

Proceedings of the Berkeley Carroll



INDEPENDENT RESEARCH CONFERENCE

# SCIENCE RESEARCH PARTICIPANTS

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Jane Moore Director of Upper School **Robert Vitalo** *Head of School* 

# Welcome from the Editor

uestions are a part of the human experience. It's in our nature to ask them. Most of the time, we try to get the answer quickly – we ask someone or something. You can look up an answer in a textbook or just ask a voice in a phone.

The great thing about science is that it provides a way to answer questions. That's the whole point. As long as you can measure how one variable affects another, you can answer anything.

In that sense, you can think of scientists as people who are both curious and patient – good at thinking up questions, but also willing to take the time to answer them.

In this 6th Independent Research Journal, you'll see some really good questions. We've got a lot of curious and patient students at Berkeley Carroll, and the student-scientists represented here have followed some interesting paths in asking and answering their experimental questions.

Some authors based their questions on personal experience.

Grace Morales, for example, who concentrates better when she fidgets, asks if fidgeting actually improves test scores. Albert Rubin, who gets injured every year playing soccer, asks if there's a correlation between playing time and injury for student-athletes. Rachel Goluboff, who believes journaling makes her feel better, asks if prompted journaling can improve mood.

Other authors based their questions on observations about their school and community.

Alessandro Getzel, who walks by happy Middle School students in the halls every day, asks if there is a correlation between happiness and age and, if there is, if it has anything to do with grades. Lauren Tinglin, always a keen observer of human behavior, asks if self-segregation increases with age at Berkeley Carroll.

Still other authors based their questions on scientific literature they hadn't seen before joining the Science Research and Design program.

Ananda Sahihi read about health changes in circumpolar people, so she asks if diet affects mood. Joey Ball, inspired by peer-reviewed literature on the dream-lag effect, asks if you can trigger dreams by listening to music before you sleep. Joseph Arias asks if watching happy films can help you remember positive words and Dayna Weissman asks if viewing beautiful art reduces heart rate.

Some questions in this journal really pushed the envelope about what's possible for a high school student. Kellen Penner Coxon, for example, wanted to find out if she could alter the color of a fluores-cent protein in bacteria. Emily Gordon wanted to know if it would be literally possible to grow a brain.

I don't quite have the space here to share all the questions posed in this journal, but I can assure you they're amazing.

I know what you're thinking. If the question is amazing, then the answer must be spectacular. The thing is, in science at least, that's not necessarily the case. The process of deciding on your question, figuring out how you'll set up an experiment to answer it and sifting through the results to formulate your answer is far more important – and lasting – than the answer itself.

It's like Trinity tells Neo when they first meet in the 1999 film "The Matrix." "It's the question that drives us. It's the question that brought you here."

And now, you get to ask the questions alongside our young scientists. Happy reading!

Until next year, Scott Rubin Upper School Science Chair

# Science Research and Design SENIOR RESEARCHERS



#### Olivia Abramchik-Cavallo '17

In her first year of SRD, Olivia focused on eating disorders, toxic stress, anxiety and pain. In her second year, she began to research the topic of anxiety

more in depth and realized it was something she was very interested in because it affected her daily. She knew competing in the pool or on the field caused her a lot of anxiety and she wanted to figure out if it was positively or negatively impacting her performance. Thus, her experimental question, "Is athletic performance better in high-stress competitions than low-stress competitions?" surfaced. Olivia designed an experiment to test the Boys and Girls Varsity Basketball teams and the Girls Varsity Volleyball team for performance under stress. She discusses the results in her article.



#### Joseph Arias '17

During his first year in SRD, Joseph studied animal cognition, specifically the effect of various drugs on cognitive performance. This included how S-

adenosylmethionine, an important natural compound used for the treatment of depression, affects cognitive performance in mice. During his second year, he decided to investigate similar research in human cognition and read numerous papers that broadened his interest in mood disorders and cognitive performance. Joseph's article discusses the role and effect different genres of movies play in acting as arousing tools on the human working memory.



#### Luis Arias '17

For the first two years in SRD, Luis' interests in physics, technology and alternative energy sources led him to focus on two topics: brain-computer

interfaces (defined as communication devices between the brain and a computer or machine to be controlled or manipulated) and solar tracking panels as an alternative energy source. After narrowing his focus down to solar panels, he contemplated conducting an experiment that would explore the possibility and benefits of installing solar tracking panels as an energy source for Berkeley Carroll. However, soon after, he discovered that the school already had the intention of installing a full solar PV (photovoltaic) system on top of the 181 Lincoln Place gym. Ever since, he has been working with the school and its architects to achieve this goal. In his article, Luis discusses the technical feasibility and economic viability of solar PV Berkeley Carroll.



#### Joanna Ball '17

In her first two years in SRD, Joey researched the brain, sleep and dreams, incorporating music into her experiments. By the end of her second

year, she conducted a pilot study which involved listening to music while sleeping and measuring the positive, negative or neutral emotions of dreams. For her final experiment, she tested whether listening to music directly before going to bed has an effect on dream frequency and music-related dream frequency in musicians and non-musicians. For the first phase she asked her subjects not to listen to any music an hour before going to bed for five consecutive days. Then, she asked them to listen to music for half an hour before going to bed for the next five consecutive days. Overall, Joey concluded that listening to music did not affect dream frequency or music-related dream frequency in musicians or non-musicians.



# Jacob Boehm '17

Jacob's article focuses on a multifaceted effort to combat HIV – reducing transmission through education and analyzing the traject-

ory of HIV recovery to unearth biomarkers. Throughout the Science Research and Design program, Jacob has explored HIV in various lights, including its basic mechanisms, effective methods of antiretroviral therapy and ways to reduce transmission. His in-house experiment was a surveybased study that assessed how knowledge about HIV varies among BC students based on age and whether they have taken a health course. Over the past two summers. Jacob had the opportunity to work at the Beth Israel Clinical Trials Unit and spent his time there studying HIV biomarkers. In the summer of 2016, he participated in the Yale Young Global Scholars program, where he designed a prototype HIV vaccine. In the future, Jacob hopes to research social means of reducing the transmission of HIV.



#### Liam Cryan '17

Liam has been in the SRD program since his sophomore year. During that time, his focus has changed from ebola to developing an algo-

rithm for predicting the UEFA Champions League winner each year. He uses a linear mathematical multiple regression model in order to make these predictions. Liam has found that his experiment is effective at predicting certain parts of the tournament, but weak at predicting others.



#### Nathaniel Dunn '17

Throughout his time in Science Research and Design, Nathaniel has researched a variety of topics, including autoimmune diseases, food

allergies, the adolescent brain and, most recently, judgment and gratification. He designed and conducted an experiment on how instant and delayed gratification differs by age. The experiment aimed to test participants from age 6 to age 18 and was designed to see if delayed gratification is expressed more often as people get older. Unfortunately, there were no significant results from the experiment because of several logistical problems that made it impossible to conduct the experiment in its entirety.



# Alessandro Getzel '17

Alessandro spent sophomore year examining Alzheimer's disease and dementia. The following year, he pivoted from neurodegenerative dis-

eases to sociology with a specific focus on stress and anxiety. In his experiment, Alessandro examines how age, school division, academic achievement and academic satisfaction affect happiness in middle and high school students. Initially, he conducted a pilot study with 20 students in several grades – this study failed to yield significant results. Then, he expanded the field to include more than 100 students in grades five through 11. Overall, Alessandro's study had some significant results. Middle schoolers seem to be happier than high schoolers and students who are satisfied with their grades seem to be happier than those who are dissatisfied.



# Rachel Goluboff '17

Throughout her three years in the Science Research and Design program, Rachel has studied adolescent depression and mood and the strate-

gies with which teenagers deal with their problems. For her experiment, which was conducted in the spring of her junior year, she examined the impact that journaling (freewriting as opposed to prompted writing) can have on increasing one's positive mood and decreasing one's negative mood. The experiment was conducted over a four-week period with 15 participants journaling at least twice a week in either a prompted group or freewriting group, as well as a control group which didn't journal at all. Rachel's experiment did not yield significant results, but she hopes she gave her participants a good way to cope with their moods!



#### Emily Gordon '17

Emily has spent the past two years studying cerebellar hypoplasia, after adopting a cat with the condition and deciding that she wanted to find

a cure. She proposed studying the efficacy of cerebellar transplantation, for which she was invited to the Tufts University Biomedical Engineering Lab to grow cerebellar neurons in a 3D, functional brain model. In her article, she presents the results of the neuron growth as well as its implications in using cerebellar transplantation to restore motor deficits in the future.



# Alice Lechtchinskaya '17

For her first year in the Science Research and Design program, Alice researched sedentary time and its association with risk for disease inci-

dence, mortality and hospitalization in adults. She shadowed an ICU doctor in a local Brooklyn hospital for several months during her junior year and then presented her observations and experiences at the hospital. During her final year of the SRD program, she conducted an in-house study to see if there is a correlation between how frequently a student washes their hands and how often they are sick in the Berkeley Carroll Upper School. While Alice found no direct correlation between washing hands frequently and getting sick less, she now has data on students' hand-washing habits and whether they need to be altered in order to avoid the spread of sickness.



#### Xabi McAuley '17

During his time in the Science Research and Design program, Xabi explored a variety of topics, ranging from genetically-modified mosquitoes

to filoviruses. Eventually he decided to research astronomy after reading an interesting article about life on other planets. Xabi was interested in the ways in which astronomers discover faraway planets, also known as exoplanets. For his SRD project, he simulated the transit discovery method in order to better understand its intricacies.



