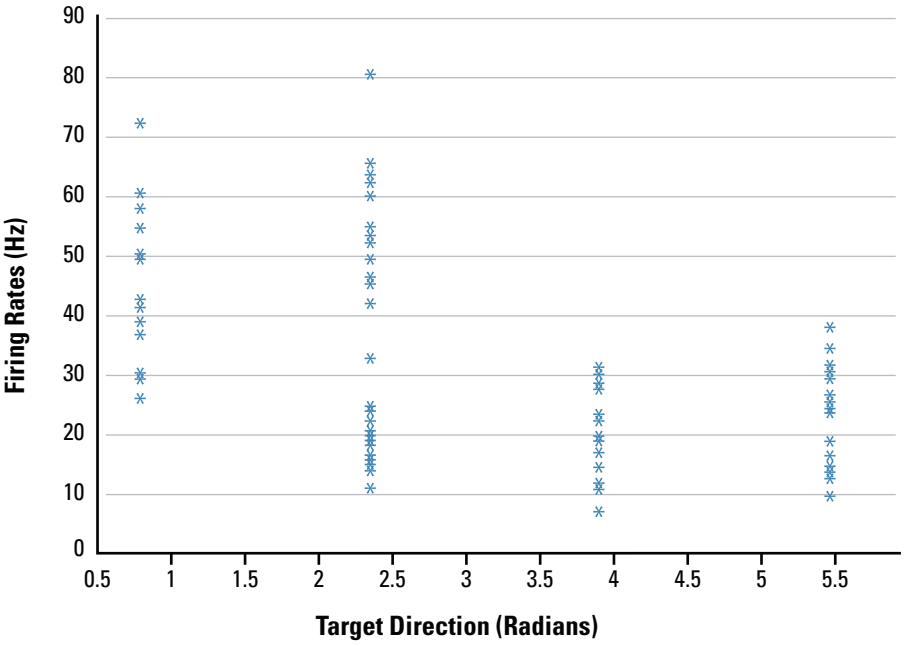
where X represents the target directions matrix. This is necessary to make the cosine-tuning curve. The components of B are used in the equation:

$$f(t) = b_0 + |b||v| \cos\theta$$

to generate the cosine curve relating the variables of the scatter plot.

Graph A

Scatter Plot Comparing Angular Target Direction and Neural Firing Rates Per Trial



The next step in interpreting the data was to find intended movement velocity of a group of neurons. This involves summing the preferred directions or "votes" of many neurons. The many preferred directions at hand are determined. The summing of these preferences (along with other statistical manipulations) determines the overall intended movement velocity, which is otherwise referred to as the population vector. The equation below is a mathematical representation of the vector; essentially, the individual preferences of a group of neurons are summed to find the overall vector for a large group. This step employs much more data in that it takes in consideration the preferred directions of multiple neurons rather than just one.

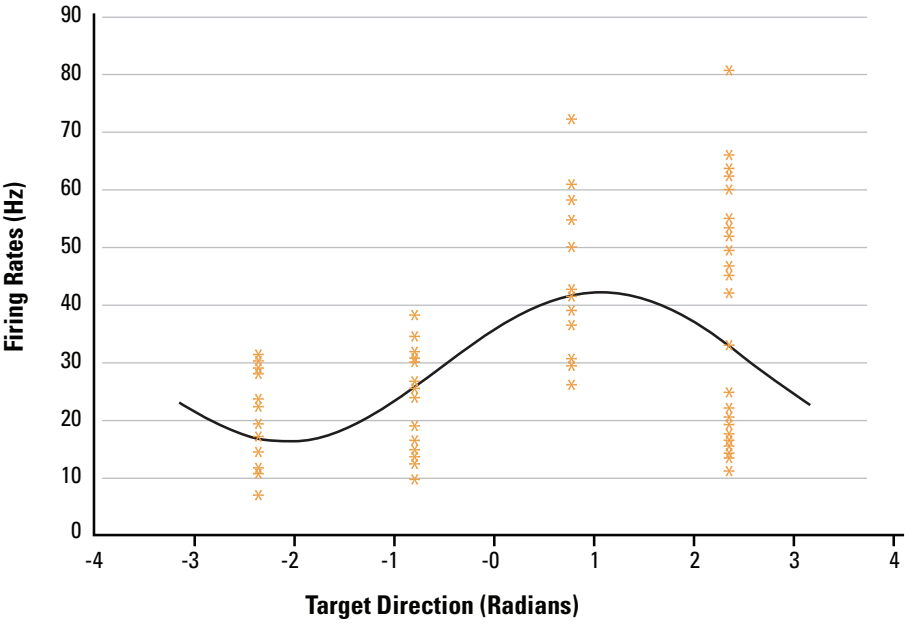
$$Population\ Vector = \sum f_i\,(t) b_i$$

where fi(t) = firing rates, bi = regression coefficients.

A graphical representation of this vector is shown in Graph C below. It is apparent in the graph that the patient's intended movement velocity (dotted line) accurately aimed toward the target (blue star). Though not perfect, the neural mapping depicted in this section allows for a patient to move the bionic limb to the target in a very similar fashion to how he/she would move a real arm. Note, here, the axes are not the angular target direction and the neural firing rates as they were in the previous two graphs. The coordinate plane represents real space, the experiment from a bird's eye view. This is why the vector starts at the center. In the procedure, the patient moved the arm from the center to a target, and his thoughts reflect this intention. At the end of my work, I was able to generate a mini-movie, depicting the target location and population vector for each of the 121 trials, with Graph C being one of 121 frames. As shown in Graph C, the

Graph B

Cosine Tuning Curve Mapped over Initial Scatter Plot



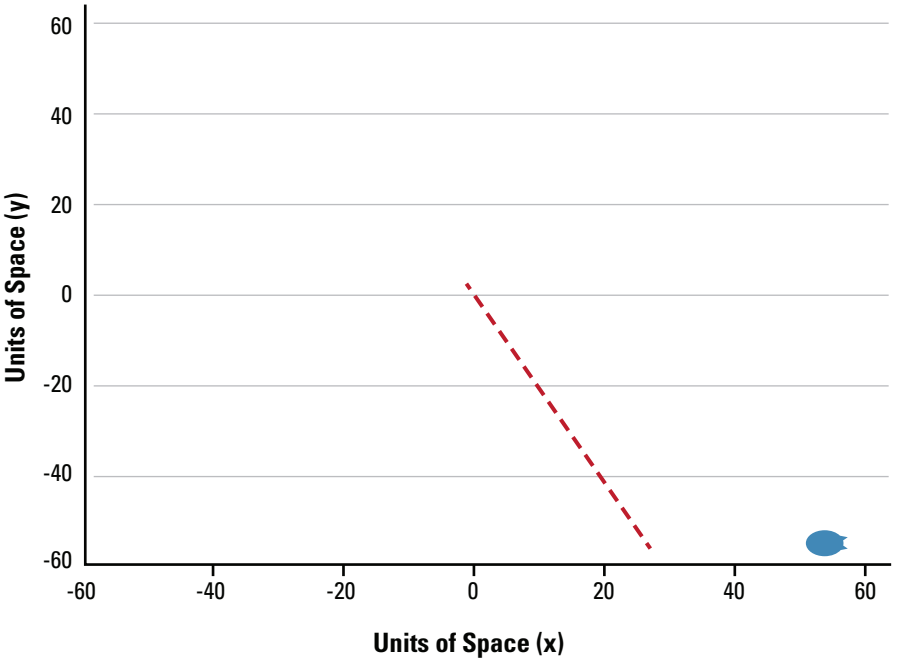
arm's intended movement velocity vector doesn't exactly align with the target. In order to measure the angular error of the arm per trial, a histogram was made (shown in Graph D below). The angle between the decoded movement direction and the target direction was measured as the "angular error" and the frequency and magnitude of the angular error is depicted in the histogram. In these trials, it's clear from Graph D that the arm was overall accurate considering that in approximately 110 of the 121 trials, the angular error was between -1 and 1 radian (close to 0 error).

Conclusion

Neural decoding allows for groundbreaking developments such as the BMI and neuroprosthetic devices. Through an experiment in which monkeys moved a bionic arm to various targets arranged in a circle, a neural decoder specific to the patient was calibrated. Using a multivariate regression to generate a cosine tuning curve, the preferred direction of a single neuron was determined. Then, using this fundamental method, the intended movement velocity of a group of neurons was determined and compared to the spatial location of the target. Such a development serves as the first steps in programming a bionic limb to move in accordance to neural activity. Additionally, the use of concise programs and mathematical concepts on the Matlab interface allows for the interpretation of massive blocks of data such as that of Project II. However, while this procedure dealt with two-dimensional movement, BrainGate works with three dimensions to use the neural decoder to command mechanical devices according to the patient's desires. Most importantly, the intricate coding of the BMI is significant in that it accurately and precisely bypasses spinal cord injuries and peripheral nerve damage, restoring limb function for amputees or paralyzed individuals.

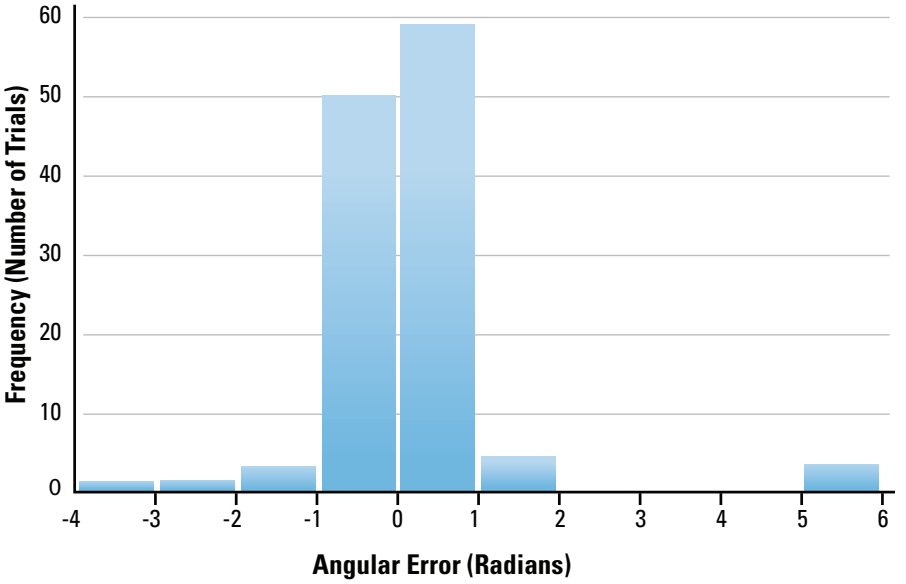
Graph C

Spatial Representation of Intended Movement Velocity Relative to the Target Location



Graph D

Frequency of Angular Error



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Autism and the Theory of Mind: An Analysis of the Neurotypical and Autism Empathy Spectra

by Michelle Madlansacay

Background

Human beings depend on social interaction and collaboration to survive. From the basic imitative actions of a newborn all the way to the everyday encounters with peers, over time collaboration has led the human race to societal advancements, and improvements to our means of survival. Communication is the key aspect of social interaction, and can be described as a process of cause and effect, in which a statement or action made by one person should cause another person(s) to react in a particular way. Looking deeper into the system of communicative response, humans use their ability to predict the intentions of others in order to respond during an instance of social interaction. If people were unable to understand how and why their peers behaved in certain ways, there would be a major communication barrier that would prevent humans from collaborating and interacting with one another. Learning more about the processes of human communication and interaction, as well as the potential impairments that exist, can help the community further strengthen collaboration with one another and eventually find innovative ways to build on our society.

In order to communicate and connect with others, every human uses a theory of mind. A theory of mind is the ability "to attribute independent mental states to self and others in order to explain and predict behavior[1]." People start to develop their theory of mind as newborns, specifically through basic social interaction and mimicry. The specific developmental process involves: the newborn's imitation of the parent's expressions and movements, periods of time where the newborn obtains a better sense of the connection between their mental and physical attributes, and the newborn finding the association between the actions of others and their own past actions[2]. Building upon these skills will eventually allow one to become capable of empathizing with others.

The general ability to empathize enhances human reactions during social communication because it allows people to emotionally connect with their peers. Empathy is defined as the ability to sense and understand another person's mental and emotional state[8]. There are two different kinds of empathy: emotional empathy and cognitive empathy. Emotional empathy is the type of empathy that allows a person to comprehend a person's emotions, while cognitive empathy is the ability to look at a situation from another person's perspective. Each form of empathy is associated with unique parts of the brain, thus further defining their distinguished roles in human behavior.

Emotional empathy is processed in the inferior frontal gyrus part of the brain[3]. Studies have shown that the brain's mirror neuron system is located within the inferior frontal gyrus[3]. Mirror neurons are brain cells that fire, both when we perform an action and when we see another person perform the same action[4]. Their activation in the brain contributes to a human's emotional understanding of others, where he/she is able to feel what others feel based on shared personal experiences.

Cognitive empathy is believed to be associated with the ventromedial prefrontal cortex (vmPFC) of the brain[3]. The vmPFC is highly involved with decision-making, specifically through its connections to other parts of the brain that monitor emotions and reasoning[9]. The interactions between the vmPFC and cognitive empathy leave humans with the ability of "perspective taking" or "mentalizing"[3]. This means that rather than immediately referring back to personal experiences to empathize, a person can put themselves in the shoes of another and consider their mental states/intentions as they are performing a particular action. Many find cognitive empathy to be more associated with the theory of mind than emotional empathy because studies have demonstrated disruptions in using the theory of mind for patients with ventromedial prefrontal lesions[3].

While there are two different forms of empathy, there are also two different "theories" of the theory of mind: the simulation theory and the "theory" theory[5]. The simulation theory describes the theory of mind as a more creative tool, rather than a systematic one. This first theory's focus is on the simulation aspect of the theory of mind, and the necessity of putting oneself in another's shoes at the present moment in order to comprehend a person dealing with a specific situation. The simulation theory correlates best with emotional empathy. The "theory" theory is the exact opposite of the simulation theory, and presents the theory of mind from a systematic view; one must use behaviors that one has learned from past experiences to know how to react in a present situation. This interpretation of the theory of mind associates with cognitive empathy.

In certain cases, there can be impairments in these fundamental aspects of social communication, and as a result they can cause neurodevelopmental disorders like Autism Spectrum Disorder (ASD). According to the most updated version of the American Psychiatric Association's Diagnosis and Statistical Manual of Mental Disorders (DSM-5), Autism Spectrum Disorder is defined as a disorder that involves any type of communication impairment that highly affects social interaction[10]. Since this is a spectrum disorder, several other neurodevelopmental disorders can be categorized under ASD including Asperger's Syndrome and Childhood Disintegrative Disorder.