#### Grace Morales '17

Grace originally started researching blood type and diet during her sophomore year of Science Research and Design. While she was intrigued by

this field of study, there was not enough research or ways to adapt an experiment from this topic. During her junior year she started researching the topic of fidgeting. Grace's article focuses on the role fidgeting plays in comprehension and concentration in professional institutions throughout the world.



#### Kellen Penner Coxon '17

For the first two years of SRD, Kellen researched different molecular biology research tools and genetic engineering techniques. Then she began to focus on

fluorescent proteins and developed a project to change the color of fluorescence through a genetic mutation, replicating the techniques she'd been studying. Her article presents the results of this experiment and discusses the current literature on fluorescent proteins.



#### Arian Pentza '17

Arian began his journey in the SRD program studying epilepsy. Going into his junior year, he switched over to studying superconductivity and maglev tech-

nology. Arian's article presents his independent research on magnetic levitation and whether it can be affected by the size of the levitating magnet. He used magnets of different sizes and built tops to test different levitation heights. The results of his research showed that changing the radius of the magnet on the top did not affect the height it was able to levitate.



# Luis Peromarta '17

Luis began his work in the Science Research and Design program by studying research on quantum computing and the development of a more

efficient way to analyze the spin of the qubits in a computer. Due to a lack of ways to move forward in this field as a high school student, he decided to shift gears and investigate material science and alternative power production. During his junior year, he researched piezoelectric ceramics and their application as small-power generators. Specifically, Luis focused on finding ways to harness vibrations in 181 Lincoln Place to produce power and to see if small, self-powered wireless sensors could be installed in the building. His article presents his data and the research he has collected over the past two years.



#### Dmitry Pokushalov '17

Dmitry initially expressed interest in medical sciences as well as the mechanisms of memory in the human body in his first two years of the SRD pro-

gram. He decided to combine both of his interests in his research project, where he investigated the effectiveness of current methods of teaching first aid. For his project, Dmitry designed and performed an experiment which assessed students' abilities to retain first aid information over long periods of time. His article presents the results of this experiment and potential areas for improvement in the first aid education system.



# Darrell Pona '17

In his first year of Science Research and Design, Darrell studied neuroscience and human psychology, which led him to investigate hypnosis and

drug addiction's effect on the brain. In the following year, he expanded his drug addiction research to include the effects of marijuana. He also further researched microbiology and bioengineering, which led him to conduct an experiment about the effectiveness of hand sanitizers. In his article, Darrell explores the possibility that certain colors are more effective in information retention, which is a good liaison between his interests in neuroscience and biomedical engineering, the latter of which he plans to study in college.



# Sneha Punukollu '17

As a sophomore and junior, Sneha's research focused on psychiatry and brain function/structure. This included doing research and presenting on

mood disorders, substance abuse and brain imaging. For her final project, Sneha participated in a sixweek internship at New York University's biochemical lab with Professor Tamar Schlick. There, she began her journey studying and analyzing the physical structure of pre-existing ribonucleic acid in attempt to improve future structure prediction. In her article, Sneha elaborates on her experiences and findings from her time at NYU.



# Dean Ross '17

Dean began his time in the Science Research and Design program exploring genetic engineering and modification. After realizing the complexity of

this topic, he began focusing on the science of sports. His extensive research in this area led him to explore athletes' ability to perform under pressure. In his article, Dean discusses how both athletes and non-athletes are able to deal with, and perform in, high-stress situations.



#### Leah Ross '17

In her first year of SRD, Leah researched how gender, anxiety and sports interact with each other. As a junior, she decided to focus on age,

gender and physical activity and was struck by the apparent lack of female students in the school gym. After looking into the positive effects of physical activity and strength training, Leah wanted to see if Berkeley Carroll female students participated in physical activity less than their male peers. She undertook a pilot study which ultimately proved too difficult to conduct due to a small sample size, but inspired her to shift topics for her senior project. Drawing from personal experiences with basketball, she wondered if players of color in the NBA received more fouls than white players. Her article discusses whether there is a significant difference between a player's fouls per minute and race.



# Toluwani Roberts '17

Toluwani has been studying stem cells since she first started the SRD program in 10th grade. Her interest in the topic took root after she read an arti-

cle about their potential to repair spinal cord injuries, which currently have no cure. After reading many papers on stem cell therapy, Tolu noticed a common denominator – embryonic stem cells – and began to study their pluripotency and use on injuries. Her final research project focuses on the different methods of guiding the differentiation of embryonic stem cells, and other types of stem cells, in subjects. Tolu plans to continue to read papers and follow scientific news to see what new methods scientists have discovered and developed.



# Albert Rubin '17

Albert has been researching sports injuries over the past two years in order to answer his experimental question: "How does an increase in

playing time affect the probability of sustaining an injury in soccer?" As a junior, he conducted a preliminary study on the Barclays Premier League in which he analyzed the injury statistics of professional soccer players and was able to make several conclusions. This inspired him to conduct his own study at Berkeley Carroll, so in 2016 he used the same methodology to analyze subjects on the Boys and Girls Varsity Soccer teams. Although his results weren't significant, Albert believes if the study were redone with a larger sample size it could show a correlation between injury and playing time.



# Ananda Sahihi '17

During her sophomore and junior years, Ananda developed an interest in psychological and nutritional science. These two topics linked together when

she discovered some of the latest work in nutritional psychiatry, which studies the relationship between diet quality and mental health. At the end of her junior year, she conducted a study which followed a group of high school students as they transitioned to a vegetarian diet. Her observations from that study led her to expand the sample of subjects in a new study this year. She collected dietary information and self-reported mood test scores from two New York high schools to observe the correlation between mood and food.



# Miles Schappell-Spillman '17

Miles' main field of focus is environmental science. His article presents his research on renewable energy production and alternative energy

sources. Over the past two years, Miles has been fascinated with improving clean energy production methods (specifically using semipermeable membranes). This year, his experiment was focused on pressure retarded osmosis and reverse osmosis. The goal of the experiment was to test if energy can be produced using the gravitational potential energy of water as the driving pressure source as well as having the pressure-retarded osmosis membrane replaced with a reverse osmosis membrane. There were no statistical results because the pressure from just the water was not enough for desalination to occur across the reverse osmosis membrane.



# Lauren Tinglin '17

In the beginning of Lauren's sophomore year, she showed great interest in neurology and found herself intrigued by scientific articles that

explored the intricacies of the brain. Her newfound fascination for neurology, accompanied with her preexisting interest in adolescents, brought her to study the topic she presented at the 2016 SRD symposium – how child abuse affects the physical, emotional and cognitive development of a child's brain. Lauren found it difficult to conduct a study on child abuse, but still wanted to study adolescents, so she honed in on another of her passions – diversity – which brought her to the experimental question for her SRD project: "Do the students in the seventh, ninth and 11th grades at The Berkeley Carroll School racially self-segregate, and does the degree to which students self-segregate vary as a function of grade?" The study tested the stereotype that as children get older and mature they become more aware of their race and the role it plays in their school, neighborhood and world.



#### Dayna Weissman '17

During her first two years in SRD, Dayna focused on researching theoretical physics and neuroscience, with a particular interest in the discovery of

the Higgs boson particle. During her junior year, she zeroed in on neuroscience, performing an experiment in which she hypothesized that meditation can lower heart rate. She decided to continue testing the effects of different stimuli on heart rate for her senior year project, as this allowed her to study neuroscience despite lack of access to brain-scanning equipment. In this final experiment, Dayna combined her love of art and science to study the effects of viewing aesthetically beautiful art on heart rate.

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# The Effects of Anxiety on Athletic Performance

by Olivia Abramchik-Cavallo

# Abstract

s athletic performance better in high stress competitions than low stress competitions? To answer that question, free throw statistics in low stress competitions and the fourth quarter of higher stress competitions were collected from four years of the Boys Varsity Basketball Team, and two years of the Girls Varsity Basketball Team at Berkeley Carroll. Serve accuracy was also measured for one year of senior students on the Girls Varsity Volleyball Team in two sections, deciding sets and nondeciding sets. In volleyball a deciding set would be the set that wins the game and a non-deciding set would not be the last set played of the game. For example, if a team wins the first two sets, loses the third, and wins the fourth, the fourth set would be the deciding set and the first two would be the nondeciding sets. No consistent significant difference was measured in either free throw or serve percentage as a result of stress.

# Introduction

When athletes compete they enter an intense environment. It has been shown scientifically that in stressful situations people's adrenaline levels rise and that playing competitive sports can cause anxiety or other psychopathologies (mental disorders such as anxiety and depression). For example, a French study involved testing athletes who were on the "High Level" or "Junior" athlete lists to see the difference in psychological issues between men and women (Schaal et al., 2011). These athletes had to meet specific performance criteria and played nationally and internationally. The study looked at anxiety disorders (panic attacks, agoraphobia, obsessive-compulsive disorder, generalized anxiety disorder [GAD, duration of at least 6 months] and social phobia and depression present over a two week period). It also explores a correlation in sex-specific vulnerabilities to particular disorders and the occurrence of psychopathology according to the type of sport played. To collect data, scientists collected and analyzed yearly psychological evaluations that athletes filled out.

It was found that in most sports, psychological issues were more prevalent in women than men, and that anxiety was very present in both genders. In total, 17% of all high level athletes have ongoing and recent disorders. The most common disorders were anxiety and eating disorders; 6% of people had an anxiety disorder and 4.2% had an eating disorder. At least one psychopathology was found present in 20.2% of females and 15.1% of males. The results show that in aesthetic sports (like gymnastics), there was a 9.9% increase in anxiety disorders for men and a 28.6% increase for women. It was also

shown that the high risk sports (like wrestling) had the least amount of psychopathologies (Schaal et al., 2011).

A second study zoomed in on anxiety and who has it. This paper, *Informing Early Intervention: Preschool Predictors of Anxiety Disorders in Middle Childhood* (Hudson and Dodd, 2012), focused on anxiety in children and the factors that cause anxiety disorders. Researchers were trying to find whether behavioral inhibition (inability to act in a relaxed way); maternal psychopathology (mental disorders such as anxiety disorders or depression); maternal over involvement (parents that coddle their children); maternal negativity; or mother-child attachment determine if a child will have anxiety by the age nine.

Researchers tested 202 children; 102 of them were behaviorally inhibited and 100 of them were behaviourally uninhibited. The children were 3-4 years old and the predictors outlined above were assessed. After testing the children, diagnostic assessments were given using the *Anxiety Disorders Interview Schedule* (Hudson and Dodd, 2012). Then the researchers conducted it again five years later.

Researchers found that younger children who show signs of anxiety are more likely to have overinvolved mothers. This means that children with over-involved mothers tend to get anxiety disorders.

A third study, *Relationship Between the Anxiety and Performance of a Basketball Team During Competition* (Avenza et al., 2009), was about the correlation between trait and state anxiety and athletic performance in basketball players. Trait anxiety is experiencing negative emotions, like worrying or fears towards future events. State anxiety is brought up by a dangerous or threatening stimuli and is the arousal of the autonomic nervous system. Researchers examined trait and state anxiety and performance in different levels of competition by analyzing athletes from the Spanish Amateur Basketball League and focusing on 10 specific players. To measure players' state and trait anxiety, they used the State-Trait Anxiety Inventory-Scale, which is a self reported survey that asked questions about their anxiety 30 minutes before a game against the number 1 team and before a workout. The independent variable was anxiety based on the level of competition. The dependent variable was athletic performance. Athletic performance was measured in "overall rating (the sum of total points, rebounds, fouls received, recovered balls, and assists; and the subtraction of missed shots, fouls made, and turnovers), fouls committed, free throw percentage, 2- and 3-point field goal percentages, and points scored" (Abenza et al., 2009).

Correlations were found in field goals worth two points (points scored that were not free throws) and turnovers. There was a negative correlation with anxiety and field goal percentage which means that when there was more state anxiety, the percentage of field goals made decreased. There was a positive correlation with turnovers which means that the higher the state anxiety, the greater the number of turnovers. However, in analyzing the whole season's statistics and trait anxiety, no significant results were found.

I wanted to zoom in and test just anxiety with the experimental question: Is athletic performance better in high stress competitions than low stress competitions? In other words, does anxiety affect an athlete's performance?

Basketball analytics, statistics used to track a player's performance throughout their career, is emerging. However, I could not find an analytical test that has been done to measure a player's anxiety and how they perform under it. This topic can be of importance to a coach because if he or she knows one particular athlete plays well under pressure, he or she can put that player in the 4th quarter of a close basketball game to ensure a win. This person can be the "closer," like a baseball pitcher that goes in to finish the game. It would be important for this person to work well under pressure because if a team is up or down by a point you need a person who would not let it get to their head and can dig

deep to either get the winning point or stop the other team from scoring.

Basketball and volleyball were used to test the correlation between anxiety and athletic performance because they were the easiest sports to isolate one person and quantify anxiety. Quantifying anxiety was the hardest part of the experimental design because it is an emotion. It was presumed that free throws and serves were the best way to measure anxiety because there were few outside factors that affected the player. For example, there is no one guarding (in basketball) or blocking (in volleyball). In this moment, all of the pressure is on one person to make the free throw or serve. The assumption can be made that there is more anxiety in the 4th quarter of a close game or a deciding set (as in a game of tennis when a set determines the winner) than throughout the whole game because the athlete either wants to keep the lead or catch up to the other team.

#### **Methods/Procedure**

The independent variable was high-anxiety or low-anxiety, as measured by how many points the game was defined by and the quarter of the game. And the dependent variable in this experiment was the proportion of free throws were made.

For volleyball, the independent variable was high-anxiety or low-anxiety, measured by whether or not the serve was made in a deciding game, and the dependent variable was the proportion of serves made. I used the statistics only of the seniors on the volleyball team because they had the most experience and played the most in the past year. The independent variable was if it was a deciding or nondeciding set. The dependent variable in this experiment was if the serve was in or out. The only materials I used were the respective statistics books for Varsity Boys Basketball, Varsity Girls Basketball, and Varsity Girls Volleyball.

To analyze the data, number of free throws, free throw attempts, serves made, and serves attempted were found, then a two tailed proportions test was used (vassarstats.net) to determine the significance level.

In basketball, I split my data up into two groups: games that were defined by 6 or fewer points and games defined by 7 or more points. For the games that were defined by 6 or fewer points, I input the number of free throws made and free throws attempted in the first through third quarter vs. the fourth quarter to a Google spreadsheet. For games defined by 7 or more points, I input the number of total free throws made and total free throws attempted throughout the game on a Google spreadsheet. I added total number of free throws made and total number of attempts for games margined by 7 or more points to the 1st- 3rd quarter of close games so that I could calculate the total percentage to graph them. I then did the same for the 4th quarter of games that were margined by 6 or fewer points.

In volleyball, I broke down the statistics to 1st set, 2nd set, 3rd set (deciding), 3rd set (non-deciding), 4th set (deciding), 4th set (non-deciding), and 5th set (deciding). Then I added up the total serves made and total attempts in all of the deciding sets and the total serves made and total attempts in nondeciding sets. After this, I found the proportion by dividing the serves made by the attempts and graphed the results.

#### **BOYS VARSITY BASKETBALL**

#### 2012-2013, 2013-2014, 2014-2015, 2015-2016

The graphs below represent combined data for all four seasons of the Boys Varsity Basketball team. The y-axis represents the average of free throws made, and the x-axis represents whether the situation was high-stress or low-stress. The error bars were found using +/- standard error of the mean (SEM).

#### Free Throw Percentage Boys Varsity Basketball









10th Grade Boys Varsity Basketball





12th Grade Boys Varsity Basketball



#### GIRLS VARSITY BASKETBALL

#### 2014-2015, 2015-2016

The graphs below represent the combined results of the two years of Girls Varsity Basketball team. The y-axis represents the average of baskets made, and the x-axis represents whether the situation was high stress or low stress. There is no data for the 12th grade because in 2014-2015, there was only one senior and she did not play and in 2015 -2016, there were no seniors on the team.



#### 9th Grade Girls Varsity Basketball





#### **10th Grade Girls Varsity Basketball**

#### 11th Grade Girls Varsity Basketball



#### **GIRLS VARSITY VOLLEYBALL**

#### 2016

This graph represents the Girls Varsity Volleyball in 2016. The y-axis represents the percentage of serves made and the x-axis represents the set it was in. Results were only taken from seniors because they were played the most.

Percentage of Serves Girls Varsity Volleyball



#### Limitations

The only limitations in my experiment for both basketball and volleyball were the sample sizes. For example, it would've been helpful to have more than 2 years of Girls Varsity Basketball and 4 years of Boys Varsity Basketball. It also would have made my results more accurate if there were more games in each season. Due to this, there is a smaller possibility that the results would be statistically correct.

A difficulty in my study was inconsistency of record-keeping. For each game there is a different person recording the statistics and every person filled it out differently. Sometimes scorekeepers would not write the score of the other team so I could not use it in my data collection. Other times the score-keeper would write a dot, the symbol for free throws and then erase it. However, they did not fully erase it and I could not tell if it was there or not. Another difficulty in reading the book was that some of the people keeping track would not differentiate if it was an open dot or a filled in dot. This made it hard to tell if the person made the free throw or missed it.

#### Conclusion

#### **BOYS VARSITY BASKETBALL**

In conclusion none of my results were statistically significant except for 10th grade boys on the Varsity Basketball Team. However, I could not conclude anything significant from the testing the 10th grade because although there were significant results, they did not follow the trend. The data fluctuated too much to be able to conclude anything significant. Also, a singular "star player" had a strong influence making these results anomalous.

It was found that in the 4 years of data compiled, that in the 4th quarter of close games, 81/135 free throws were made, and for games margined by 7 or more points, 720/1056 free throws were made. As shown above, there was an 8% difference in the free throws made in the 4th quarter vs. free throws made for everything else, However, when analyzing through a comparison of proportions test, the p-value was .0565, which is not a statistically significant result (to conclude significant results the p-value must be .05 or less). This means that the null hypothesis cannot be rejected: that a player's athletic performance will be the same in high stress competitions as low stress competitions because there is insufficient evidence. This is because there is a 5.65% possibility that the results are due to random chance. This doesn't mean that the alternative hypothesis – that an athlete's performance will be better in high stress competitions than low stress competitions – is not correct; it just cannot be demonstrated from this test.

In the "9th Grade Boys Varsity Basketball" graph, the "everything else" column is approximately 12% greater than the 4th quarter close column; in the 4th quarter of close games, 8 of 14 free throws were made and in game margined by 7 or more and the 1st-3rd quarter of close games, 99/142 free throws were made. However, the difference was not statistically significant because a comparison of proportions yielded a p-value of .3335. This means that there is a 33.35% possibility that the results are due to chance, so again the null hypothesis cannot be thrown away.