A common belief is that because people with autism have impairments in their social communication skills, they lack a theory of mind. Such a claim was tested in a 1985 study, where twenty children with autism were asked specific questions regarding the following story: T*wo girls named Sally and Anne were in a room,* and *Sally had been holding a marble. She placed it in a box in front of her, and then left the room. Anne immediately transferred the marble to a basket next to the box. Sally returned and understandably looked first in the box for her marble*[6]. After listening to the story, all subjects were asked comprehension questions[6]. Then, the subjects were asked a "belief" question, which focused on where the children thought Sally was going to look first for her ball[6]. Sixteen out of the twenty children answered the question incorrectly, stating that Sally would look in the box because *they knew* that was where the ball

currently was[6]. This experiment serves as a model for many researchers, and does support researchers' statement that people with autism would lack a theory of mind[6].

However, different views from the autism community present the idea that people with autism may not necessarily lack a theory of mind, but rather have other developmental issues that account for their communication impairments. These other issues will not be discussed in this study. However, the theory that people with autism lack a theory of mind leads to the question of what distinguishes the empathizing skills of a person with autism from the empathizing skills of a neurotypical person? The study presented looks into this topic, and asks the essential question: Is the autism empathy spectrum a continuation of the neurotypical spectrum, or are they two separate spectra?

Experimental Design

Independent Variable: Neurotypical subjects
Dependent Variable: Ability to identify the correct state of mind of a character in a story (number of empathy questions answered correctly).
Controls: grades subjects are in, narrator of story, survey questions

Materials

- Video camera (Flip camera and cell phone)
- An open classroom

Procedure

This study involved nineteen subjects, males and females, ranging from 15-16 years old, all of whom participated in the study with consent from their parents. A confederate (an actor from the school's theater department) told each individual subject a two minute long story. The advantage of having the confederate be an active member of the theater department is that he/she was able to deliver the emotions of the story's characters well. All subjects were unaware of the study's actual purpose: to see if one can determine another's state of mind through conversation. They were originally told that this was a study on reading comprehension. Each session was videotaped.

After a subject listened to the story, a survey with questions about the story was sent to them. The survey consisted of ten short answer questions, both related and unrelated to the study; for every reading comprehension question there was an associated empathy-related question. Subjects' answers would determine whether or not they were able to identify the characters' states of mind.

Story

Once there lived an astronaut gecko named Ridley, who fought evil space hippos. His spaceship, The Crouton, allowed him to travel all over the galaxy and have many space adventures. There was one particular adventure that drastically changed his identity; it occurred during one of his monthly trips to planet Notearth.

Ridley was shopping in the Notearth flea market when suddenly an evil space hippo landed his flying saucer on top of Ridley's shopping basket. "Why did you do that!? You damaged my purchases!" Ridley screamed.

"Ha ha ha! I don't care! Now, Ridley Waver, I, the great Haroldimus Hippopotamy, will rule the world!" Haroldimus exclaimed.

"No you won't!"" Ridley replied. Ridley then took out his keys to The Crouton and summoned the ship to shoot lazers at Haroldimus. Lazers were shot in all directions, causing bystanders to flee the premises. Suddenly Haroldimus's arm was shot off, but to Ridley's dismay, it immediately grew back.

That was the moment Ridley realized Haroldimus was unstoppable. "I can't do this. He is unstoppable!" Ridley cries. He was convinced that the he will never, in eons, be able to stop Haroldimus. Then a space caterpillar passing by comes up to tell him: "Ridley, you have a weakness, which we'll talk about later. And now that you aware that you have a weakness, you should realize that Haroldimus also has a weakness. Now look for it, you can do it Ridley!" The caterpillar then walked away. After some thought, Ridley took the caterpillar's advice to heart. "Actually, I can do this. I will work my hardest to defeat that malicious hippo." And that was the day Ridley gained his genuine self confidence.

Now to the present day, and Ridley goes out to the supermarket to buy some kale. On his way he stumbled across a floating marshmallow. The marshmallow barked at Ridley and he smiled back. "Hello there, how are you today?" Ridley asked. The marshmallow then floated onto the top of Ridley's head. "You are a beautiful marshmallow. I think I'll keep you, and name you... hmmm... Kale!" Kale suddenly shot himself up into the sky, and then slowly floated back down to the ground. "What are you doing? I don't understand..." Ridley stated. Kale began to dance around Ridley. "You sure are something Kale..."

Questions

1. What did the evil space hippo use to destroy Ridley's shopping basket?
2. How did Ridley feel after Haroldimus' arm grew back?
3. What was the name of Ridley's space ship?
4. How did Ridley feel after talking to the caterpillar?
5. What kind of substance was Kale made out of?
6. What type of reaction did Ridley have after Kale flew to the sky, and returned back to the ground?
7. What was the name of the planet where Ridley would take monthly trips to?
8. How was Ridley feeling when he first encountered Kale?
9. Which limb of Haroldimus was shot off by Ridley?
10. How was Ridley feeling when he said "why did you do that?"

Master Answer Sheet for Questions

1. His flying saucer/space ship
2. Depressed
3. The Crouton
4. Hopeful, confident
5. Marshmallow
6. A confused, *surprised one
7. Notearth
8. Happy
9. Arm
10. Upset

Data

All data from the experiment was organized into tables and scatter plots. Results from the empathy questions (EQ) and story comprehension questions (SC) were compared to each other.

Grading System

Answers to all questions were graded on a 1-5 point scale. Wrong answers were given 1 point each and correct answers were worth 5 points each. The maximum number of points for each individual question is worth 5 points. The maximum number of total points for each type of question (SC or EQ) is worth 25 points.

All answers were graded using the master answer sheet. The process for grading SC questions was much simpler, in which grading was based on correctness. However, for the EQ questions grading was more complex. The choice of words for each subject's answer to an EQ question had to be considered. Thesaurus.com was used to confirm all potential synonyms from the subjects' answers.

List of answers from subjects that were counted correct (based on context and word definition):

#	SUBJECTS' ANSWERS	MASTER SHEET ANSWERS
#2	Defeated, Disempowered	Depressed
#4	Empowered, Determined	Hopeful, Confident
#6	Amazed	Confused, Surprised
#8	Surprised	Happy
#10	Angry, Confused	Upset

Example of Graded Questions:

Subject 1

SC= X - R R R (1 wrong, 1 no answer, 3 right)
CE= R R R R X (4 right, 1 wrong)

Subject 2

SC= R X R R X (3 right, 2 wrong)
CE= R X X X R (2 right, 3 wrong)

Table A

This table presents all the scores from each individual subject. In Figure B. all the data is organized into two scatter plots on one axis. The X axis represents the student participants while the Y axis represents their total points scored.

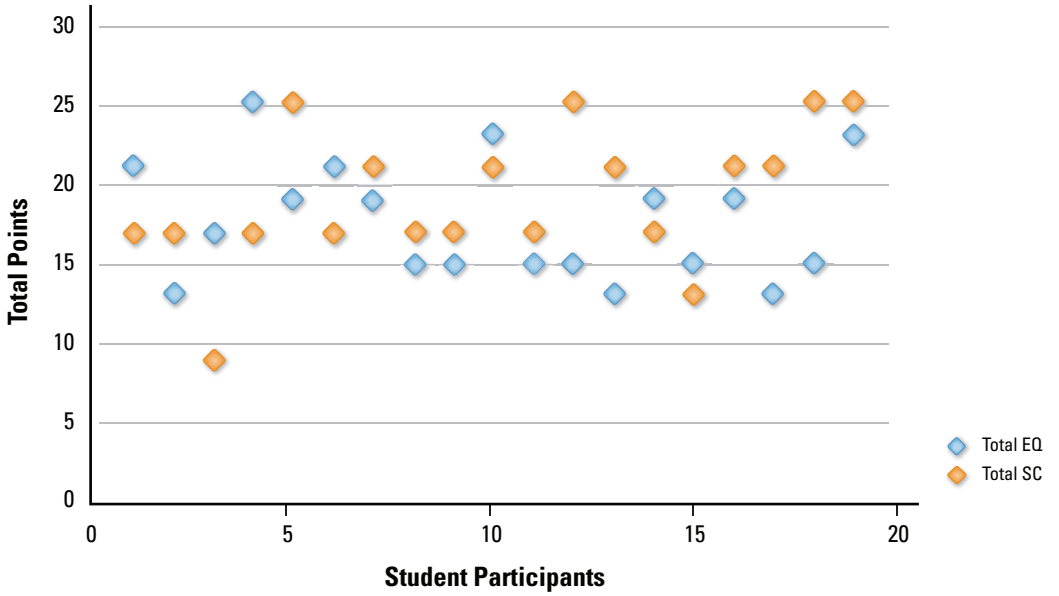
Subjects	Total Points EQ	Total Points SC
1	21	17
2	13	17
3	17	9
4	25	17
5	19	25
6	21	17
7	19	21
8	15	17
9	15	17
10	23	21
11	15	17
12	15	25
13	13	21
14	19	17
15	15	13
16	19	21
17	13	21
18	15	25
19	23	25

Mean EQ score: 17.63
EQ Standard Deviation: 3.61
EQ Range: (25-13) 12

Mean SC score: 19.10
SC Standard Deviation: 4.17
SC Range: (25-9) 16

Figure B

EQ and SC Total Scores Combined



Analysis/Conclusion

Based on the results of this experiment, it can be concluded that the autism empathy spectrum and neurotypical empathy spectrum are separate from one another. By examining Figure B. it is clear that there is more spread for the SC graph than there is for the EQ graph. The smaller spread for the EQ graph provides no indication for a neurotypical empathy spectrum. The calculated ranges and standard deviations support this conclusion, where SC scores were shown to have a higher standard deviation than the EQ scores

Although the results from this study do indicate a difference between the two spectra, they do not offer strong enough evidence to solidify the conclusion. In this paper's study, there were too few subjects to offer great variation in the results. The subjects were also all neurotypical. If the experiment included subjects from both spectra, the evidence to support the conclusion might have been stronger.

While observing the videos of each subject's trials, all subjects except for two were shown to maintain eye contact with the narrator. Research suggests that eye contact is indicative of whether or not the subject finds certain information important. Prior to a person utilizing their theory of mind, they undergo a selection process to determine what information concerns them, and what does not. A 2008 study looks at the specific selection process for communicated information. In situations where people are presented information to analyze in some way, they must differentiate common ground information from privileged information.7 Privileged information is defined as information that the subject would only know from their perspective, while common ground information is seen as information that others know as well (not just the subject). According to the study, people heed the situation more when they encounter privileged

information, and a greater interest in the subjects' task was indicated through increased eye contact. When common ground information is presented, humans will not give as much importance to the associated task. However, it cannot be inferred from the conclusions of this 2008 study that that the people who were not making eye contact, were not paying attention. Some people are able to listen and not make eye contact with others who are speaking to them.

The results of this paper's study do present information regarding the empathy spectra of people with autism and neurotypical people. However, differences and/or similarities would have likely been more evident if certain aspects of the experimental design were altered. Clearer instructions for the subjects when answering the questions in the questionnaire would have also made the grading process easier, for there were few who misunderstood the questions and did not use adjectives for their EQ responses. Overall however, the study does offer important information about the relationship between the theory of mind and communication, and educates the community more on the autism empathy spectrum and those who are affected by it.

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The Power of the Growth and Fixed Mindsets: Are Educators Aware Of The Effect They Have On Students Performance?

by Emma Raible

Abstract

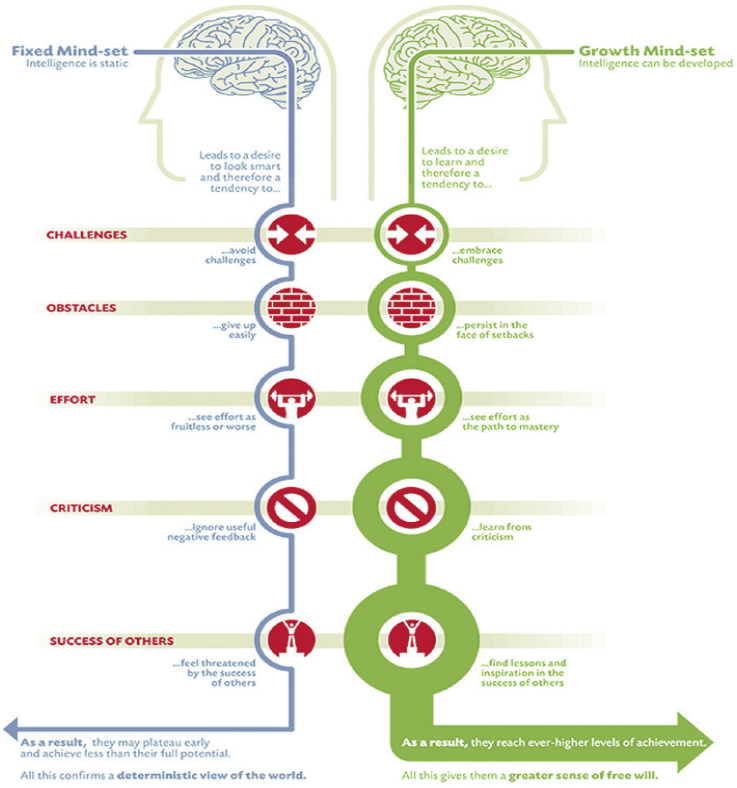
How much power do we have over our own minds to perform well in an endeavor? How much power do other people have over our ability to perform at our best? Are you more in control of your performance than you think? Mindsets are more powerful than we know; there is even a correct mindset that educators should be promoting in the classroom. This is not theoretical; mindsets change the way we think, feel and engage with the rest of the world. Through classroom observations and research, I have identified several fixed mindset statements that have an impact on students' learning process and understanding.

Background

"I was fascinated by how people cope with failure or obstacles. I was curious about why some students love challenge, and others who may be equally talented, shy away from challenges – play it safe." *— Carol Dweck*[1]

Mindsets have a direct effect on performance. Professor Carol Dweck has devoted her life to fully understanding the power of educational mindsets on the performance of students. She has always been interested in general psychology, but found that her real passion is learning more about the growth and fixed mindsets. Dweck identifies a mindset as a "self-perception" or "self-theory" that people hold about themselves, such as a belief that you are either "intelligent" or "unintelligent". She has defined a fixed mindset as "a belief by students and educators that people have different levels of intellectual ability and nothing can be done to change that." This can be someone who has always been at the top of the math class, getting A's without even trying; or someone who has "never" been a French student, and does not believe that effort will result in a better result. Fixed mindset students tend to ignore all positive and constructive feedback[2].

Dweck has defined a growth mindset as "a belief by students and educators that intellectual abilities can be cultivated and developed through application and instruction, that all students can improve their underlying ability." This can be a student who has always received



A's in math, but who does extra and more difficult practice to ensure that their mind is still expanding and making new connections; it can also be a student who stays at a consistent grade point (not amazing), but has perseverance and the ability to learn from criticism and embrace challenges[2].

Dweck's research began with two pilot studies that set the framework for the rest of her career. Her first experiment was conducted in a preschool studying the power of young minds and their ability to expand, and the other was conducted on "geniuses" who already had significant educational background. Both of these experiments concluded that intelligence is not fixed, regardless of the prior educational experience and that through executive control tasks such as problem solving through training, everyone has the ability to stretch their mind[3].

Dweck's Experimental Journey

Dweck was inspired by these two pilot studies to conduct experiments to further her understanding on these topics; this is when she created the definition for growth and fixed mindset. One of the first experiments Dweck conducted focused on tracking and understanding the mindsets of seventh grade math students for two years. She assessed three hundred and seventy-six students using a survey that asked them to agree or disagree with statements about themselves and their views on the mind and its plasticity. [Fixed Mindset Statement: You have a certain amount of intelligence, and you can't really do much to change it; Growth Mindset Statement: No matter who you are, you can significantly change your intelligence level.] This survey set a numerical value to express the extremity of the students' growth mindset. After

assessing each student's initial mindset, she tracked them for the next two years to ensure a recording of long-term performance since the impact of mindsets does not typically emerge until students face challenges or setbacks. She discovered that students with a growth mindset and students with a fixed mindset ended the first fall term with grades already significantly diverged, and they continued to diverge at the same rate for the next two years. By the end of the two years, the students with a classified growth mindset had better grades.

In an attempt to dig deeper into the psychology behind these mindsets and how it affects the larger professional world, Dweck conducted a series of experiments in an attempt to answer the question: What role do mindsets play in the performance of women in math? Before taking a challenging math test, a calculus class was split into two groups. One group was told that the gender difference in math involvement was genetically based (a fixed mindset), and the other group was told that the gender difference in math involvement originated in the different experiences that males and females have had (growth mindset) and that math skill had nothing to do with the person's gender and was all about the person's mind. The researchers then followed hundreds of college females at an elite university through their calculus course, after their mindsets had been measured and recorded. Researches observed test scores and sense of belonging in classes. They concluded that females who held a growth mindset were less susceptible to negative stereotypes and females who held a fixed mindset were more affected by these stereotypes, as they felt less of a sense of belonging in the math class (resulting in lack of interest in further math courses and a decrease in their final grades). In both of these experiments, females with or taught to have a fixed mindset performed significantly worse than those with or taught to have a growth mindset. Carol Dweck blames this eroding sense of belonging in this community on the fixed mindset as it is a key factor on the women's occupational choice. Alternatively, a growth mindset leads to success and women's acceptance as members of the math community.

After conducting many more experiments, Professor Carol Dweck came to the conclusion that growth mindset students are more oriented towards learning goals and care more about learning the material and understanding it than the final grade. Growth mindset students also believe in the power of effort and that effort promotes the ability to employ positive strategies when encountering a setback. In addition, she concluded that fixed mindset students were against the concept of effort because they thought it was only necessary for those who lacked ability, so they dealt with setbacks in negative ways such as cheating and effort withdrawal. All in all, this information led her to believe that students' beliefs about their intelligence play a key role in their performance[3].

Teachers and the Growth Mindset

Dweck has now spent the rest of her career guiding parents and educators to promote a growth mindset and make students feel good about themselves and their learning process more than to help them achieve an "A" on a test. This is to ensure that students do not ignore challenges, in fear of failure, if they should arise. It is easier for students to lose confidence and motivation when the task becomes hard as it affects their performance on problems in the future, and leads them to lie about future test scores. Dweck believes that praising effort over grades and/or ability is far more beneficial to the student. Praise on process leads students to continue discovering new ways to learn and succeed and thrive on challenges[4].

A few years ago, Dweck took four hundred students and gave them a simple puzzle. Soon after, each student was given six words of praise; half were praised for intelligence; half were praised for effort. This experiment was conducted to test if these statements, with small differences, clearly affected the students' mindsets. After solving the puzzle, students were given a choice of whether to take a hard or an easy test. The results were clear; two-thirds of the students praised for the intelligence chose the easy test because they wanted to keep their smart label, while ninety percent of the students praised for their effort chose the difficult test because they wanted to prove that they were hardworking and not afraid of challenges. Then, the experiment came full circle, giving the students a chance to take a test of equal difficulty to the first test. The group praised for intelligence showed a twenty percent decline in performance compared with the first test, even though it was no harder. But the effort-praised group increased their score by thirty percent. In the end, failure was an essential and helpful step. Dweck claims that "these were some of the clearest findings [she has] seen. Praising children's intelligence harms motivation and it harms performance." That was only the effect of six words[5]!

Dweck has concluded that the most effective ways for teachers to promote a growth mindset are the following:

a) Through teaching students about the new science of brain plasticity, intelligence is malleable (it will help if students can actually picture the neurons in their brain forming new connections; ie. not studying = breaking connections)
b) Through the portrayal of challenges, effort, and mistakes as highly valued (it will help if students are not afraid of failure, and if they know that questions and mistakes will lead to ability; ie. "Who thinks they made a really interesting mistake?" "Boy this is hard. This is what I call fun.")
c) Through process praise and feedback (ie. "I like the way you tried all kinds of strategies on that math problem until you finally got it. You thought of a lot of different ways to do it and found the one that worked!")

Dweck spreads this information by hosting discussions all around the world, open to everyone in the area. This sixty-minute presentation allows educators (and others) to comprehend her research with a clear plan going forward as to the best way to teach or approach their own obstacles in life. When I attended one of Carol Dweck's discussions, she spoke about a math game she created called "Brain Points" where students receive a higher score if they show their work and processes (while getting the answer incorrect) than if they were to get all problems correct on the first try. This is to ensure that students are not praised for being naturally good at something, but for learning something and working through difficult concepts as they learn from their mistakes. She also discussed how the world would be different if there were "Growth Mindset Schools" where a whole new value system was established in which process is praised as opposed to praising good grades. Dweck ended her lecture by applying the power of growth and fixed mindset performance on much more than just education[4].

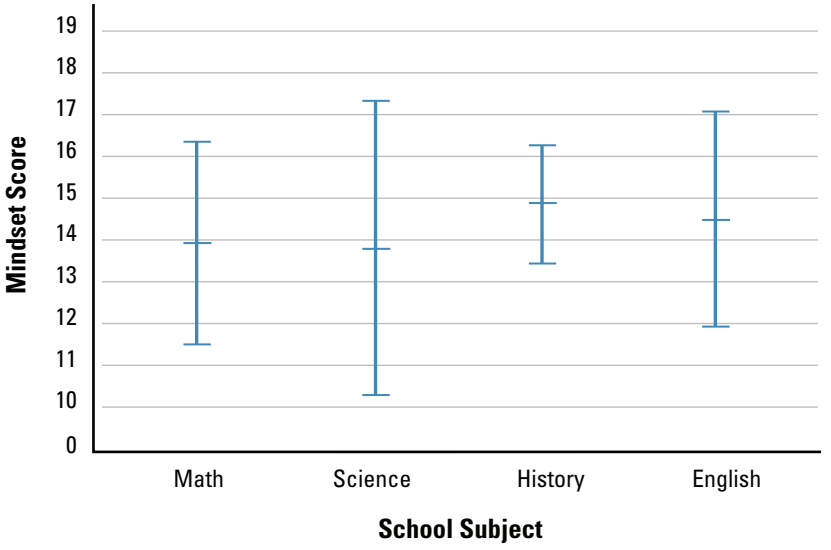
"People can be aware or unaware of their mindsets, but they can have profound effect on learning achievement, skill acquisition, personal relationships, professional success, and many other dimensions of life." — *Carol Dweck*[4]

Methods, Results and Analysis

Interested in how Berkeley Carroll educators were promoting a growth mindset in the classroom, I chose to send a survey to the entire seventh grade to identify their mindset (on a scale of 1-16; the higher the number, the more of a growth mindset they have). My results were not surprising; seventy out of seventy-one students have a growth mindset (score under eight), and only six students had scores under ten. In my survey, I also asked what their favorite subject was in school to see if I could find a correlation between all the numbers; but there was no significant difference between the mindset scores as a function of favorite subject; the figure to the left shows average score +/- SEM. Instead of focusing on these students, I decided to focus on Berkeley Carroll teachers and their knowledge about these important teaching concepts. Unlike what I did with the teachers, I accepted the survey results from the 7th graders stating that they believed in a growth mindset without following up with an observational study. I did this because teachers are in a much better position to give informed consent, so it is therefore more ethical to observe them.

Then, I completed a case study in which I observed three teachers in the English Department, sitting in on one or two classes each. Before observing them, I sent out a survey to

Extremity of Growth Mindset V
Favorite School Subject



identify the mindset they thought they had. Again, not surprisingly, all three teachers had growth mindsets, all with the same exact score. After this, I tested the accuracy of these teachers self-proclaimed mindset.

My experimental question was "How accurate is the self proclaimed [growth] mindset of these teachers in the English department?" There is a lot of discussion about the idea of a growth and fixed mindset, but are teachers truly aware of all the small words and ideas that can shift a student's entire mindset and ultimately their performance? While observing these teachers in the classroom environment, I used my extensive knowledge on the subject to identify each action as either a growth or fixed mindset "promoter." When doing this, my goal was to use previous studies that identified fixed mindset "bad" statements to identify and discover my own. It is my hope to test these self identified "fixed mindset statements" in a study using a similar experimental design as Dweck's puzzle test which looked at the power of only six fixed mindset words[3].

While the teachers did approach teaching with a growth mindset, I observed some statements that I found to be more typical of a fixed mindset including the following:

"This is a very hard topic to capture"

"You have chosen something almost impossible to write about"

"You are just thinking as you write"

"Do you really want to make that much work for yourself?"

"I got a lot of vague answers from you guys which proves that you don't really care"

While I was able to identify some new specific fixed mindset statements, I was also able to discover new tactics to help promote a growth mindset in the classroom that Carol Dweck did not necessarily touch upon or specifically mention in her research. These include statements and techniques such as:

"Please join me in google classroom"

"I think this is going to be really great, you all have the power to really radicalize the class"

"When you raise your hand, hold up fingers to show how many times you have spoken. Make sure you give everyone a chance to talk"

"I know grades have emotional value for some of you. I encourage you to not attach too much emotional identity to your number grades"

"I really enjoy teaching all of you"

"I am going to write down all of your ideas on the board"

Conveniently, in the class with the greatest number of these growth mindset statements, the class was told to reflect anonymously on the lesson. This gave me direct insight into how the students were feeling (in the most honest way possible) about the teacher and the classroom comfort level. I noted the responses below:

"I feel like the classroom environment is very supportive. Everyone is interested in helping each other"

"I love that everyone contributes"

"We all learn from each other, more than in any other class"

"I find myself always thinking about the conversations that happen in this room. This class is always on my mind"

"I like how [the teacher] treats every student individually but also equally"

Conclusion

Through this extensive research and a thorough observational study, my work showed that mindsets are not easily explained through a numerical scale. Since I had the chance to hear from students in one grade and teachers in three different classes, I discovered a lot about how effective these specific growth and fixed statements were. Overall, Berkeley Carroll is aware of Dweck's ideas for the growth and fixed mindset. With that said, English teachers are still making blatant fixed mindset statements. As a school of the future, Berkeley Carroll does not feel the need to box in any of its lesson plans. English teachers, specifically, experiment while teaching and have many different approaches to classroom learning. After observing one class the teacher said to me, "Learning is a lot of different things. There is a stereotype of what teaching truly is, while really it is a lot more than just sitting down and getting lectured."

In the future, I would like to further understand the qualitative nature of my study. After conducting a purely observational case study and identifying several bad teaching habits, I am ready to quantify my results. In addition, I am interested in finding a way to confirm the mindsets students think they have through a closer look at specific test scores or class participation. I am also wondering how these results would differ if I were observing the teachers in the Math or Science Department. How many people in the world are using these fixed mindset statements, unaware, and changing the internal motivation of the people around them? This is incredibly important for the upcoming generation, as we are moving into a more modern and informed approach to education.

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Mild Traumatic Brain Injury: The effects that sub-concussive blows have on the brain

by Thomas Shea

Abstract

The goal of this experiment was to answer the following question: does the amount of headers sustained from playing soccer affect cognitive function? At the end of this experiment, I was able to answer that question with conviction. The data from the experiment suggested that headers sustained from a season of high school soccer do not negatively affect one's cognitive function. The experiment was conducted with five male test subjects and five female subjects from the Berkeley Carroll boys and girls varsity soccer teams. The experiment took place over the fall season of 2015. Test participants were subjected to two cognitive tests: the baseline test and the King Devick test. The two different tests were intended to measure both the change in cognitive function over the course of the whole season, and the change in cognitive function before and after a given match. In addition to the ten experimental subjects, there were five control subjects in the experiment who were subjected to the King Devick test.

Introduction

A well-renowned professional athlete leads a life similar to that of superhero. Professional athletes are worshipped by people across the world and they often make millions of dollars a year. Outside of sports they can rarely lead a normal life. In the public, they are mobbed by beloved supporters. Most children look up to their favorite professional athletes. They admire the athlete's ability to perform and are amazed by the fame and fortune they accumulate. This admiration often leads to a child's desire to become a star professional athlete someday as well. Although only a handful of athletes ever reach this stature, children all over the world dedicate their lives to achieving this goal.

My scientific research focuses on brain injury in sports. I wondered if the brains of young athletes who aspire to achieve greatness in their sport would take a toll throughout many years of intensive training and gameplay. Specifically, I have focused on the sport of soccer and the affects that sub-concussive blows have on the brain. After years of watching professional soccer, it struck me that players who frequently head the ball could experience damage to their brains. The research I conducted on this topic suggests that retired soccer players who have played their whole lives often experience mild cognitive impairment and damage to the white matter of their brains[1]. More specifically, athletes are less able to recall information and suffer from decreased neurocognitive performance[1]. As a soccer player this research makes me won-

der if my own brain, and the brains of my teammates, are at risk of being injured as well. The research I conducted and my personal connection to the topic prompted me to conduct an experiment with the Berkeley Carroll boys and girls varsity soccer teams. I conducted the experiment in the fall season of 2015 and selected five males and five females from each team to participate. Each of the test participants took a baseline test at the beginning and end of the soccer season along with a King-Devick concussion test. These tests were intended to determine whether or not one's cognitive performance changes after a full season of soccer. I also tested a group of five non-athletes who served as control subjects. Each control subject took the King Devick Test twice throughout the season just as the experimental test subjects did. My goal in this experiment is to provide research that broadens my own understanding of the potential dangers of head impact in soccer and helps to educate the Berkeley Carroll Community as well.

Background

The body of scientific research on sub-concussive brain injury attempts to determine a relationship between repeated sub-concussive head impact and brain injury. Researchers are attempting to determine how many sub-concussive blows one must sustain in order to injure a brain. Research on this topic explores sub-concussive blows in sports such as football, hockey, boxing, and soccer. The articles I read explored the sub-concussive impact soccer players experience when heading the ball. Sub-concussive blows to the head can seem less damaging than a concussion at first glance. However, it turns out that consistent sub-concussive impact can cause chronic traumatic brain injury.