In the "10th Grade Boys Varsity Basketball" graph, it is clear that there is a bigger gap between the "everything else" column and the "4th Quarter Close Games" column. In the 10th grade, the boys shot better in the 4th quarter of close game making 23/25 shots, meanwhile only making 101/156 shots in games margined by 7 or more points. This is approximately a 28% difference between the two columns. These results were significant (p-value of 0.0064 from a comparison of proportions) and it can be concluded that 10th graders work well with anxiety. The p-value means that there is a 0.64% chance

that the results are due to chance. Thus, I can reject the null hypothesis and conclude that the 10th grade does work well under pressure. However, due to the general trend, the results were too inconsistent to draw meaningful conclusions about secondary school students as a whole.

The "11th Grade Boys Varsity Basketball" graph shows that there is a 15% increase from the "4th Quarter Close Game" column to the "everything else" column. The "4th Quarter Close Game" column represents the 29/41 shots that were made in the 4th quarter of close games and the "everything else" column represents the 283/513 shots that were made in games defined by 7 or more points. These results were not significant and it cannot be concluded that 10th graders work well with anxiety because it had a p-value of .0531 in a comparison of proportions. This means that there is a 5.31% chance that the results are due to chance. Once again, the null hypothesis cannot be rejected because the p-value is over .05.

In the "12th Grade Boys Varsity Basketball" graph, it can be observed that two bars on the graph were very close together. Although the "4th Quarter close" column is 1% greater with 32/48 shots made while in games defined by 7 or more only 216/332 shots were made, I was unable to conclude that it is because the 12th graders worked well under anxiety. This is because a comparison of proportions yielded a p-value of 0.08274 which means there is an 8.274% probability that the results conclude ed were due to random chance. Thus the null hypothesis cannot be rejected – it cannot be concluded that anxiety does help the athletic performance of a 12th grader.

Originally I had thought older players would be more experienced and would perform better under pressure. However, it was not necessarily true that the older players had more experience. This threw off the results. I had to accept that perhaps the results were more individualized because of the players' specific relationship to working with their own anxiety.

Looking at the older players, 11th and 12th graders, I thought because of their experience on the varsity level, their percentage of free throws made would be greater under pressure. However, both the 11th and 12th graders disproved my theory. Because of the varied results I could not make any conclusive statements regarding a correlation between anxiety and athletic performance.

#### **GIRLS VARSITY BASKETBALL**

For the 2 years of compiled data of the Girls Varsity Basketball Team, the results were not significant. The girls made 15/26 free throws in the 4th quarter of close games, and 113/238 total free throws. This was a 10% increase in free throws made from the games margined by 7 or more and the 4th quarter of close games. However, because the p-value was .3227 in a comparison of proportion there was a 32.27% possibility that the results were due to chance. Thus the null hypothesis must be accepted.

Before conducting my data analysis, I believed that the 9th grade girls would not work as well under pressure, again because of lack of experience. I hypothesized that as age increased, so would the level of experience, thus the 11th and 12th grade would work better under pressure. In the 9th and 10th grade graphs, the "4th Quarter Close Game" column was higher than the "everything else" column. The 9th grade made 6/14 free throws in the 4th quarter of close game and made 22/54 free throws in the 1st - 3rd quarters and games defined by 7 or more. Thus, the percentage made was greater for the close games but because a comparison of proportions yielded a p-value of 0.8863, there was an 88.63% probability that my results were due to chance. The null hypothesis had to be accepted: that a player's athletic performance will be the same in high stress competitions and low stress competitions. The 10th grade supported my theory because there were significant results that they do indeed work well with anxiety. With a 1.05% possibility that the results were due to chance (p-value = 0.0105, comparison could proportions), I could throw away the null hypothesis and conclude that the 10th graders work

well under anxiety. However, the 11th graders had a higher "everything else" column than the "4th Quarter Close Game" column, contradicting my theory. The 11th grade made 1/2 free throws in the 4th quarter of close games and 30/52 of "everything else." However, there was an 82.9% chance that it was due to chance so I cannot reject the null hypothesis (p-value = 0.829 in a comparison of proportions). And the 12 grade didn't even take free throw shots, which is why there is no graph. This seems to be the opposite of what I hypothesized. Although the 9th grade results were not significant, the results did hint that they do work well with anxiety. On the other hand the 11th grade's results hinted that 11th grade girls work better without anxiety.

#### GIRLS VARSITY VOLLEYBALL

For volleyball, I studied the average number of in-bounds serves in non-deciding games versus the average number of in-bounds serves in deciding games. I found that 93% of serves were made in non-deciding games and 91% of the serves were made in deciding games. However, once again, my results were not significant because of a p-value of .755 meaning there is a 75.5% probability that my results were due to chance. This means that I have to accept my null hypothesis.

Due to these results overall, I conclude that there are no significant results from high school athletes. At this age, the majority of athletes do not have a lot of experience; thus some people might work better under pressure but others may not. High school performance is too dependent on individual characteristics. It may not be possible to draw conclusions about them as a group because I got the p values, 0.0565, .335, .0531, .8274, .3227, 0.8863, 0.829, and .755. I did, however, get two significant results for the 10th grade boys. I found a .0064 p value, and for the girls 10th grade I found a .0105 p value. I believe significant values were found in these grades due to two individual players with more experience who perform well under pressure.

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# The Effect of Mood on Memory: Using Movie Clips as Arousing Tools

by Joseph Arias

# Abstract

his experiment addresses how the working memory — "a theoretical construct where an active idea or memories held briefly in the mind can be manipulated" — is affected by mood, specifically when memorizing emotionally related words ("What Is Working Memory?" n.d.). The specific question investigated was "Do teens who are positively emotionally aroused have better memory recall than teens who are negatively emotionally aroused?" Previous work on the topic has failed to take a closer look at arousal and the affect it has on memory when using different arousing tools. This question was tested by having participants watch film clips, with either a negative or positive mood induction, and observing how well they were able to remember words after watching their respective movie clip. Participants took recognition tests in order to measure the amount of hits and false alarms in each group, as well as to analyze what specific words were hits more often. The only significant finding was that the positive mood group scored higher than the negative mood group in positive word hits. From this, the hypothesis was partially shown to be right — that there would be a correlation between mood and remembering words related to that mood. The findings of the study increase understanding of the complexity of mood and emotion, and also look at new arousing tools to discover new modes of therapy for people with mood disorders.

# Introduction

Depressive realism, which is the hypothesis that depressed individuals make more realistic inferences than non-depressed individuals, has pushed scientists to look at how depression, and mood in general, affects the mind (Hussain, D., 2012). By making more realistic inferences, depressed individuals have been thought to have better cognitive abilities, such as having a greater people-and-event recognition (Choi, C.Q, 2011). However, there are studies that trigger controversy and reveal other aspects behind this hypothesis and, overall, the relationship between memory and mood.

In one study, a mix of 30 dysphoric (people feeling emotional or mental discomfort) and 45 non-dysphoric participants were asked to complete two tasks, the Affective Working Memory task (D-span task) and the Reading Test span (R-span task), that measured their working memory (Hubbard et al., 2015). Two groups were formed from the 75 participants with different conditions based on the order of the two tasks, whether D-R (D-span task followed by R-span task) or R-D (R-span task followed by D-span task). Both tasks were meant to see if participants could successfully complete the tasks, but the only difference was the interference cues. The D-span task contained depressive cues, whereas the R-span task contained non-depressive cues (meaning neutral). During both tasks, the participants were asked to declare a set of sentences as true or false. These sentences were either personal or impersonal. The sentences were emotionally based for the D-span task (for instance, "I am sad all the time."), whereas they were neutral for the R-span task (for instance, "This sentence makes sense."). In both cases, a number was given at the end of each sentence. Subjects were asked to recall these numbers at the end of each task, in which scores of correct and incorrect numbers revealed the effect of each cue on each participant's working memory. The study's results, as predicted, reported that in both cases, the dysphoric group performed significantly worse than the non-dysphoric groups on the D-span task due to the depressive cues. In addition, dysphoric participants who were in the D-R condition demonstrated a decrease in performance, supporting the idea that depressive cues continued to affect the participants' working memories even when the cues were not present.

Another study that continues to show the effect of depression on memories regards the association of depression with false memories. A new key term in this study is arousal level, which is defined as "a level of alertness, situational awareness, vigilance, distraction, stress and direction of attention," ("Level of Arousal," n.d.). In the study, 52 participants, 25 currently diagnosed with major depressive disorder (MDD) and 27 controls, were each presented with 40 lists of words (Joormann, Gotlib & Teachman, 2009). Each list contained 15 words. The lists did not vary in arousal level, word frequency, or average word length, but there were three types of critical lures in valence ratings: positive, negative, and neutral. Valence pertains to the natural attractiveness or aversiveness of an event or situation. A low valence rating would correspond to aversiveness (negative feeling), or a negative lure, whereas a high valence would correspond to attractiveness (positive feeling), or a positive lure. By using a falserecall model, participants were asked to memorize the fifteen words in each list, which were presented for 250 milliseconds each with a 32 millisecond interstimulus interval. Then they were given 40 seconds to write down as many words as they could remember. After the 40 seconds were up, the process would immediately repeat with the next list. Their responses were then analyzed. Scientists found that the participants with MDD falsely recalled a higher number of negative lures, and had a lower accuracy at recalling words than the control participants.

These two studies uncover the cruel truths behind depression: it makes one more susceptible to lower cognitive performance and false memory-making. However, there seems to be much more to the story. Though these particular experiments demonstrated the effects of words inducing emotions, how do other materials add to the story? This disorder, or rather negative mood, may take over one's cognitive ability, but what other factors are implicated?

These questions hint at the effects of mood on cognitive performance, and more importantly how arousal - "the state of being physiologically alert, awake, and attentive" - plays a major part in this process ("Arousal in Psychology," n.d.). It is known that mood affects humans' learning processes and memory accuracy, but the significance behind arousal is often overlooked and misunderstood. According to Dictionary.com, to arouse is defined as "to evoke or elicit (a reaction, emotion, or response)." In other words, arousing may be triggering certain feelings, or a certain mood; nonetheless, it is, in fact, not so simple. An arousal level may correspond with the mood being elicited, but not always. It would be expected that a high arousal level would evoke "high," or positive, feelings - "feeling highly active, alert, and ready to respond to different things in the environment," ("Arousal in Psychology," n.d.). However, there are instances where high arousal levels give off negative feelings – the complete opposite. This condition is seen in the following paper titled, "Interplay between Affect and Arousal in Recognition Memory," (Greene, Bahri & Soto, 2010). In the study, researchers had participants memorize abstract shapes while listening to different genres of music. The music had distinct combinations of mood and arousal levels, allowing them to be separated into four categories: positive mood-high arousal, positive mood-low arousal, negative mood-high arousal, and negative mood-low arousal. Participants took a recognition test afterwards, and their tests were analyzed. Scientists found that participants who

received more "hits," meaning correct answers, than "false alarms," meaning incorrect answers, were those who were grouped positive mood-high arousal or negative mood-low arousal. Not only does this support the sense of depressive realism and go against the previous studies mentioned, but it also brings up a rather intriguing question: why did those in the positive mood-high arousal group perform just as well as those in the negative mood-low arousal? In addition, why the other two conditions (positive mood-low arousal and negative mood-high arousal) did not perform just as well as the two extremes? What made this study special was the use of musical pieces with different arousal levels to elicit different moods, but what other concepts or objects can replace music? Abstract shapes seem to have no simulation in memory performance, but could films with different genres and arousal levels have a different effect on memory performance?

In the current study, films were utilized as arousing tools for emotions with the theory that perhaps this substitution would yield different results, help society understand more about mood and memory, and inform society that being sad is not entirely maleficent. It may even change the preconceived idea that depressed individuals, or people with lower moods, achieve less than people with higher moods (Bowers, 2012). Therefore, the following question was posed: Do teens who are positively emotionally aroused have better memory recall than teens who are negatively emotionally aroused? The film clip (a comedy scene from *When Harry Met Sally* and a sorrowful scene from *The Champ)* screened for each group was the independent variable, whereas the recognition test performance was the dependent variable. Aside from these two films, a serene scene from *Alaska's Wild Denali* was the control variable. In addition to the question stated, another was asked: Do teens who are positively emotionally aroused and teens who are negatively emotionally aroused remember more positive words and negative words, respectively?

#### **Materials**

- Twenty participants from the Science Research & Design Program
- An empty classroom (every student took the test alone and not simultaneously)
- Two laptops (one to project clips, and one to project word slideshow)
- Headphones
- PMOS (Profile of Mood States)
- Movie Clips: Alaska's Wild Denali, When Harry Met Sally, The Champ
- All movie clips used were derived from J.A. Coan and J. J. B. Allen's *The handbook of emotion* elicitation and assessment.
- Recognition Test

#### **Methods/Experimental Procedure**

The study was conducted at the Berkeley Carroll School, and subjects were systematically chosen among students in the Science Research and Design Program (SRD). Twenty subjects, eleven males and nine females, who agreed to participate, were taken from SRD because permission slips for the program already covered participation in studies. Twenty seemed to be a fair number because it was not too small and would allow for substantial results to be obtained. Two groups were randomly formed within the participants. Initially, there were ten males and ten females, but an adjustment was made for a female who was unable to participate. This left one group with five females and five males and the other with six males and four females. All movie clips were projected on a laptop, and students were asked to bring headphones to block out background noise while watching their respective movie clips.

Taking place in a quiet, empty classroom, all participants were individually asked to watch the neutral film Alaska's Wild Denali first to hopefully level their moods. Immediately following the end of the movie clip, all participants were asked to take the Profile of Mood States (PMOS) and to answer the questionnaire solely based on their current mood. Analysis scores were recorded. Next, participants were asked to sit in front of a whiteboard with a slideshow titled "Words," which was projected by another laptop to avoid spending time setting up the last laptop. The slideshow was another control variable, and it consisted of a mixture of twenty positively emotion based words and twenty negatively emotion based words. The selected words were not derived from any source like the movie clips were, but the words are familiar in use and theme, allowing for them to be categorized as either positive or negative. Participants were told that 40 words would be presented on the screen with each word being displayed for 5 seconds. The only instruction they had during this time frame was to memorize as many words as possible. Every participant followed this procedure, and they then followed the path that corresponded with the group they were in. The group with five females and five males formed the negatively emotionally aroused group, and the group with six females and four males formed the positively emotionally aroused group. After the slideshow, participants in the positively emotionally aroused group watched a joyful and funny movie clip from When Harry Met Sally, and participants in the negatively emotionally aroused group watched a rather bloody and sorrowful movie clip from *The Champ*. Following their respective clip, all twenty participants took the same recall memorization test with a mixture of ten "old" words presented on the "Word" slideshow and ten new words that were similar in arousal level to some of the previous words. Their performance on those tests was analyzed. Their test scores were based on the amount of hits and false alarms, and the percentage of hits was calculated. Incorrect words that were checked and correct words that were not checked by participants were recorded as well to look for a possible correlation with the two groups.

A copy of the following recognition test was given to the participants after watching their perspective film:

	RECOGNITION TEST	
structions:		
ted below are 20 word	ls. Please mark a check next to the	e ones you recall seeing
the screen prior to the	movies.	
Heartwarming	8. Animated	15. Atrocious
Flowers	9. Grouchy	16. Stressed
Angry	10. Enthusiastic	17. Laughable
Black	11. Amusing	18. Bitter
Charming	12. Chicken	19. Difficult
Vibrant	13. Spring	20. Enchant
Storm	14. Selfish	

# Data/Results

Chart 1

**Memory Recall** 



Chart 2



Positive Hits vs. Movie Clip Groups

# Chart 3



# Positive False Alarms vs. Movie Clip Groups

# Chart 4



Negative Hits vs. Movie Clip Groups

#### Chart 5



#### **Negative False Alarms vs. Movie Clip Groups**

The first chart shows the average difference in the general correct responses between the two movie groups. After performing a one-tailed independent t-test, Chart 1 yielded a p-value of 0.2142595. The other four charts show the averages of the twenty participants in how many positive hits, positive false alarms, negative hits, and negative false alarms they scored, respectively to the movie clip they watched. After performing a one-tailed independent t-test for each chart, Chart 2 yielded a p-value of 0.0512895, Chart 3 yielded a p-value of 0.4295815, Chart 4 yielded a p-value of 0.149379, and Chart 5 yielded a p-value of 0.383807.

From these results, mainly that of Chart 1, we are forced to accept the null hypothesis that teens who are positively emotionally aroused have the same memory recall as teens who are negatively emotionally aroused. Furthermore, both groups performed similarly in regards to positive false alarms, negative hits, and negative false alarms after watching the films. On the other hand, according to Chart 2, the p-value of 0.0512895 rounds to 0.05, which is the significance threshold, meaning the positively emotionally aroused group performed better, in terms of memorizing more positive words, than the negatively emotionally aroused group.

#### **Discussion and Conclusion**

From the p-value presented in Chart 1, it is shown that the positively emotionally aroused movie group did not perform better than the negatively aroused movie group. The null hypothesis that there was no difference in performance between the two groups is accepted here, but looking deeper into what words were memorized by the two groups hints at another possible correlation. The p-values (which were greater than 0.05) in Charts 1, 3, 4, and 5 do not show significant results. Chart 2 stands out from the others though: its p-value rounds to 0.05, which is at the threshold of statistical significance. In other words, the positively emotionally aroused group. This finding supports part of the alternative hypothesis for

the sub-question – Do teens who are positively emotionally aroused and teens who are negatively emotionally aroused remember more positive words and negative words, respectively? The positively emotionally aroused movie group did, in fact, memorize more positive words than the negatively aroused movie group. However, the alternative hypothesis is only partially supported because the study did not conclude that the negatively emotionally aroused group (the other extreme) memorized a higher number of negative words than the positively emotionally aroused group.

By looking back on the experimental design, there are some flaws that could have possibly affected the data and results. The following factors could have led to different results, specifically strengthening or contradicting what is shown about the working memory tendencies of the subjects in both groups. First and foremost is the study's subject pool. Although gender was not being tested within the experiment, this experimenter attempted to control it by having five females and five males in each movie group. However, adjustments had to be made because some participants dropped out. Having more people, probably meaning a larger range in scores, would have increased the accuracy of the study's results. In addition, there were multiple lag times in almost every participant's time slot. On some days, in between setting up laptops, adjusting film clips, and projecting the word slideshow between steps, the laptops would malfunction. This created a larger gap for some participants in the amount of time they were mood induced by the film, or were able to retain the words they had just observed. Therefore, there was no set time for each person's turn, each lasting between twenty to thirty minutes. If the procedure had run more smoothly with a tighter-to-no lag time, the results may have been different. Lastly, the movies utilized in the study were rather old, The Champ debuting in 1979 and When Harry Met Sally debuting in 1989. Participants might have not been able to identify with the old productions, affecting the mood induction they were intended to be under.