An article written by the Journal of the American Medical Association entitled, "Neuropsychological Impairment in Amateur Soccer Players" discusses an experiment which assessed the neurocognitive abilities of 33 soccer players (experimental group) and 27 non athletes (control group)[2]. Each subject was administered a neurocognitive examination and the results of experimental subjects were compared with the results of control subjects. The results of this experiment associated mild cognitive impairment with the sub-concussive blows experienced from heading a soccer ball[2]. This article claims that in extreme cases the effects of repeatedly heading a soccer ball can be similar to the effects of boxing. In extreme cases both a boxer and a soccer player can suffer from chronic traumatic brain injury[2]. This form of brain injury causes damage to axons, or nerves in the brain responsible for transmitting signals. Damage to axons causes irregular transmission of brain signals and ultimately impaired brain function.

A second article published by the same scientific journal discussed an experiment that investigated potential changes to the white matter of soccer players' brains[3]. Specifically, the test used diffusion tensor imaging, an advanced brain scan, to analyze specific parts of the brain that might be abnormal in soccer players. The experiment consisted of 40 German soccer players all of whom had played soccer competitively their whole lives, along with 20 control subjects who were swimmers. After analyzing the results of the brain scans, the researchers noticed differences in the white matter of the brains of soccer players compared to those of the swimmers[3]. Specifically, the soccer players' brains showed increased levels of radial and axial diffusivity, which signifies abnormal distribution of water throughout white matter pathways[3]. Both of the articles listed above provide pieces of concrete evidence which suggest that soccer players run the risk of experiencing some form of brain injury or cognitive impairment over the course of a career. There needs to be continued research on this topic for a concrete claim to be

made. I hope that my own experiment can provide another piece of evidence on this topic. The experiment I conducted addresses the topic in a unique way. The experiment uses a unique combination of the King Devick and Baseline Concussion tests to identify cognitive changes over the course of a soccer season. Using the baseline test, I will attempt to identify long-term differences in cognitive performance before and after a full season. Using the King Devick test, a brief assessment of one's ability to recite a series of numbers, I attempted to identify short-term differences in cognitive performance. I tested the male and female subjects over the same period of time, and was able to notice any differences in the ways that sub concussive blows affect the brain of a female and the brain of a male. The experiments I have read thus far have yet to make a significant claim as to the threshold at which one starts to experience brain deficiencies. In other words, the question is how many sub-concussive blows must one sustain over a certain period of time in order to injure their brain? In an attempt to answer this question, I recorded the number of headers incurred by experimental subjects per game in order to determine the threshold. Given my unique experimental, I hope to build upon the body of existing research.

Materials/Methods

I used the following set of materials to conduct my experiment:

1. Two neurological baseline tests for 5-10 soccer players from both the boys and girls soccer teams.
2. One King Devick Concussion Test Card.
3. A physical trainer to certify the use and administration of the tests.
4. ImPACT to interpret the results of the tests.

To clarify, a total of five male soccer players and five female soccer players took one baseline test at the beginning of their season and one at the end of their season. These ten soccer players made up the experimental group. On two separate occasions during the season, I administered the King-Devick test to each of my experimental subjects before and after a game. The intention of administering two different neurocognitive tests was to create a more accurate and reliable set of data, both short and long term, that will help explain the cognitive effects of heading a soccer ball. I also tested a control group, consisting of five students who did not play a fall sport. The control subjects followed the same procedure as the experimental subjects, taking both the King Devick Test and baseline test on two separate occasions.

Analysis

This experiment tested cognitive function in two different ways. The first way that this experiment tested cognitive function was through the baseline test. The baseline test measures long term changes in cognitive function. The baseline test quantifies the cognitive performance with a single value. The figure is known as the CEI Value, or Cognitive Efficiency Index. The CEI value compiles scores in the memory, motor speed, and reaction time sections of the test. The second cognitive test used in this experiment was the King Devick test which measures short term differences in cognitive function. The King Devick test measures cognitive function immediately before and after a match.

Baseline Test Data Tables

Table 1

Female Cognitive Efficiency Index (CEI) Comparison

Participant	First Score (CEI Value)	Second Score (CEI Value)	Score Difference
Female 1	0.46	0.45	-0.01
Female 2	0.40	0.38	-0.02
Female 3	0.18	0.18	0
Female 4	0.46	0.48	0.02
Female 5	0.35	0.44	0.09

Graph 1

Female CEI Comparison Graph

This figure provides a comparison between the baseline test score of the female participants before and after the season. The difference between scores per test subject is represented by the difference between the blue and red bar. The y-axis represents CEI scores.

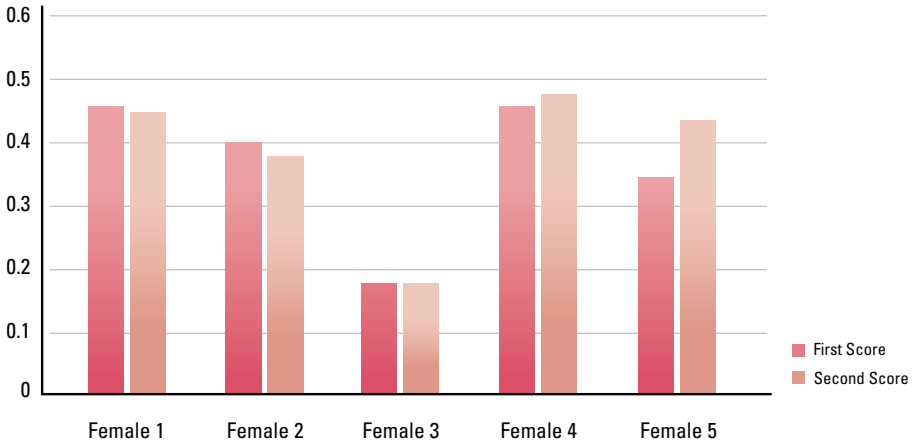


Table 2

Male Cognitive Efficiency Index (CEI) Comparison

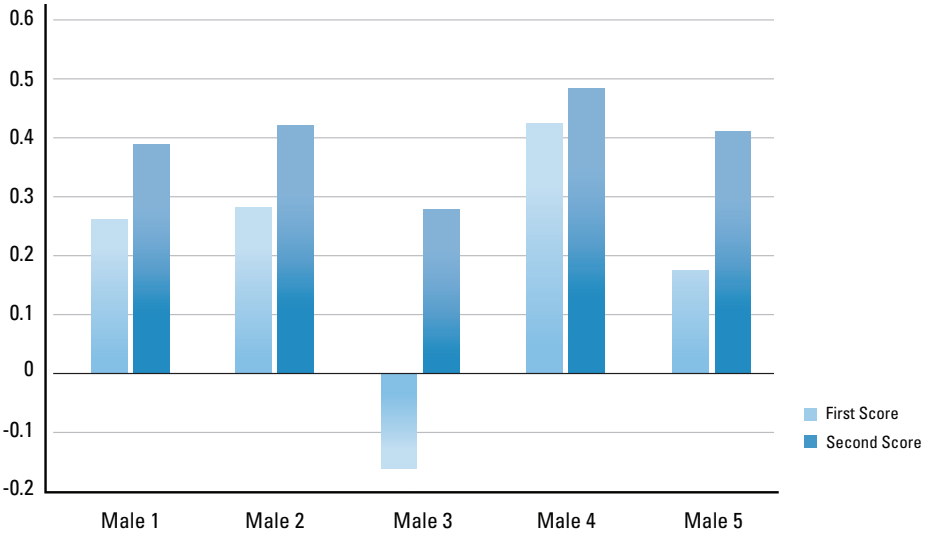
Participant	First Score (CEI Value)	Second Score (CEI Value)	Score Difference
Male 1	0.26	0.39	0.13
Male 2	0.28	0.42	0.14
Male 3	-0.16	0.28	0.44
Male 4	0.42	0.48	0.06
Male 5	0.17	0.41	0.24

The data I collected from the baseline tests indicated a very slight increase in cognitive performance from before the soccer season to the end of the soccer season. This increase was found from the averages of both the male subjects and female subjects score difference values between the first and second test. Specifically the average score difference value for the female subjects was 0.016. The average score difference value for the male subjects was 0.202. Graphs #1 and #2 provide a more specific visual breakdown of the score differences. The first graph represents the data from the female subjects' scores. In that chart, there are two instances in which the second score is marginally lower than the first score. But, there is also an instance in which the first and second scores are essentially equal, and another two instances in which the second scores are greater than the first score. Even though the positive

Graph 2

Male Cognitive Efficiency Index (CEI) Graph

This figure provides a comparison between the baseline test score of the male participants before and after the season. The difference between scores per test subject is represented by the difference between the blue and red bar. The y-axis represents CEI scores.



King Devick Test Data Tables and Graphs (Experimental Group)

Table 3

Female King Devick Test Comparison (Part 1)

Female 1st Test	First Time (sec)	Second Time (sec)	Headers in Match	Score Difference
Female 1	45.52	42.62	3	-2.9
Female 2	48.18	40.92	1	-7.26
Female 3	45.69	42.57	4	-3.12
Female 4	39.60	35.97	5	-3.63
Female 5	76.00	59.04	3	-16.96

score difference is not absolute, the average of all of the score differences represents an overall positive trend. Graph #2 represents the male participants' data. In this chart, all of the second scores are greater than the first scores. The difference between scores happens to be marginal, but this data suggests a more absolute trend of positive score difference. Overall, this data does not suggest a very decisive trend one way or the other. In both the male and female data the trend of positive score difference suggests that over the course of a season, one's cognitive performance is not negatively affected.

The second method of cognitive testing, The King Devick Test, was administered to three different groups of test subjects. The test was administered to the female soccer players (experimental group), the male soccer players (the experimental group), and the control test

Graph 3

Female First King Devick Score Difference Chart

This figure represents the difference in scores on the King Devick test before and after a match. This figure represents the female test participants' first round of King Devick testing. Score difference is compared to number of headers sustained in the given match in this figure. RSQ value: 0.0951652479.

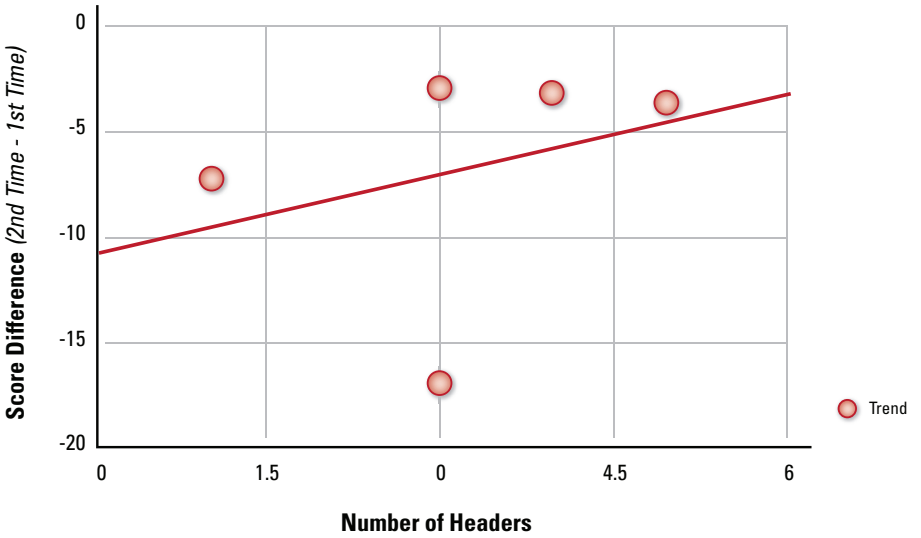


Table 4

Female King Devick Test Comparison (Part 2)

Female 2nd Test	First Time (sec)	Second Time (sec)	Headers in Match	Score Difference
Female 1	38.36	44.22	2	5.86
Female 2	44.70	40.02	0	-4.68
Female 3	37.18	35.82	5	-1.36
Female 4	31.57	32.23	3	0.66
Female 5	53.54	56.98	6	3.44

subjects. The cognitive test was administered on two occasions to each of those groups. The experimental female subjects took the test twice, the experimental male subjects took the test twice, and the control participants took the test twice. To begin with the females, the number of headers sustained during a given match was compared with the difference in King Devick test scores. The concept of the experiment would suggest a negative correlation between the number of headers sustained and performance on the King Devick Test. The logic follows that the more times you head a soccer ball during a game, the more slowly you will read through the King Devick test, producing a higher time after the game than before the game. In the case of the female test participants, the data suggests that there is no correlation at all. In fact, for the first round of testing there was a R-squared value of 0.095. And, for the second round of testing

Graph 4

Female Second King Devick Score Difference Chart

This figure represents the difference in scores on the King Devick test before and after a match. This figure represents the female test participants' second round of King Devick testing. Score difference is compared to number of headers sustained in the given match in this figure. RSQ Value: 0.1465822874.

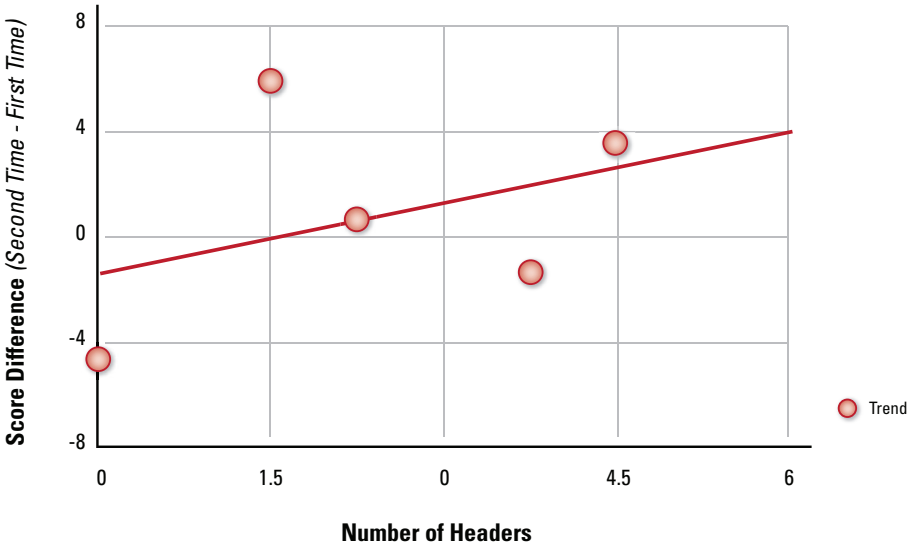


Table 5

Male King Devick Test Comparison (Part 1)

Male 1st Test	First Time (sec)	Second Time (sec)	Headers in Match	Score Difference
Male 1	43.49	31.40	10	-12.09
Male 2	45.17	36.73	10	-8.44
Male 3	40.93	35.62	3	-5.31
Male 4	36.04	31.34	6	-4.70
Male 5	35.18	34.22	5	-0.96

there was a similarly R-squared value of 0.147. To provide some context, a value 1.0 signifies a completely linear relationship and a value of 0.0 signifies no relationship at all. As a result, these two values are very close to the 'no relationship at all' side of the spectrum.