Results from the participants' individual PMOS were confidential, but general information and the effect from watching *Alaska's Wild Denali* were not included because of its lack of significance. There were major gaps in the total mood points that the PMOS calculated for the participants, therefore, demonstrating that the film did not function in creating a leveled field for the participants' mood prior to watching the slideshow and watching their respective film. Some participants conveyed that they were having a hard day and had some misfortunes, while others displayed tranquility. Therefore, this imbalance may have also impacted the amount of hits and false alarms obtained, and the focus and effort put into memorizing words.

The study and its results reinforced the findings that influenced it. Chart 2 shows that the words, at least the positive ones, were effective in emitting their respective emotions. This study adds to the conversation regarding which tools can replace music, and to what extent film clips have the same arousal effectiveness. In addition, this study and the study that influenced this one both reinforce depressive realism. Although there were no mildly depressed subjects in this study, the subjects that were mood induced to a certain negative degree were expected to encompass some similar qualities, such as sadness, from watching *The Champ*. This group performed similarly to those in the positively emotionally aroused group. Therefore it is possible that in both conditions, subjects were able to still memorize similar or different words and still achieve the same score. By using the results from this study, there may be ways of finding other arousing tools and delving into their effectiveness to solve the complex relationship between mood and memory.

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# Economic Viability of Solar PV at the Berkeley Carroll School

by Luis Arias

# Abstract

s grid energy has risen in cost, so has interest in solar photovoltaic (PV) systems. In this paper, we analyze two viable sectors for solar PV: business and education. There are two factors to consider before adopting solar PV: technical feasibility and economic viability. There is a wealth of literature suggesting the success of these two qualities in the business sector, but an absence of such for the education sector. In our study, we analyzed economic feasibility at the Berkeley Carroll School by comparing our own estimates with that of the installers, EcoMen Solar, from their proposal for the 181 Lincoln Place campus roof which is currently being renovated. Solar PV is economically viable at the School, with a payback time of 14 to 15 years and a cumulative savings of \$71,224 to \$109,312 over the 25 year lifetime of the system.

# Introduction

As the cost of grid energy increases and the costs of solar photovoltaic (PV) systems continue to decrease, interest in solar PV systems has grown (Milea, Oltu & Stoian, 2009). Fossil fuel reserves continue to diminish, causing a greater push toward implementing renewable energy sources, of which solar PV can be expected to be a leading participant due to the natural accessibility of sunlight across the globe. Solar PV systems (referred to in this paper as such or simply as solar PV) produce power when sunlight befalls a solar panel, and are the conglomerate of the components needed to convert sunlight into usable electricity, including solar PV arrays, direct current-alternating current power inverters. (Florida Solar Energy Center (2014).

The wealth of scientific literature on solar PV in the business and education sectors suggests that these two sectors are greatly interested in the renewable energy source (The Solar Foundation, 2014). As this interest continues to grow, more businesses and schools will consider whether solar PV is technically feasible (Can it be implemented in a given facility? Will enough power be produced?) and economically viable for their facilities (Dalton, Lockington & Baldock, 2009). The needs for each sector vary. Therefore, feasibility and viability for each must be analyzed independently.

# Technical Feasibility and Economic Viability in the Business Sector

Tourist Accommodations in Australia. Small tourist accommodations in remote areas of Australia have to rely on stand-alone power supply systems instead of a connection to a power grid (Dalton, Lockington & Baldock, 2009). These systems are usually made up of diesel generators (referred to as gensets in the study and this paper) due to their reliability and low cost of operation. They use fuel to produce electricity. Renewable energy supplies (RES) have not been as widely implemented in these accommodations due to a lack of confidence in their technical performance and general confusion as to which RES "is the most suitable technology from both a performance and economic point of view" (Dalton, 2009, p. 1134-35). To address these two concerns, three small to medium-sized tourist accommodations with renewable energy supplies in Australia were chosen to conduct a case study. All three were not solely dependent on their renewable energy supplies but instead used a hybrid configuration with gensets. Two of the accommodations only used photovoltaics (PV) for their renewable energy. while the third used both PV and a wind energy conversion system. Since the focus of this paper is on solar PV, only the former two will be discussed. The present configuration of power supplies for these sites (PV and genset in hybrid configuration) shall be referred to as the "present configuration" in this paper. Hybrid Optimization of Multiple Energy Resource (HOMER), a "public domain modeling software for distributed power produced by the National Renewable Energy Laboratory" (Dalton, 2009, p. 1135) was used in the study. After inputting one year of load data, environmental inputs (solar irradiance-the amount of energy that falls on a given area over the earth as a result of sunlight), and system components and costs, HOMER determines if the system is technically feasible (Can the power system "adequately" serve the power demand of the site?). If so, HOMER will calculate the net present cost (NPC), the sum of all of the costs of the system during its lifespan, to determine economic viability. NPC includes initial set-up costs, component replacements, and operation and maintenance costs. 25 years was chosen as the project's lifespan. HOMER can also determine optimised configurations that would result in the lowest NPC for different categories like genset-only, PV/genset only, or RES-only systems.

**Sites and Results.** The tourist accommodation Hinchinbrook in Hinchinbrook Island, Queensland is an "eco-lodge type facility" with 22 cabins, a guest capacity of 50 lodgers, 490 kWh (kilowatt-hour) average daily energy usage, and a 5 kW PV system. It had an NPC of \$1.4 million. HOMER's recommendation for the optimised PV/genset configuration was to reduce both PV and gensets, resulting in an NPC of \$1.2 million. The HOMER optimised genset-only configuration had an NPC of about \$0.9 million dollars.

Accommodation Wilpena in Flinders Ranges, South Australia, has 34 motel rooms and 26 cabins, a guest capacity of 180 lodgers, 2600 kWh average daily energy usage, and a 100 kW PV system (Dalton, 2009, 1136). It had an NPC of \$1.1 million (1141). HOMER's recommendation for an optimised PV/genset configuration was to reduce both PV and gensets, resulting in an NPC of \$1.0 million (1140, 1141). The optimised genset-only configuration had an NPC of about \$0.850 million dollars (1141).

**Discussion.** Since NPCs were calculable, HOMER determined that the sites' present configurations were technically feasible. The present configurations' NPCs were higher than the other two configurations discussed here, and those we have failed to discuss (no relation to solar PV). Yet, the authors still concluded that the present configurations "can adequately supply the power required at an affordable price to the respective" (Dalton, 2009, p. 1143) site. This is most likely the case because the difference between the present configuration and the most inexpensive configuration, optimised genset-only, was not significant for each site (\$0.5 million dollars for Hinchinbrook, \$0.225 million for Wilpena). NPCs of the present configurations can be reduced through RES addition. However, PV was not the RES to use, with HOMER previously suggesting its reduction for both Hinchinbrook and Wilpena. While PV is capable of providing sufficient power, adding more would increase the NPC of the present configurations due to its high initial cost. Additionally, these have to be replaced every 20 years on average. The study looked at a project life of 25 years. Therefore, the addition of photovoltaics would have the double effect of increasing both initial cost and maintenance cost when replacement time comes.

While the present configurations of solar PV and gensets, and the optimised PV/genset configurations for the two sites discussed were economically viable, they were not cheaper than the gensetonly configurations. While some facilities will be willing to spend more to be more environmentally conscious, it can be expected that many would not. However, the results should not discourage businesses or schools from adopting solar PV. The higher NPC of the present and optimised configurations can be attributed to the "high initial cost" of PV. As the school study explores later on, there are programs that can help find solutions to mitigate the cost and, as will be discussed in "Our Study," there are incentives available that can directly mitigate those costs.

Printing Business in Antwerp, Belgium. Small companies (and some individuals) who decide to install solar PV base their investment decisions on commercial solar panel installer companies. Yet there is evidence to suggest that the payback time (time taken to regain money invested) projected by these installers is an underestimation "due to [neglect of] technological, environmental, and economic parameters" (Verhelst, Desmet, Debruyne, Van Landeghem & Vandevelde, 2010, p. 509). Although factors like solar panel materials, inclination angle, amount of solar radiation befalling an area, shade, temperature, and pollution have an effect on efficiency and, consequently, power yield, installers often only take into consideration the inclination angle. Realizing this, Verhelst et al. developed a software tool that would account for these factors, alongside the replacement of components once out of warranty, recycling costs, and annual maintenance costs. To use the tool, information like size, irradiation, costs, deductions through grants and taxes, and others, must be entered. To test the tool, a case study was performed in a "printing business near Antwerp (Belgium)" (p. 512). After conducting research and eliminating offers based on installment cost and services offered, the printing business narrowed down fourteen offers to just three: Offers 2, 3, and 14. Both the installers and the software tool provided their calculations for the estimated payback time: Offer 2, 7 years by the installer and 14.8 years by the tool; Offer 3, 7 years by the installer and 13.3 years by the tool; Offer 14, 6 years by the installer and 10.1 years by the tool. As concluded by the authors, in most cases, the actual payback time will be twice that of what the installers predicted. Tools like this help businesses make informed decisions and, in turn, decide whether or not solar PV is economically viable for them.

**Energy Optimization for Businesses.** Energy consumption optimization alongside solar PV can further increase the economic viability of solar PV. Milea et al. (2008) proposed a device targeted at small homes and businesses. The device consists of a Field-Programmable Gate Array (FPGA) and an Automatic Power Switch. The FPGA Controller carries the circuitry that "control[s] all the system functions" (p. 373). The Automatic Power Switch is able to switch loads on and off and between solar PV and the electric grid itself. The Automatic Power Switch can produce three loads for three types of devices. The Continuous Load (CL) is for devices that require continuous power. The High Priority Load (HPL) is for devices that require short but frequent access to power. Low Priority Load (LPL) is for devices that require infrequent and "long time access" to power. Furthermore, Milea et al. offers tracked solar panels to further optimize energy consumption. Tracked solar panels, with the help of a detector, are always parallel to the sun, constantly producing the maximum amount of power the panel

is rated for. In comparison, fixed panels only achieve their maximum once a day, when the sun is directly above them. For tracked panels, this can result in "50% power boost over the fixed panels solution" (p. 373), further adding economic viability to solar PV.

#### **Technical Feasibility and Economic Viability in the Education Sector**

To analyze feasibility and viability in the education sector, *Solar for Schools: A Case Study in Identifying and Implementing Solar Photovoltaic (PV) Projects in Three California School Districts* by Alice Kandt (2011) was chosen. In this case study, the technical assistance support given by the National Renewable Energy Laboratory (NREL) through the Solar Schools Assessment and Implementation Project (SSAIP) to implement solar PV in three California school districts (West Contra Costa, Berkeley, and Oakland Unified) is described. SSAIP is a Solar America Showcase award winner founded by the non-profit Sequoia Foundation. Solar America Showcase is a program run by the US Department of Energy (DOE) which "seeks to accelerate demand for solar technologies among key end use market sectors" (Kant, 2001, p.1). Award winners get access to the NREL and its technical assistance support. This paper will describe the support as it pertains to solar PV technical feasibility and economic viability.

**Technical Feasibility.** To determine if solar PV is technically feasible at a certain school, a number of factors must be observed, including: access to the sun, age of the roof, school designation as "historic or emergency shelter," roof size, electrical load, and electrical cost of the school. NREL provided support in determining and addressing some of these factors. They provided a report for the district representatives that detailed various aspects of solar PV. One of these was PV technologies, including emerging ones. Among them were building-integrated PV (BIPV). BIPV use "thin-film solar cells," different from the typical crystalline cells. They are made out of silicon, providing greater flexibility to integrate them into building materials like tiles and building facades. This increases the technical feasibility of solar PV, especially in places where space is a concern or the roof is not available, but comes at the price of less efficiency when compared to crystalline cells.

The best way to determine feasibility is through solar mapping analyses. Mapping analyses can quantify the available space for solar PV and calculate the capacity and production of the system. There are web-based tools to do this, like NREL's own In My Backyard (IMBY). The districts worked with SunPower Corporation, which uses aerial snapshots for their analysis and calculations, to carry out their own. To provide an example of the data produced, SunPower Corporation determined a potential PV capacity of 7,252 kW for 42 schools in the West Contra Costa school district, with an annual production of 9,700,000 kWh and savings of \$1.8 million dollars. However, SunPower does not take into consideration all of the factors mentioned above, like structural integrity and roof age. NREL built on SunPower's assessment by taking those factors into consideration and made a list of the most promising schools in each district. From NREL's list, each district chose five schools, which NREL will assess structurally. As of the writing of the study, no physical visits had taken place.

**Economic Viability.** To make solar PV as economically viable as possible, it is important to choose the most cost-effective rate structure from an electric utility. Rate structures are the "set of factors that a utility firm chooses in computing consumers" (Business Dictionary, 2016) charges. Whereas most telephone and water bills are quite straightforward, electricity bills can be very complex due to inclusion of factors such as demand charge, fuel charge, power factor penalty, and time of day billing. Different rate structures will have different effects on power system economics. To help the school districts, NREL performed a case study using the Berkeley (California) High School to conduct a utility rate analysis "comparing the value of PV electric generation for different rate structures" (Kandt, 2011, p. 6)

using their System Advisor Model (SAM). After inputting the school building's electrical load and simulated solar data (irradiance) over the same period of time and the rate structures, SAM was able to determine net PV value for the different rates by PV penetration. Net PV value is the difference between electric cost without the PV system under the least expensive rate and cost with the PV system under the rate in question divided by total kWh produced by the PV system, yielding units of \$/kWh. A higher net PV value means more savings from the PV system since more of the electrical costs are being offset by the system. PV penetration is how much of the buildings' annual power consumption is fulfilled by the PV system as a percent. Some rates are most economical under a certain PV penetration. For example, in the Berkeley High School case study, rate E-19 provides the highest PV value until 35% PV penetration. Afterwards, rate A-6 is the best choice.

# **Our Study**

Solar PV can be technically feasible and economically viable for businesses. However, most of the literature addressing the two qualities in question are geared to the business sector, with a lack of attention to the education sector. In our study, we seek to work with Solarize Brooklyn CB6 (SBC) and EcoMen Solar to bring solar panels to the Berkeley Carroll School in Brooklyn, New York to determine the technical feasibility and economic viability there. This paper will seek to answer the question: Is solar PV economically viable at the Berkeley Carroll School? Technical feasibility for PV at the school will not be analyzed in this paper. This quality would have been determined by an analysis of the preinstallation and installation processes. However, as of the writing of this paper, the school has still not made the decision to install the panels, but is still considering. Economic feasibility will be analyzed through two sources: estimates and predictions original to this paper and the installers' (EcoMen Solar) proposal. The latter will be analyzed and compared to the former. Lastly, payback time, savings, and percentage of energy covered by Solar PV will be determined and analyzed.

# Methods

To calculate the energy production of a potential system, the online tool PVWatts by the NREL was used. PVWatts is part of the SAM software. NREL has also made PVWatts available online, separate from SAM. This version has been used. PVWatts requires that a weather data source, also known as a Typical Meteorological Year (TMY) is chosen. TMYs are collections of meteorological measurements for a specific location. The tool can automatically select one based on zip code. The TMY2 found in New York City was selected automatically. TMY2 is the second update to TMY, providing more recent measurements than the original TMY(1). It is found 9.6 miles away from the school's zip code, 11217.

Next, values were plugged into the "System Info" section. For "DC System Size (kW)", a size of 36.8 kW was used. This value is found in the installers' proposal for the school's system. In the words of the installers, their proposal "should be treated as a draft as we have not surveyed your location in person" (Cascio, 2016). For "Array Type", "Fixed (roof mount)" was chosen. For "System Type", "Commercial" was chosen. Lastly, for "Average Cost of Electricity Purchased from Utility (\$/kWh)", \$0.15 was chosen. This value had already been calculated by the installers and provided in their proposal based on the school's utility bills from the 12-month period of June 2015 to May 2016. All other parameters were left with their default values. With this information, PVWatts is able to produce average yearly production, average AC energy in kwh per month, average energy value per month and year, and provides average solar radiation per month in kWh / m2 / day, based on its weather data source.

The data generated was then compared to similar data from the installer's proposal, and energy savings and payback time using both predictions were analyzed.

# Data

# Figure 1

# Estimated New Utility Bill, Net Savings, and Cumulative Savings, original to this paper

Year	Old Utility Bill	New Utility Bill	Net Savings	Cumulative Savings
0				\$-132,974
1	\$28,394	\$21,196	\$32,958	\$-100,016
2	\$29,218	\$22,020	\$7,198	\$-92,818
3	\$30,065	\$22,867	\$7,198	\$-85,620
4	\$30,937	\$23,739	\$7,198	\$-78,422
5	\$31,834	\$24,636	\$7,198	\$-71,224
6	\$32,757	\$25,559	\$7,198	\$-64,026
7	\$33,707	\$26,509	\$7,198	\$-56,828
8	\$34,685	\$27,487	\$7,198	\$-49,630
9	\$35,691	\$28,493	\$7,198	\$-42,432
10	\$36,726	\$29,528	\$7,198	\$-35,234
11	\$37,791	\$30,593	\$7,198	\$-28,036
12	\$38,887	\$31,689	\$7,198	\$-20,838
13	\$40,014	\$32,816	\$7,198	\$-13,640
14	\$41,175	\$33,977	\$7,198	\$-6,440
15	\$42,369	\$35,171	\$7,198	\$-756
16	\$43,597	\$36,399	\$7,198	\$6,442
17	\$44,862	\$37,664	\$7,198	\$13,640
18	\$46,163	\$38,965	\$7,198	\$20,838
19	\$47,501	\$40,303	\$7,198	\$28,036
20	\$48,879	\$41,681	\$7,198	\$35,234
21	\$50,296	\$43,098	\$7,198	\$42,432
22	\$51,755	\$44,557	\$7,198	\$49,630
23	\$53,256	\$46,058	\$7,198	\$56,828
24	\$54,800	\$47,602	\$7,198	\$64,026
25	\$56,390	\$49,192	\$7,198	\$71,224

# Figure 2

# Estimated New Utility Bill, Net Savings, and Cumulative Savings by the Installers

Year	Old Utility Bill	New Utility Bill	Net Savings	Cumulative Savings
0				\$-132,974
1	\$28,394	\$21,816	\$32,338	\$-100,636
2	\$29,218	\$22,491	\$6,727	\$-93,909
3	\$30,065	\$23,188	\$6,877	\$-87,032
4	\$30,937	\$23,906	\$7,031	\$-80,001
5	\$31,834	\$24,646	\$7,188	\$-72,813
6	\$32,757	\$25,408	\$7,349	\$-65,464
7	\$33,707	\$26,195	\$7,512	\$-57,952
8	\$34,685	\$27,005	\$7,680	\$-50,272
9	\$35,691	\$27,841	\$7,850	\$-42,422
10	\$36,726	\$28,702	\$8,024	\$-34,398
11	\$37,791	\$29,590	\$8,201	\$-26,197
12	\$38,887	\$30,505	\$8,382	\$-17,815
13	\$40,014	\$31,448	\$8,566	\$-9,249
14	\$41,175	\$32,420	\$8,755	\$-494
15	\$42,369	\$33,423	\$8,946	\$8,452
16	\$43,597	\$34,456	\$9,141	\$17,593
17	\$44,862	\$35,521	\$9,341	\$26,934
18	\$46,163	\$36,619	\$9,544	\$36,478
19	\$47,501	\$37,750	\$9,751	\$46,229
20	\$48,879	\$38,917	\$9,962	\$56,191
21	\$50,296	\$40,119	\$10,177	\$66,368
22	\$51,755	\$41,358	\$10,397	\$76,765
23	\$53,256	\$42,636	\$10,620	\$87,385
24	\$54,800	\$43,953	\$10,847	\$98,232
25	\$56,390	\$45,310	\$11,080	\$109,312

#### Figure 3





As seen in Figures 1 and 2, the Old Utility Bill increases every year due to the utility's 2.9% yearly inflation. In Year 1, there is an additional savings of \$25,760 due to the NY PON 2112 incentive (an incentive provided by the New York State Energy Research and Development Authority for PV systems that are both connected to the grid and are less than 200 kW for non-residential sites).