The King Devick test data from the experimental group of male soccer players is slightly more suggestive of a trend than the female data is. The experimental male subjects data shows a general negative correlation between the number of headers and the score difference. A negative score difference occurs when test subjects read through the numbers faster after the game than before the game and their second score is smaller than their first. Although this data does suggest trend, the trend that it suggests is illogical. The trend suggests that as the number of head impact increases, brain function improves. In more specific terms, as a player sustains more headers he

Graph 5

Male First King Devick Score Difference Chart

This figure represents the difference in scores on the King Devick test before and after a match. This figure represents the male test participants' first round of King Devick testing. Score difference is compared to number of headers sustained in the given match in this figure. RSQ Value: 0.5886451747.

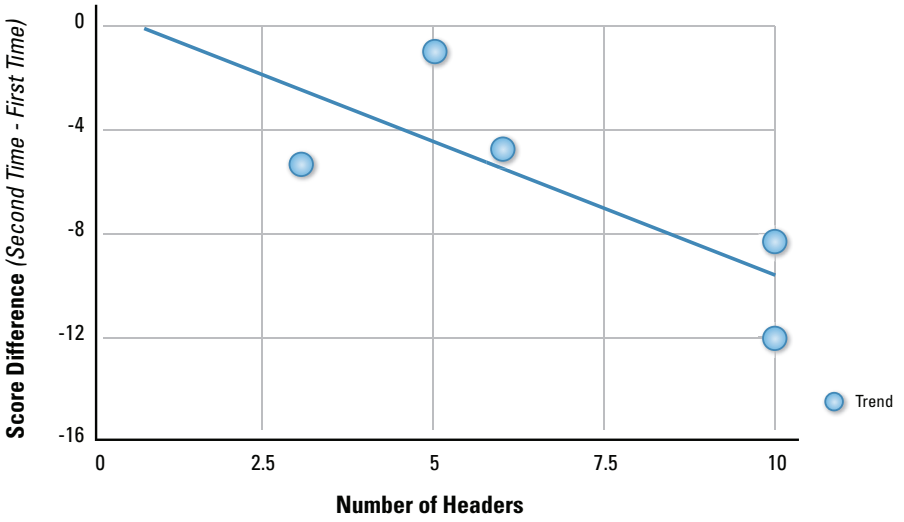


Table 6

Male King Devick Test Comparison (Part 2)

Male 2nd Test	First Time (sec)	Second Time (sec)	Headers in Match	Score Difference
Male 1	33.07	31.33	7	-1.74
Male 2	31.47	31.19	5	-0.28
Male 3	39.22	38.72	3	-0.5
Male 4	30.82	26.64	6	-4.18
Male 5	34.10	33.17	2	-0.93

improves his score on the King Devick test, or exhibits a decreasingly negative score difference. The first trial of the male subjects data exhibited an R-squared value of 0.588. The second trial exhibited an R-squared value of 0.277. These values are interesting, but they certainly do not suggest a decrease in cognitive performance as a result of heading a ball.

The last set of King Devick test data is that of the control participants. There were five control participants in this experiment, all male, and all seniors. These control subjects did not play a sport in the fall or the winter and did not sustain a concussion, or any type of significant head trauma during the period of experimentation. The control participants took the King Devick test on two separate occasions, but their data, unlike that of the experimental group, was not compared to number of headers, because that number would have been zero for all of them.

Graph 6

Males First King Devick Score Difference Chart

This figure represents the difference in scores on the King Devick test before and after a match. This figure represents the male test participants' second round of King Devick testing. Score difference is compared to number of headers sustained in the given match in this figure. RSQ: 0.2771865406.

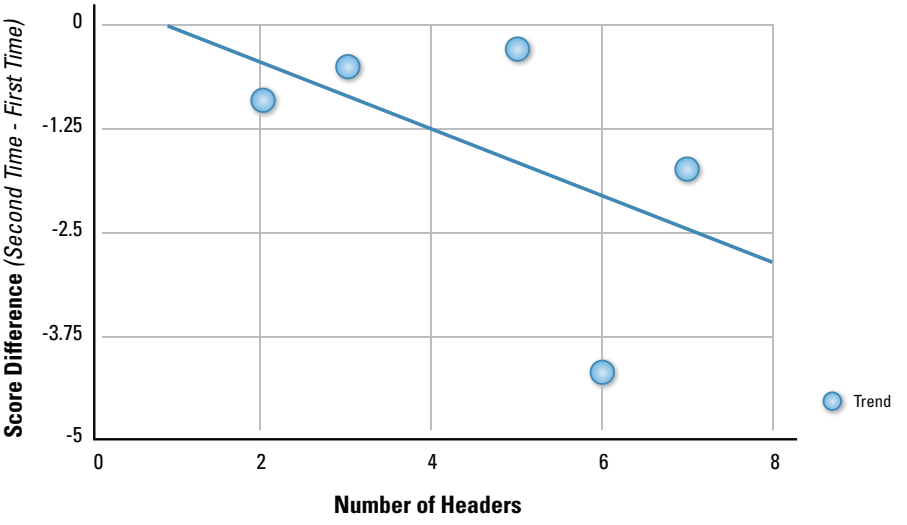


Table 7

King Devick Test Comparison Control Table (Part 1)

Males 1st Test	First Time (sec)	Second Time (sec)	Score Difference
Male 1	38.42	32.22	-6.2
Male 2	45.39	46.30	0.91
Male 3	35.72	22.84	-12.88
Male 4	24.72	28.48	3.76
Male 5	29.75	26.32	-3.43

Instead, in order to analyze this data the average of the score differences for each subject was measured to get a sense of the overall trend. This process of was the same as the one conducted with the baseline tests. The data in both the first and second set of King Devick tests suggests a negative score difference between the first and second trials. Specifically, the average score difference for the first trial was -3.568. The average score difference for the second trial was -0.574. To break down the average decrease value of the first trial, it is beneficial to reference Graph #7: a bar graph that compares the first and second scores for each of the five control subjects. Three of the subjects exhibited a negative score difference and two of the subjects exhibited a positive score difference. As to the second trial, reference Graph #8. This graph suggests that three of the subjects had a negative score difference and two had a posi-

King Devick Test Data Tables and Graphs (Control Group)

Graph 7

King Devick Test Comparison Control Table (Part 2)

This figure represents the difference in King Devick scores of the five male participants of the control group. The figure represents the control participants' first round of testing. Note: the control participants did not head soccer balls so that variable is eliminated in this chart.

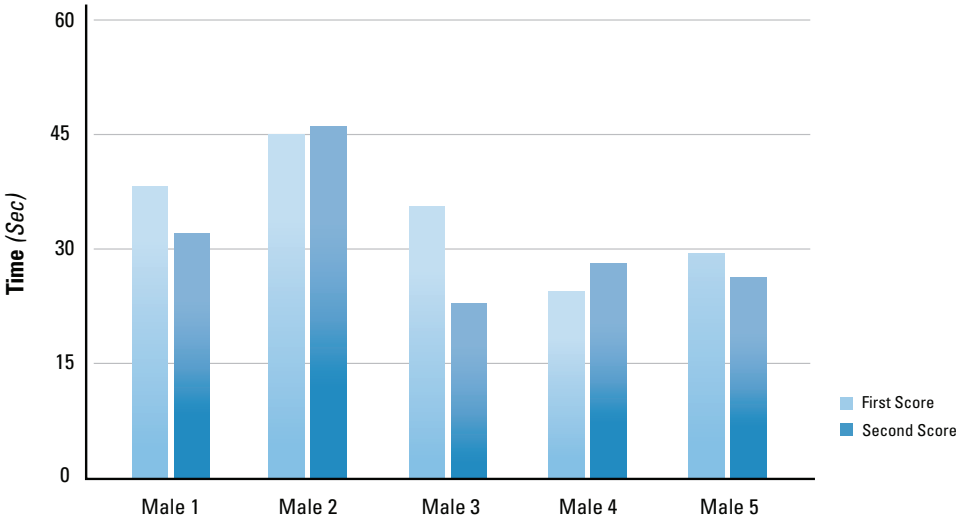


Table 8

King Devick Test Comparison Control Table (Part 2)

Males 2nd Test	First Time (sec)	Second Time (sec)	Headers in Match	Score Difference
Male 1	33.07	31.33	7	-1.74
Male 2	31.47	31.19	5	-0.28
Male 3	39.22	38.72	3	-0.5
Male 4	30.82	26.64	6	-4.18
Male 5	34.10	33.17	2	-0.93

tive score difference. Overall, the control data does not shed much light on the experimental data. This is because there was no consistent correlation established in the experimental data, making the control data rather insignificant.

In order to make an accurate overall statement about the King Devick Test data, an Analysis of Variance (ANOVA) test is necessary. Although there doesn't seem to be a significant result, one must verify those results with a p-value determined by the ANOVA test. The ANOVA test includes all three test groups: experimental males, experimental females, and controls. The test simply analyzes score difference for all three groups. The test produced a p-value of 0.185. This provides further evidence to support the lack of significant differencethe threshold for a significant difference is a p-value of 0.05.

Graph 8

King Devick Test Control Group Time Comparison (Part 2)

This figure represents the difference in King Devick scores of the five male participants of the control group. The figure represents the control participants' second round of testing. Note: the control participants did not head soccer balls so that variable is eliminated in this chart.

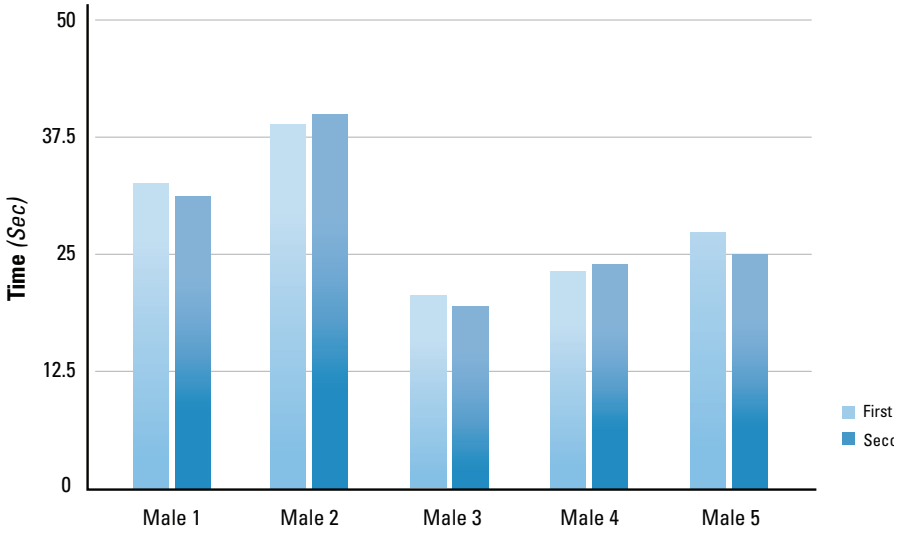


Table 8

King Devick Test Comparison Control Table (Part 2)

Males 2nd Test	First Time (sec)	Second Time (sec)	Score Difference
Male 1	32.77	31.67	-1.1
Male 2	39.00	40.16	1.16
Male 3	21.00	19.52	-1.48
Male 4	23.34	24.10	0.76
Male 5	27.62	25.41	-2.21

Conclusion

In this experiment, I set out to answer a very clear question: does the amount of headers sustained from playing soccer affect cognitive function? The data I collected does suggest a definitive answer to that question. Overall, the data did not exhibit any significant trend that would connect an increase in headers with a decrease in cognitive performance. More specifically, the baseline data suggested that over the course of a season, cognitive function remains essentially the same. Overall, the King Devick test data produced values of no significant difference and the ANOVA test produced a p-value which supported that notion. The experimental female subjects' King Devick data indicated a statistically insignificant trend, connecting an increase in headers to very slight increase in positive score difference. The experimental boys' King Devick data connected an increase in headers to an increasingly negative score difference, which would not suggest cognitive impairment. And, finally, the control data showed a negative score difference suggesting that test subjects were faster on the second than first test.

Since my data does not suggest a statistically significant trend consistent with cognitive impairment, I can conclude that playing a season of soccer does not damage cognitive performance. The baseline and King Devick test data suggest insignificantly small trends in one direction or the other, but from a statistical perspective cognitive performance stays essentially constant throughout the entirety of the season. As a result, my data suggests that heading a soccer ball does not inhibit one's cognitive function in a high school soccer season. The limited research that has been done on this topic demonstrates that heading a soccer ball will ultimately lead to decreased cognitive function in the long run. Despite my data, I still believe that it might be possible for heading a soccer to eventually negatively affect one's brain. In the future, I would like to revisit this experiment and test a larger group of subjects over a longer period of time. The length of a soccer season, although seemingly long relative to a school year, is small period of time relative to one's life. So, it would be interesting to conduct an experiment that tracked test subjects for five to ten years. As of right now I am pleased with the data I have collected and I can say that I have found evidence that heading a soccer ball for a season does not pose a threat to one's brain. That being said, there is much experimentation still to be done and much to be learned.

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Psychiatric Disorders and Marijuana Use: An Analysis of Anxiety, Depression, and Insomnia

by Max Wu

Introduction

What are the characteristics of drug addiction, and what are the factors behind it? My project to answer these questions involved working with two influential researchers in the field: Dr. Keith Humphreys, Senior Director for Mental Health Policy in Stanford University, and Senior Policy Advisor at the White House Office of National Drug Control Policy, and Dr. John Mariani, the director of Columbia University's Substance Treatment and Research Service (STARS) clinic.

First, during the summer of 2015, I met with Dr. Humphreys once a week to discuss his research on the ins and outs of alcohol addiction. We also discussed how alcohol and drug addiction is a multi-faceted global health issue that requires research into the epidemiology of the condition to help cure it. Differences in cultural norms are a factor in addiction. For example, opium and not alcohol is the culturally accepted drug in Iran. In some US communities, drinking a six-pack of beer every day is considered normal. These meetings with Dr. Humphreys assisted me in conducting my secondary analysis project with Dr. John Mariani. I analyzed a dataset that Dr. Mariani collected from his own experiment (a currently ongoing study on the use of quetiapine to treat cannabis dependence) to see if increased baseline cannabis use among cannabis-dependent patients correlated with an increased frequency of depression, anxiety, and insomnia.

This research is important because it potentially sheds insight on the factors that contribute to cannabis dependence. Elucidating the components that underlie the condition not only sheds light on concurrent conditions that contribute to cannabis dependence but also leads to more effective and efficient uses of critical resources. Researchers therefore can shift attention and resources from the symptoms to the cause, allowing for a faster path to treating conditions such as depression and anxiety, in addition to cannabis dependence in itself.

Abstract

The relationship between cannabis and psychiatric disorders has been shown to be a complicated two-way street; many theories have been proposed, but there is no clear answer. However, as cannabis usage continues to increase worldwide, it is critical to figure out this relationship

[1] Quetiapine is an antipsychotic drug used in the treatment of "schizophrenia, bipolar disorder and as an adjunctive treatment for major depressive disorder" (Mariani 280)

to fight complications such as dependency. To help figure out the link, I conducted a secondary analysis on existing data of cannabis dependent users. The secondary analysis focused on finding a correlation between their baseline cannabis use (measured in mean dollars per day) and their baseline depression, anxiety, and insomnia scores. With a regression analysis, I found each tests' Pearson r value (correlation) and corresponding p value (significance). My results found no correlation for depression and anxiety, with R and P-values of .037 and .059, and .737 and .589 respectively. However, I found that there was a small correlation with cannabis use and insomnia, finding a R value of .221 with a significant P-value of .042. From these results I concluded that there is a very small correlation between insomnia and cannabis use. In addition, there was no association between anxiety and depression symptoms and baseline cannabis use in this sample.

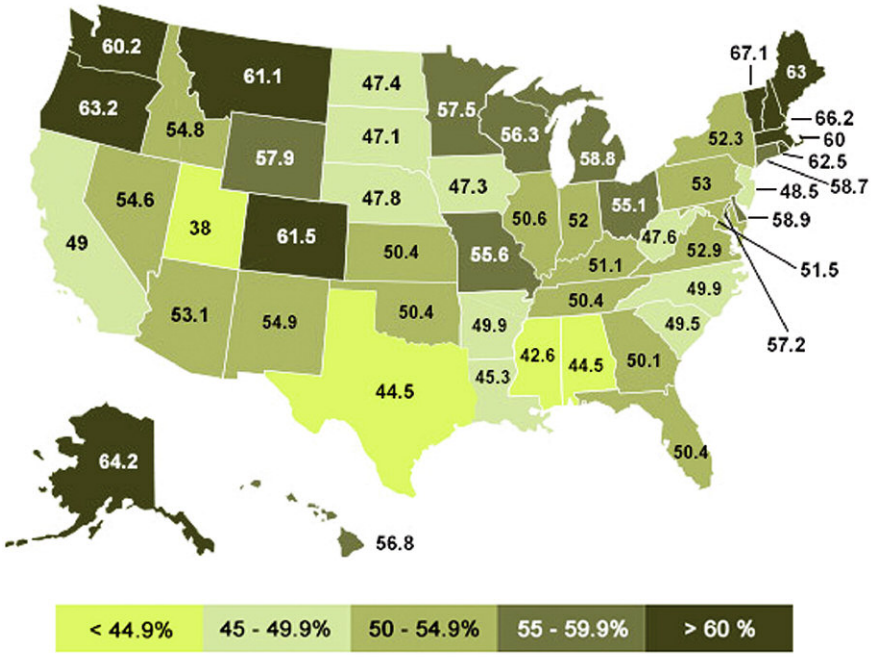
Background

Cannabis is the most widely used illicit drug around the globe. According to the World Health Organization, 2.5% of the world's population, or 147 million people, consume cannabis, compared to only 0.2% consuming cocaine or opiates. A significant portion of those users are in the US; the 2014 National Survey on Drug Use and Health reports that 22.2 million Americans aged 12 and older (8.4% of the US population aged 12 and older) have used cannabis at least once in the past 30 days. (Hedden). Cannabis use has been on the rise in the past decade and continues to grow. In 2007 only 14.5 million people in the US (or 5.8% of the population older than 12) consumed cannabis during that year (DrugFacts).

Figure 1

Marijuana by State (as of 2014)

Percentage of people 18-60 who have ever smoked pot



These numbers portray a concerning trend, as cannabis has been shown to be linked to many psychiatric disorders. The association has been shown as a two-way relationship. There is evidence of an increased proportion of people with mental disorders using cannabis. The National Comorbidity Survey has shown that 79% of individuals with a lifetime mental disorder had an additional co-morbid disorder, often related to drug abuse (Lev-Ran, 2013a). In the same study, the researchers discovered that increasing cannabis use correlated with the number of psychiatric disorders the patient was diagnosed with (Lev-Ran, 2013a). Researchers have not found the reason for this trend. One theory is the self-medication hypothesis, which posits individuals use cannabis to alleviate their symptoms. Other studies have shown that cannabis use can also lead to the development of problems. A meta-analysis of longitudinal studies that analyzed the link in cannabis use and depression found that cannabis use, in particular heavy use, possibly led to the development of depression (Lev-Ran, 2013b).

While this two-way street has been shown for depression, what about other disorders? In two studies on social anxiety, anxiety has been found to be both a risk factor for use, yet also cannabis use has been linked to anxiety (Buckner). Insomnia has also been found to be related to cannabis use. In a study of 98 adults, daily cannabis use was found to increase sleep disturbances (Conroy). However, interestingly enough, in another study which examined the relationship between various cannabis strains and sleep-management, many adults actually reported using cannabis to help manage insomnia and nightmares (Belendiuk).

In the light of evidence demonstrating positive relationships between various mental disorders and cannabis use, it is important to understand the connection and correlation between the two. I conducted a secondary analysis of an existing data set of individuals with cannabis use disorder to test if the subjects' baseline cannabis use was related in any way to their HAM-D (for depression), HAM-D Anxiety (for Anxiety) and Medical Outcomes of Sleep scores and subscores. I hypothesized that higher mean daily amount of cannabis use would be associated with higher depression, anxiety, and insomnia scores.

Study Design

The study was conducted at the Substance Treatment and Research Service (STARS) of Columbia University. A secondary analysis of baseline data for a cannabis use disorder pharmacotherapy clinical trial was conducted. All of the data was collected prior to participants receiving intervention.

Subjects

The Institutional Review Board of the New York State Psychiatric Institute approved this research protocol and all participants provided informed consent prior to study enrollment. Participation was confidential and voluntary. Participants were recruited from a combination of paid advertising and clinical referrals. Participants were 92 men and non-pregnant women (73 male; 25% white; 35.8% black; 28.3% Hispanic; 3.2% Asian, 6.5% mixed) with a mean age of 32.05 (ranging from 18-60) who meet DSM-IV criteria for current cannabis use disorder. Participants reported using cannabis on average more than 4 days per week over the past 28 days and were seeking treatment. Participants did not have any other current Axis I psychiatric disorders as defined by DSM-IV-TR. Participants prescribed psychotropic medication were excluded.

Measures

At the baseline screening, a complete medical history was obtained, and both a physical exam, and a psychiatric evaluation were performed. A Mini International Neuropsychiatric Interview (MINI Version 6) for DSM-IV (Sheehan DV & Lecrubier, 2009) was conducted to determine current and lifetime DSM-IV (MINI) Axis I diagnoses. The Hamilton Depression Scale (XXX) and The Medical Outcomes Study—Sleep Scale (MOS-SS) (Hays, et al., 2005) were administered at the baseline prior to study medication administration. Cannabis use was recorded by the Timeline Followback (TLFB) method (Litten & Allen, 1992) modified for Cannabis and confirmed by creatinine-normalized quantitative urine THC levels.

Data Analyses

Pearson's correlation coefficient was calculated to examine the relationship between cannabis use and HAMD, HAMD Anxiety subscore, and MOS-SS score. An alpha value of .05 was set as the level of significance for all two-tailed analyses. Sample Dataset pictured below.

Table 1

Participants' Raw Data

Sample of dataset used in my analysis; first ten participants out of 84-85 analyzed (depending on test conducted).

Participant ID	Baseline Cannabis Use (Mean Dollars Per Day)	Total HAMD Score	Total HAMD Anxiety Subscore	Total MOS-SS (Sleep Disturbance Score)
QUEST_001_GSK	11.48148148	13	4	16.25
QUEST_002_JPD	15.85714286	3	1	15
QUEST_003_JMV	64.44444444	0	0	52.5
QUEST_004_LCG	39.21428571	8	3	62.5
QUEST_005_CEM	6.115384615	4	2	32.5
QUEST_006_MTV	13	3	0	63.75
QUEST_007_AWN	23.21428571	6	1	67.5
QUEST_008_MAM	13.7037037	0	0	11.25
QUEST_009_EXD	50	0	0	30
QUEST_010_AJS	14.88888889	9	3	41.25

Results

Because the data was normally distributed, a regression test analysis was conducted to obtain Pearson's correlation coefficient (or r-value), which was used to find any direct or inverse relationship between baseline cannabis use (measured in dollars per day) and HAMD Score (Depression), HAMD Anxiety Subscale (Anxiety) and MOS-SS Sleep Disturbance Score (Insomnia). Separate tests were conducted for each variable, with 84 subjects (n=84) tested in the HAMD and HAMD Anxiety Subscale tests, and 85 (n=85) for the MOS-SS Sleep Disturbance Score.

Table 2

Regression Test Results

Depression values were based on HAMD scores, Anxiety on HAMD Anxiety Subscores, and Insomnia on MOS-SS Sleep Disturbance Scores. Mean MJ Use value changes depending on number (n) of subjects tested.

Variable Tested	Mean Baseline Cannabis Use (Dollars Per Day (With Range)	Mean Score For Rating Scale (With Range)	Number of Cases Included in Analysis (n)	Pearson's R Value (-1 - 1)	Significance or R Value (P-Value) (0-1)
Depression	27.74 (0-233.94)	4.63 (0-14)	84	.037	.737
Anxiety	27.74 (0-233.94)	1.63 (0-6)	84	.059	.589
Insomnia	27.51 (0-233.94)	32.57 (0-95)	85	.221	.042

Looking at Table 2, the results show no significant direct or inverse relationship between baseline cannabis use with depression or anxiety (r-values were 0.037 and 0.059, respectively). However, for insomnia, while there was weak correlation (with a r value of .221), we can see that its P-value was .042, showing that the results were significant. We can conclude therefore that a subject's mean baseline cannabis use has a small correlation with their insomnia.

Discussion

The goal of this study was to determine if there was any association between a subject's baseline cannabis use and their depression, anxiety, and insomnia. Elucidating the complex relationship between cannabis use and various psychiatric disorders can lead to solutions to this global health problem. I hypothesized that there would be a direct relationship between the variables; that higher mean daily amounts of cannabis use would correlate with higher depression, anxiety, and insomnia scores. The results from my secondary analysis actually showed no correlation between cannabis use and depression and anxiety, and only a small correlation with cannabis use and insomnia.

Explanations for this difference in results may arise from lacking the necessary amount of data (n was 85 for this analysis) but also may more importantly mean that my hypothesis was incorrect. The results from the study indicate that a person's baseline depression and anxiety have no relationship with their mean daily cannabis use. This is important because it suggests that other factors possibly play more major roles. While insomnia may play a small part (due to

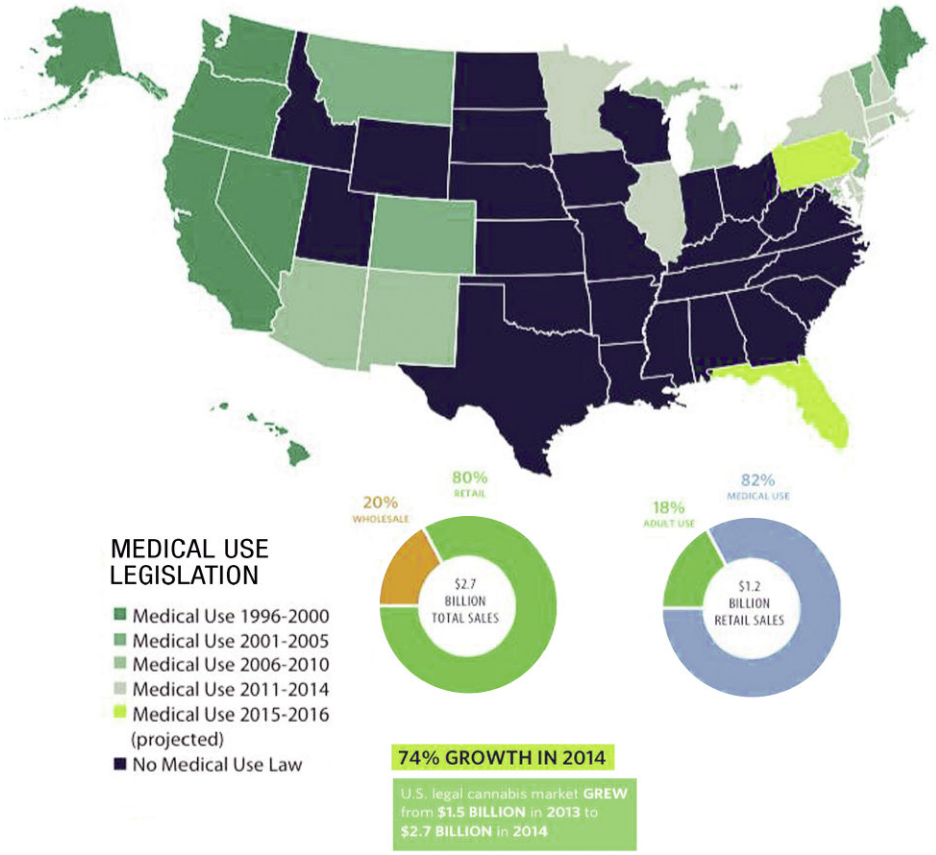
its relatively weak relationship), perhaps other psychiatric disorders (such as schizophrenia or bipolar disorder, for example) are the culprit — or maybe something else entirely.

Some limitations in this study include the fact that my study used a dataset that was not designed to answer my specific questions. This can be seen in the anxiety test for example. Instead of using the test that is specifically designed to measure a person's anxiety, each subject's baseline value was calculated from the HAMD Anxiety Subscale. This may alter the results, as the test was actually designed to measure each subject's depression. Furthermore, the study uses a convenience sample in that participants voluntarily signed up for the study. The general population of cannabis-dependent users may not be accurately represented. As an example, 73 out of 92 participants were male, which means women were not sufficiently represented in the sample. Finally, trends are better shown in a larger data sample. Some of the participants in the original study were not included in the analysis due to incomplete data. Having more participants would allow for a more normal distribution, which would give more validity to a test of r-value. In other words, having more participants would increase the chances of significant results; resulting in clearer conclusions.

Table 2

Medical Use Legislation

Consistent Growth in Medical Marijuana Legislation and Industry in the US (as of 2015)



In the future, I would like to conduct a more expansive analysis on depression and anxiety in particular. I would use a compilation of studies' baseline values to help normalize the data and to gain a clear conclusion that can apply to more of the population. In the case of anxiety, I could also look for studies or conduct my own using a specific anxiety test. The data I analyzed was a subscore of the HAMD, a test for depression. I could also test other mental disorders, such as schizophrenia or bipolar disorder, to see if they may affect cannabis use. Finally, by testing how of these disorders affect each other as well as cannabis use, I could help to unravel how these variables together play into the issue. In light of the modern legalization movement, as well as the increase of cannabis use and dependence in recent years, it is important to focus efforts on possible causes of the issue.

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Wim Hof: Testing the Method

by Gil Ferguson

Abstract

The Wim Hof breathing technique claims to use yogic breathing to allow a subject's blood to become more saturated with oxygen and therefore continue to keep the body's organs working while in extreme temperatures. Curious to find out if this technique was effective, I tested the Wim Hof method on a smaller scale. Subjects were asked to run sprints while their oxidation levels were recorded before and after the physical activity. The Wim Hof technique was done with seven test subjects and their oxidative levels were recorded using a pulse oximeter. The results showed that the Wim Hof method had no consistent effect on the oxygen saturation of subjects' blood cells. From this limited experiment I cannot conclude that the Wim Hof method allows subjects to actively increase the oxygen saturation of their blood cells any faster than without it.

Introduction

The Wim Hof method is very similar to Tummo Meditation and Yogic breathing, which are forms of breathing used to attain mind-body connection[1]. Wim Hof studied yoga and meditation in order to create his own technique[2]. By subjecting himself to the bitter conditions of nature, he learned to withstand the extreme forces of cold and heat. The core of the method are breathing exercises which can be likened to controlled respiration. The Wim Hof Method consists of rapid breathing that claims to invigorate the blood stream and fill the blood cells with oxygen[3]. One of Hof's claimed outcomes of this practice is the complete oxygenation of your blood and cells[3]. The method claims to make the oxygenation of a subject's blood cells much more efficient.

Hof uses the internet to share his message and his method[4]. He has set up his own website dedicated to attracting people who are interested in developing the needed skills to perform the method. Over the past 5 years, Hof has become increasingly popular and has used that popularity to publicize his method. The VICE documentary follows Hof through his daily practices of yoga and meditation, while allowing him to advertise his self-named brand.

There is no doubt in my mind that Wim Hof deserves all of the recognition he has received. He has climbed Mt. Everest in shoes and shorts and has set several world records including sitting in an ice bath without allowing his core body temperature to drop below normal[4]. These feats are incredible and should be celebrated. He has also run a marathon in a desert without drinking a drop of water. After accomplishing all of these seemingly impossible feats, Hof claims any person can learn to overcome the obstacles that he has by learning the Wim Hof Method.

The method uses repetitive cold immersion, mental training, and forms of yogic breathing. Hof claims that by training only a few weeks with these techniques one will be able to withstand any climate[4]. He also makes the bold claim that by mastering the Wim Hof Method, a subject can make his or her immune system more resilient and therefore able withstand such extreme conditions[4].

Hof lives in Amsterdam and practices his methods of training year round. Hof says the start and the basis of his training is breathing[5]. One must start with simple deep breaths, building lung capacity. The key is to breathe more air in than you breathe out[6]. After performing these deep breaths you should test your improved lung capacity by taking a deep breath and holding it in for as long as you are able to. Hof claims that after performing these repetitive deep breaths you should be able to hold your breath in much longer and your blood will be oxidized more efficiently[3].

The second section of the method is cold immersion. Subjects must slowly and gradually introduce themselves to colder water for longer periods. You can start with cold showers, graduating to ice baths, and then to the ocean in the winter months. Hof's claim is that using the breathing technique outlined previously, you will not feel cold. You are supposed to feel a tingling throughout your body and your natural inclination to get out of the water will fade and you will be at peace, thus not allowing your body's core temperature to drop[3].

The final piece to the Wim Hof Method is meditation and mental training. This piece of the training is the hardest to master and the most difficult to follow. Hof practices meditation on a regular basis and says that meditation needs to become a regular activity in a person who wishes to control their body completely[3]. After studying the method at great length I decided I wanted to test it for myself, as I was skeptical of its effectiveness. Being a high school student with teenage subjects, I did not have the resources to perform a large scale and in-depth experiment with the Wim Hof Method. I decided to test a small but pivotal piece of the method: breathing. Hof places great emphasis on breathing. His breathing technique is aimed to oxygenate a subject's blood more efficiently in order to maintain function in major organs and recover faster.

Materials and Methods/Berkeley Carroll Study

Since the Wim Hof method is designed for extreme conditions, the most difficult part was testing it in a low risk environment with a small sample size. I used fourteen subjects ranging from ages 14-18 from the Science Research and Design program at the Berkeley Carroll School. The subjects were placed in either the experimental or the control group at random. Students suffering from asthma or heart conditions were ruled out for health and safety considerations. In order to increase the subjects' heart rates and allow them to perform the Wim Hof breathing technique, they were asked to participate in physical activity and their body mass index (BMI) and blood oxidation levels were recorded before and after the shuttle runs. The blood oxidation levels were recorded using a pulse oximeter, while BMI was recorded using height and weight polled from the subjects.

The control group consisted of seven teens. Their heights, weights, and BMI's were recorded. Then their pulse and blood oxidation levels were recorded. Each subject ran shuttle sprints as follows: four lines were placed 10 feet away from each other. Each subject ran as fast as they could from line one to the next and back until all lines were complete. After the

completion of the sprints the subjects had thirty seconds to recover normally. At the conclusion of the thirty seconds I recorded their blood oxidation level again.

The test subjects underwent the same testing conditions as the control group. For the recovery portion of the exercise, subjects were instructed on how to use the breathing exercise. The technique used was staccato breaths followed by a deep breath in and shallow breath out. This was repeated for thirty seconds by each of the test subjects. After the recovery and breathing their blood oxygen levels were recorded.

Results

Table 1

Control Group Results

As can be seen by the table, subject 5 was the only participant to have an increase in blood oxygen level over 5%. However, over 20% is considered to be a significant change in blood oxygen levels. I consider subject 5 to be an outlier in this context due to results of the thirteen other subjects.

Subject	BMI	Percent Change Oxygenation
1	17	4
2	19	3
3	13	2
4	20	0
5	14	22
6	27	0
7	22	5

Table 2

Experimental Group Results

In this group none of the subjects experienced an increase in oxygen levels above 5 percent. There is no significant difference in the results of the control group and experimental group.

Subject	BMI	Percent Change Oxygenation
8	26	2
9	23	0
10	18	1
11	28	3
12	19	1
13	18	1
14	12	1

Conclusion

We can see from Table 2 that the results of this experiment were not significant. Only one subject of the fourteen experienced an increase in blood oxygen level over 5%. Subject five, who experienced a 22% increase will be considered an outlier.

The thirteen subjects that were considered for my result show convincingly that the Wim Hof yogic breathing did not result in a difference in the increase of blood oxygen levels.

The results from this experiment do not completely discredit the claims of Wim Hof. The experiment conducted here was done on a very small scale and the technique was taught by an amateur (me). Subjects had no previous training. Some possible sources of error and inaccuracy in the experiment are as follows: subjects were instructed to run as quickly as they could but I had no control of how much energy they exerted. Wim Hof uses his method on people in freezing water while I tested subjects who had run for a matter of seconds. This experiment is just a snapshot of Hof's method. I still believe there may be some science behind Hof's technique and I think this information could be useful and important. I would like to continue studying Wim Hof and his methods and I hope one day to be able to perform an experiment on a larger scale with more extreme conditions.

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From Mind To Machine: Building a Brain-Computer Interface

by Angela Goldshteyn

Background

Defining Brain-Computer Interfaces and Why They Matter

People all over the world use movement to perform actions, such as making coffee or running, as well as to communicate with others, whether it be raising their eyebrows or gesturing with their hands. However, not everyone is able to retain their motor functions due to paralysis, which prevents people from moving a part of or their whole bodies. For instance, paraplegia is when voluntary motor function is lost only in the lower body and Locked-In-Syndrome is when all four limbs lose motor function (Anderson 317).

The top causes of paralysis are spinal cord injuries, Multiple Sclerosis, and strokes. Spinal cord injuries tend to harm interneurons, which connect sensory input, such as a prick on a foot, to its corresponding motor output, such as the contraction of muscles to move the foot away from the sharp object. Multiple Sclerosis is a disorder in which the immune system damages healthy nerve cells in the central nervous system, causing sensory and motor neurons to deteriorate, at times prohibiting movement. This disorder affects about 2.3 million people across the globe ("Multiple Sclerosis FAQ"). Strokes may damage the parts of the brain that process inputs or determine a motor response, such as the cerebral cortex or cerebellum, inducing paralysis. According to the Christopher and Dana Reeve Foundation, in the U.S. alone, 5.5 million people live with paralysis, which means that 1 in 50 people can't do everyday tasks, such as pick objects up or even walk. It is therefore extremely important to help these people, who are locked inside their own bodies, to find a way out.

Brain-Computer Interfaces (BCIs) have the potential to restore motor functions in paralyzed patients, thus improving their quality of life. By using a computer to connect neural activity to an artificial device, like a prosthetic limb and computer cursor, BCIs allow patients to control limbs not attached to their bodies. They help people perform this function through three main steps.

The first consists of recording and analyzing brain signals by using electrodes. The most reliable and cost effective BCIs use the least invasive method to record neural activity, in which the intent of movement is present. There are two ways of recording neural activity, each with their own benefits: invasively through electrocorticography (ECoG) and noninvasively through an electroencephalogram (EEG). When using an ECoG, electrode arrays are placed in various parts of the brain and record field potentials of individual and small groups of neurons. When using an EEG, electrodes are placed on top of the scalp and record field potentials of large groups neurons. Recordings from EEGs are more general and contain information on the intent of

movement as well as voluntary and involuntary movements, such as eye motions and breathing, making it difficult to isolate the desired data. Despite this fact, EEGs are the most popular choice for recording neural activity because they are not invasive (Kipke 81).

After brain signals are recorded, data from electrodes are transported to a computer. Because this data is in the form of lists of numbers, researchers organize this data by graphing it and then use filtration, a machine learning technique, to extract specific brain frequencies that communicate the intent of moving a limb. Once the relevant brain signals are obtained, researchers classify these signals by using a computer program to connect these brain signals to corresponding movements in a prosthetic limb (Principe 123-129).

Once this program is finished, real time control of the prosthetic is enabled. In the matter of seconds, electrodes record a test subject's neural activity, the program filters and classifies the data, and sends a command to the prosthetic, instructing it to move in a specific direction.

Though BCIs have the power to restore motor function in the paralyzed population, they are limited by their variability and high price. When testing BCIs, performance varies from person to person and trial to trial, making these devices unpredictable. This variability is illustrated in a study conducted by Hochberg in 2006, where participants were split up into two groups, who either used a joystick or a BCI to move a cursor to a specific target on a computer screen (Wolpaw). The results showed that people who used joysticks reached the target faster and with minimal spread (1±0.8 seconds) compared to those who used BCIs (2.2±2 seconds). Because of this variability, BCIs have to be tailored to each individual, making them expensive. The cost of getting a BCI can range anywhere from $5,000 and $30,000, deterring people from buying them. It is therefore crucial that research be done to reduce the variability of BCIs to decrease their cost (McGimsey 10).

Experimental Design

Proposed Experiment

My original experiment consisted of building a BCI that could be controlled by more than one user to see if I could figure out how to reduce variability. In theory, the BCI would function by using a computer program to connect an individual's neural activity to a Hexbug, a small spider-like robot. I would ask one test subject to think about moving forward, backward, left, and right and record his/her brain activity for about 15 seconds per movement by using electrodes. Then I would use the neural patterns, presented as a list of numbers, to write a program that would translate them into instructions for the Hexbug, directing it to move in a specific, corresponding manner. For instance, if I programed the Hexbug to move forward when it identifies the neural pattern for moving forward, then tell my subject to think about moving forward, the Hexbug should move forward.

After creating this program, I would test it on 5 other test subjects, making any necessary edits so that the program would accurately classify different brain signals, relate them to their corresponding Hexbug movements, and allow more than one person to use the BCI.

Actual Experiment

I asked the first test subject to think about moving forward, backward, left, and right and recorded his/her brain activity for about 15 seconds per movement by using electrodes. Since I

did not have the tools to filter the recorded data, instead of fully building a program designed to translate these brain signals into instructions for the Hexbug, I organized the raw data and outlined a visual model of what this program would look like.

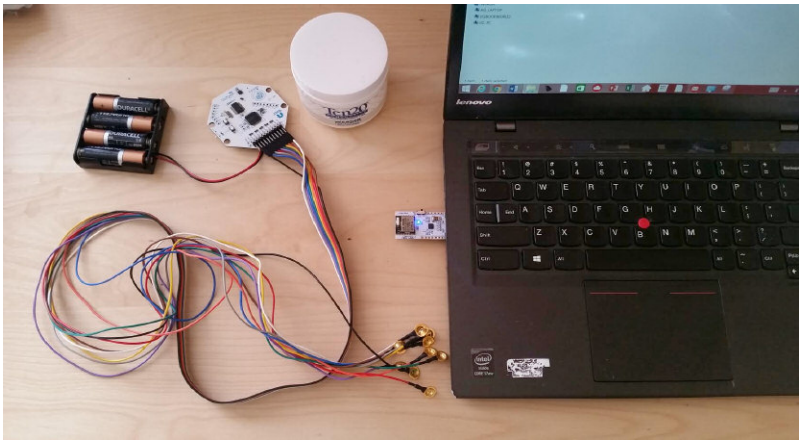
Methods

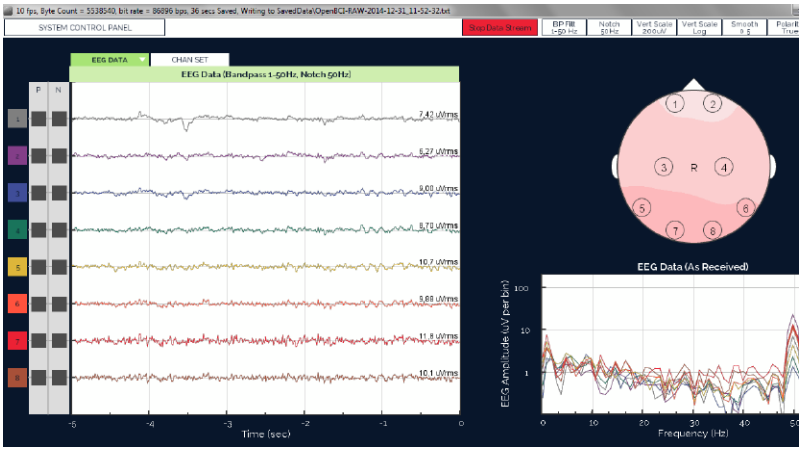
Software and Hardware Setup

The hardware in this experiment included EEG electrodes, an OpenBCI board, an OpenBCI USB dongle, and a computer. Before recording neural activity, 10 electrodes were plugged into the OpenBCI board, which was connected to the computer through the USB dongle. On the computer, an OpenBCI GUI processing tool received recordings from the electrodes. During recordings, individual voltages each electrode received were seen on the left, the placement of electrodes and intensity of brain activity was seen on the upper right, and a Fast Fourier Transform Plot (FFT) was located on the bottom right of the screen (Figure 1).

Figure 1

The top is a picture of the hardware setup. The bottom is a screenshot of the OpenBCI GUI processing tool receiving recordings during a test run.



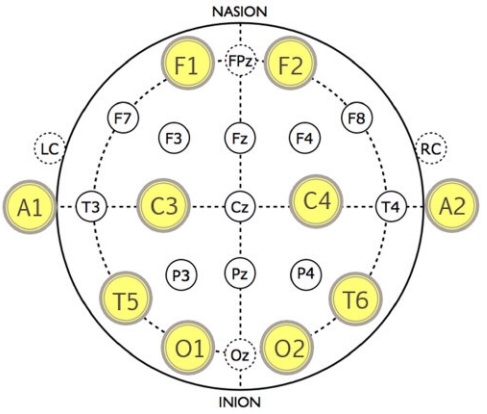


Recording Brain Activity

To record neural activity from various regions of the brain, the 10-20 system was used to place electrodes on the test subject's scalp over Frontal (F1, F2), Central (C3, C4), Temporal (T5, T6), and Occipital (O1, O2) regions of the brain with reference electrodes placed on the earlobes (A1, A2). After the electrodes were attached to the participant, he/she was told to close his/her eyes. After 10 seconds, the participant was told to think to about moving forward and not to stop unless instructed. For about 15 seconds, the participant's brain activity was recorded and he/she was instructed to open his/her eyes. After a five minute break, these steps were repeated while the participant was instructed to think about moving backward, left, and right.

Figure 2

The 10-20 system indicates where electrodes should be placed on the scalp in order to record specific regions of the brain. Yellow circles display where electrodes were placed on the participant in this experiment.



Results

Raw Data

Recordings of brain activity were displayed as raw data, long lists of numbers (Figure 3). Since neural activity was recorded four times while the test subject thought about moving forward, backward, left, and right, there were four sets of raw data. The first column shows the sample rate, which communicates the number of data points for each electrode during one second of recording. In this study, the sample rate was 250 Hz, meaning that for each second of recording, there were 250 data points for all eight electrodes. The next eight columns communicate the voltages that each electrode received while neural activity was being recorded. The last three columns contain accelerometer data, acceleration across x, y, and z axes.

Making Raw EEG Data Meaningful

To understand and analyze this data, an FFT plot was made for each data set, showing the frequency of signals recorded by all eight electrodes (Figure 4). Signals recorded from C3 and O1 regions were isolated. These regions were chosen because they are critical for limb motion. The primary somatosensory cortex (C3) processes sensory information and is aware of limb

Figure 3

The beginning portion of raw data recorded while the test subject thought about moving forward.

```
%OpenBCI EEG Data
%
%Sample Rate = 250.0 Hz
%First Column = SampleIndex
%Other Columns = EEG data in microvolts followed by Accel Data (in G) interleaved with Aux Data
```

0,	33551.04,	46317.15,	-187500.02,	-187500.02,	-44629.30,	-187500.02,	-187500.02,	-70811.60,	0.05,	-0.41, 0.92
1,	33558.26,	46323.99,	-187500.02,	-187500.02,	-44642.15,	-187500.02,	-187500.02,	-70824.41,	0.05,	-0.41, 0.92
2,	33547.08	46319.14,	-187500.02,	-187500.02,	-44628.05,	-187500.02,	-187500.02,	-70813.43,	0.00,	-0.51, 0.88
3,	33540.42,	46327.77,	-187500.02,	-187500.02,	-44605.74,	-187500.02,	-187500.02,	-70834.24,	0.00,	-0.51, 0.88
4,	33567.09,	46325.53,	-187500.02,	-187500.02,	-44623.22,	-187500.02,	-187500.02,	-70808.52,	0.00,	-0.51, 0.88
5,	33563.80,	46311.72,	-187500.02,	-187500.02,	-44646.25,	-187500.02,	-187500.02,	-70898.61,	0.00,	-0.51, 0.88
6,	33547.38,	46309.04,	-187500.02,	-187500.02,	-44648.97,	-187500.02,	-187500.02,	-70811.51,	0.00,	-0.51, 0.87
7,	33541.56,	46315.63,	-187500.02,	-187500.02,	-44663.79,	-187500.02,	-187500.02,	-70802.61,	0.00,	-0.51, 0.87
8,	33535.48	46306.55,	-187500.02,	-187500.02,	-44701.18,	-187500.02,	-187500.02,	-70845.08,	0.00,	-0.51, 0.87
9,	33538.88,	46305.84,	-187500.02,	-187500.02,	-44708.67,	-187500.02,	-187500.02,	-70838.78,	0.00,	-0.51, 0.87
10,	33542.68,	46306.62,	-187500.02,	-187500.02,	-44696.09,	-187500.02,	-187500.02,	-70813.21,	0.00,	-0.51, 0.87
11,	33536.64,	46300.59,	-187500.02,	-187500.02,	-44680.89,	-187500.02,	-187500.02,	-70787.88,	0.00,	-0.52, 0.88
12,	33531.97,	46297.68,	-187500.02,	-187500.02,	-44685.63,	-187500.02,	-187500.02,	-70820.36,	0.00,	-0.52, 0.88
13,	33530.88,	46294.48,	-187500.02,	-187500.02,	-44678.10,	-187500.02,	-187500.02,	-70781.24,	0.00,	-0.52, 0.88
14,	33536.91,	46301.86,	-187500.02,	-187500.02,	-44679.59,	-187500.02,	-187500.02,	-70745.13,	0.00,	-0.52, 0.88
15,	33552.43,	46309.89,	-187500.02,	-187500.02,	-44667.10,	-187500.02,	-187500.02,	-70781.20,	0.00,	-0.52, 0.88
16,	33572.83,	46321.64,	-187500.02,	-187500.02,	-44687.37,	-187500.02,	-187500.02,	-70773.58,	0.01,	-0.52, 0.88
17,	33539.48,	46304.63,	-187500.02,	-187500.02,	-44698.26,	-187500.02,	-187500.02,	-70843.90,	0.01,	-0.52, 0.88
18,	33524.51,	46300.70,	-187500.02,	-187500.02,	-44670.32,	-187500.02,	-187500.02,	-70764.30,	0.01,	-0.52, 0.88
19,	33557.48,	46338.20,	-187500.02,	-187500.02,	-44665.24,	-187500.02,	-187500.02,	-70717.38,	0.01,	-0.52, 0.88

location and the occipital region (O1) contains information regarding orientation of limbs and spatial frequency. During limb motion, C3 sends an output signal, contracting muscles and physically moving a limb, while O1 makes sure that this movement is accurate and purposeful.

After isolation, these two signals had to be filtered. Information concerning the intent of limb motion while the test subject thought about moving in a specific direction had to be extracted. This step presented itself as a challenge because I did not have the skills to identify where the relevant information was in these signals nor how to extract that information. Although this step prevented the program from being made and connecting the subject's thoughts to the movement of a Hexbug, a visual model of this program was created.

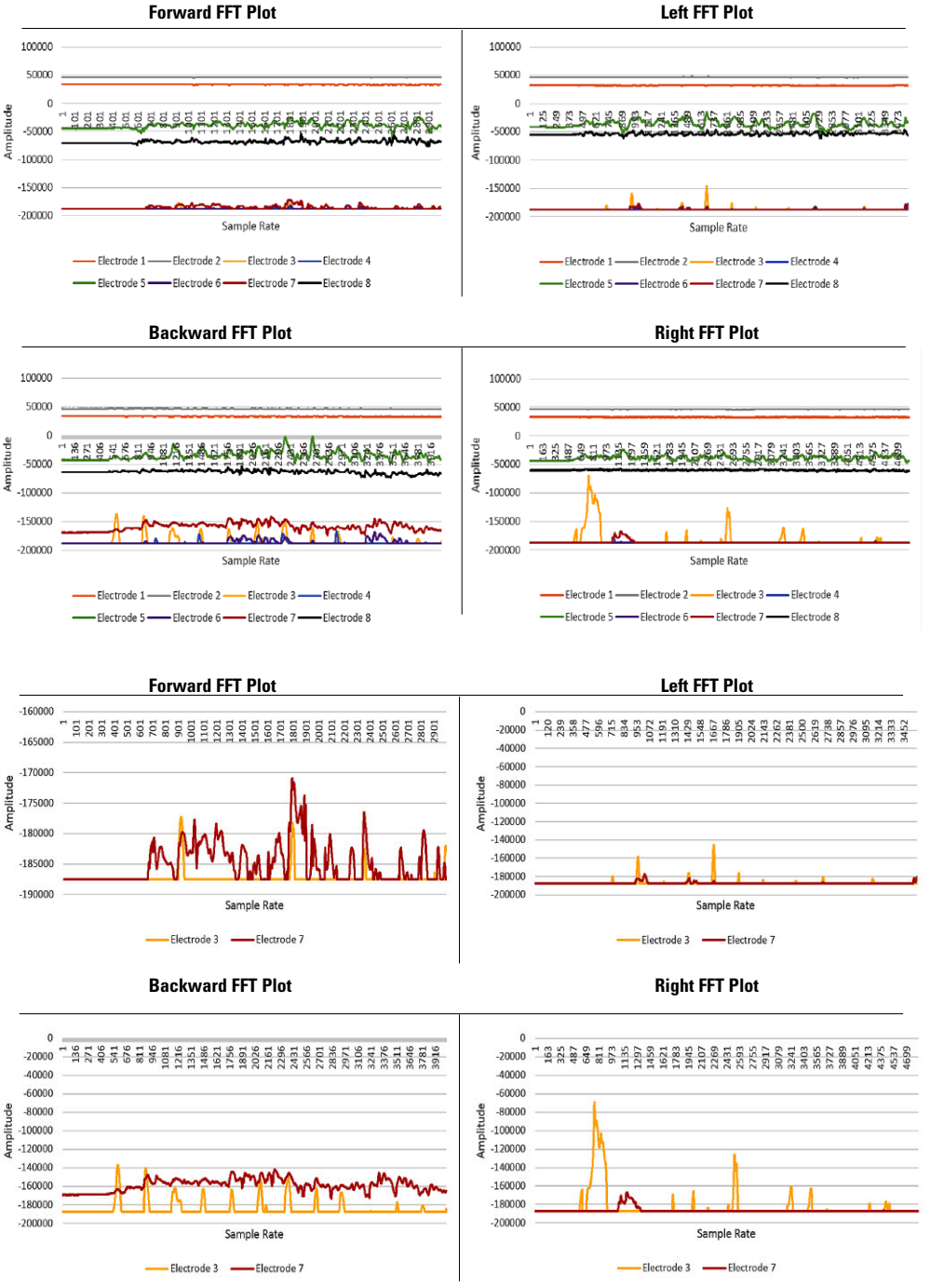
Potential Model of Program

The computer program would have four main parts: receiving the signal, classifying the signal, matching it to a correlating output, and sending that output to the remote control of the Hexbug, instructing it to move in a specific direction.

The most complicated part of this program is classification, the process of receiving new signals and determining whether a user is thinking about moving forward, backward, left, or right. In order to classify incoming data, a K-nearest Neighbor Classifier would be used. This

Figure 4

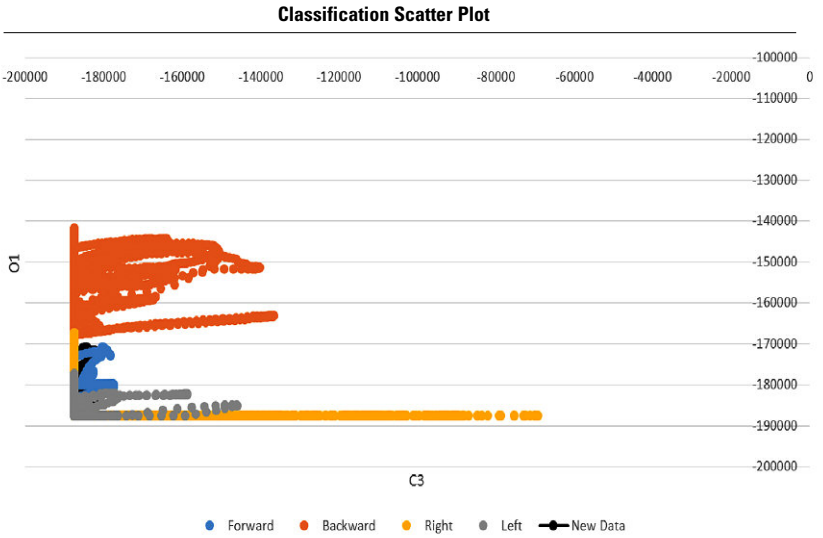
On the left there are four FFT plots that display the signals each electrode recorded when the test subject thought about moving forward, backward, left, and right. On the right there are four FFT plots that show unfiltered data from C3 (electrode 3) and O1 (electrode 7) regions.



method requires labels, which are the characteristics of data, and an assigned K-value, which is the number of original data points closest to incoming data that must be consulted before classifying this new data. The labels would be the filtered voltages from C3 and O1 recordings and the K-value would be around 2,000, a high value so that the program could accurately classify incoming data (Figure 5).

Figure 5

This is a visual representation of the K-nearest Neighbor Classifier. The scatter plot shows data from C3 and O1 regions as well as new data (black). Since it seems like this new data is mostly surrounded by original data points created while the first test subject thought about moving forward, the K-nearest Neighbor Classifier would classify the incoming data as such.



So if, for instance, a participant was instructed to think about moving forward, recordings from electrodes would be sent to the computer. Then the program would use the K-nearest Neighbor Classifier to locate around 2,000 original data points closest to the incoming data to identify that the participant is thinking about moving forward. Through an if-then statement, it would match the incoming data to the "move forward" command and send it to the Hexbug remote, causing it to move forward.

Discussion/Conclusion

Though the original experiment was not completed, this study has provided crucial information regarding data processing and illustrated why there is variability in BCIs. It seems that variability stems either from the quality of EEG recordings or classification methods. If recordings are not filtered properly, meaning that they include the intent to move a limb as well as information regarding other functions, this data will not act as an accurate indicator for that movement. Similarly, if classification techniques do not account for ranges of data indicating the same motion, incoming data may be grouped in the wrong category, making it difficult for a person to

use the BCI. It follows, then, that to reduce variability researchers must develop tools to accurately filter data and make sure that their classification techniques have a low miscalculation rate.

The next steps of this study are to figure out how to filter the existing data, use the K-nearest Neighbor Classifier to categorize incoming data, and ultimately to connect a person's thoughts to the movement of the Hexbug. After the program is built, it will be tested in three phases. First, it will be tested on existing data to make sure the classifier works accurately. It will then be tested on the first test subject to make sure the entire program works successfully. Finally, it will be tested on different users to see if it can classify their brain signals. Edits to the program will be made along the way and hopefully more ways of decreasing variability will be discovered.

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About Science Research and Design (SRD)

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Third Year: Science Research and Design Symposium – Students finalize their individual research; write a journal article reflecting their results; and mentor and help facilitate the research of younger SRD students. They publish their paper in the *Proceedings of the Berkeley Carroll Independent Research Conference,* a peer-reviewed journal, and present their results at the Berkeley Carroll Science Research Conference held in the spring.

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"We look with favor on all forms of learning, but with particular grace we encourage philosophical studies, especially those which by actual experiments attempt either to shape out a new philosophy or to perfect the old."

KING CHARLES

from the 1661
Charter for the formation
of the Royal Academy of Science;
the proceedings of which
are the oldest journal in existence