For payback time, we estimate 15 years; the installers estimate 14. For cumulative savings, we estimate \$71,224, the installers estimate \$109,312. For yearly production, we estimate 47,990 kWh per year on average, PVWatts noting that this may range from 46,065 to 49,597 kWh per year in the location in question. From this, we estimate a lifetime production of 1,199,750 kWh. The installers estimate that the system will produce 43,111 kWh in the first year, with a lifetime production of 998,585 kWh.

#### Discussion

The difference in the two models' data is due to the programs used. PVWatts only calculates the average net savings per year over the life of the system, resulting in static net savings when trying to analyze the system after Year 1, as seen in Figure 3. The installers' programs can actively calculate the net savings for each year by taking into consideration the decrease in energy production as the system ages. This does not result in negative net savings over time due to the old utility bill's greater rate of change by inflation. This feature also accounts for the installers' lower lifetime production compared to our own.

Despite the differences in the models, solar PV is economically viable at the Berkeley Carroll School. The NY PON 2112 incentive helps reduce the high initial costs. From either of the estimates, all
initial costs are recovered in 14 to 15 years time, with positive cumulative savings. From a completely economic standpoint, solar PV does help reduce cost. Despite the fact that the system's yearly production only covers 4.86%, from our calculations, or 4.36% from the installers' data, of the total energy used in the 181 Lincoln Place part of the school over the last year, the monthly bill is reduced by a consistent \$7,198 in our model or increasingly from \$6,578 from the installers' model. The school can further increase the economic viability of solar PV by considering some of the options discussed before, like rate structure analysis, and implementing tracking solar panels, further increasing system production. For a future study, we would like to determine the technical feasibility of solar PV as the panels are being installed in the school.

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# Does Listening to Music Before Bed Affect Dream Frequency and Music-Related Dream Frequency in Musicians Versus Non-Musicians?

by Joanna Ball

## Abstract

his study tested whether listening to music before bed affects dream frequency as well as musicrelated dream frequency in musicians and non-musicians. Over the course of ten days, 20 subjects recorded their dream frequency each night. Five of these nights involved not listening to music within the hour before going to bed. For the other five nights, the same subjects listened to music for half an hour directly before going to bed. There were no significant differences in dream frequency and music-related dream frequency in musicians and non-musicians.

## Introduction

In 1913, Frederick van Eeden published a study of his own dreams. At the time *A Study of Dreams* was published, "dream science" had not yet developed, and many people did not think of the study of dreams as scientific. Van Eeden studied his own dreams for several years, recording and sorting them into different types. What he did was revolutionary, and changed the way people thought about and studied sleep and dreams. Another revolutionary is Sigmund Freud who, in 1900, published *The Interpretation of Dreams*. In this, he discusses theories of unconsciousness and introduces dreaming into his theories. Although none of this is very scientific, it certainly laid the groundwork for scientists to begin the study of dreams.

Today scientists have discovered many different parts and functions of the brain, as well as how dreams occur and what areas of the brain are involved with dreaming. The amygdala deals with emotional functions. It sends memories to the hippocampus, which turns short-term memory into long-term memory. It also receives memories and information during sleep and the images are interpreted as dreams (Blagrove et al., 2011). However, even though questions about sleep and dreaming have been answered, many questions still remain. In a study conducted by Uga, Lemut, Zampi, Zilli, and Salzarulo (2005), frequency of music-related dream content over 30 days was compared among 35 professional musicians, aged 20-47 years, and 30 non-musicians, aged 18-38 years. Subjects filled out dream recall questionnaires every morning. Uga et al. found that musicians were twice as likely to have a music-related dream as non-musicians were. Additionally, 55% of musical dreams included already-existing, known pieces of music, 17% included unusual versions of known pieces, and 28% contained unknown pieces, possibly suggesting that musicians may be able to compose in their sleep.

Interestingly, the amount of time a subject has been proficient in playing an instrument did not affect frequency of music-related dreams. However the age at which they began studying music or an instrument did affect the frequency of music-related dreams. Those who had started studying music at a very young age were more likely to have greater frequencies of music-related dreams. The study also concluded that listening to music did not have an influence on music-related dream frequency, although it did not test whether or not listening to music right before going to bed did (Uga et al., 2005).

There is reason to believe, however, that even if listening to music before bed impacts frequency of music-related dreaming, the effect might take several days to be evident. A study on the "dream-lag effect," which is when one has an experience during the day and then dreams about it a certain number of days later, conducted by Blagrove et al. (2011), tested the dream-lag effect in rapid eye movement, REM, sleep and non-REM stage 2 sleep. The study concluded that the dream-lag effect in stage 2 sleep was 5-7 days, meaning it took between 5 and 7 days for participants to dream about experiences that happened in their waking lives. The dream-lag effect was only 3-4 days in REM stage sleep. However, the study did not investigate the involvement of music with the dream-lag effect. Incorporating music into dream-lag experiments may be interesting for further studies.

The purpose of this study is to investigate whether listening to music before bedtime affects the frequency with which people dream, as well as the frequency with which they dream about music. Additionally, the frequency of dreaming and dreaming about music was compared between musicians and non-musicians.

## Methods

20 subjects participated in the study over the course of 10 days. First, participants filled out a survey asking them to indicate: the average amount of sleep they get each night; if they usually listen to music before going to bed; the average number of hours they listen to music each day; how often they dream; if they are a musician; how often they have music-related dreams.

For the first five days of the experiment, subjects were asked not to listen to music within the hour before going to bed. They were also asked to keep a tally of how many nights they dreamed. After the fifth night, another survey was sent out. This survey asked: if they were a musician; how many nights they dreamt; how many of those dreams were music-related; if they did have a music-related dream, were they listening to music or playing music in the dream.

For the last five days of the experiment, subjects were asked to listen to music of their choice for half an hour before going to bed. They were allowed to do other things while listening to music, such as preparing for bed, as long as they went to sleep soon after listening to the music. Again, subjects took a tally of how many nights they dreamt. The final survey was very similar to the second survey. The survey asked: what they were doing while listening to music; if they were musicians; how many nights they dreamt; how many of those dreams were music-related; if they had a music-related dream; were they listening to music or playing music.

## Data

Listening to music was not found to have a significant effect on how frequently participants dream, nor was it found to have a significant effect on how often their dreams contain music-related content.

Specifically, participants (N = 19) (only 19 subjects filled out this specific survey) reported a mean dream frequency of 2.21 nights of dreaming per week (SD = 1.36) without listening to music prior to going to bed; after listening to music prior to going to bed, participants (N = 17) reported a mean dream frequency of 2.76 nights of dreaming per week (SD = 1.52). This difference was not significant according to an unpaired t-test (t(34) = 1.1551; p = 0.2561):

No Difference in Dream Frequency Before or After Intervention						
	N = M = SD = T-Test					
No music (Days 1-5)	19	2.21	1.36	t(34) = 1.1551		
With music (Days 6-10)	17	2.76	1.52	<i>p</i> = 0.2561		

Participants (N = 20) (all 20 subjects filled out this specific survey) reported a mean music-related dream frequency of .25 nights of dreaming per week (SD = .44) without listening to music prior to going to bed; after listening to music prior to going to bed, participants (N = 17) reported a mean music-related dream frequency of .53 nights of dreaming per week (SD = .72). This difference was not significant according to an unpaired t-test (t(35) = 1.4474; p = 0.1567)

No Difference in Music-Related Dream Frequency Before or After Intervention						
	N = M = SD = T-Test					
No music (Days 1-5)	20	.25	.44	t(33) = 1.4474		
With music (Days 6-10)	17	.53	.72	<i>p</i> = 0.1567		

Musicians (N = 8) reported a mean music-related dream frequency of .25 per week (SD = .46) without listening to music before bed. Non-musicians (N = 12) reported a mean music-related dream frequency of .25 per week (SD = .45) without listening to music before bed. This difference was not significant according an unpaired t-test (t(18) = 0.0000; p = 1.0000):

No Difference in Frequency of Music-Related Dreams in Musicians vs. Non-musicians Before Intervention						
	N = M = SD = T-Test					
Musicians	8	.25	.46	t(18) = 0.0000		
Non-musicians	12	.25	.45	<i>p</i> = 1.0000		

Musicians (N = 8) reported a mean music-related dream frequency of .50 per week (SD = .76) with listening to music before bed. Non-musicians (N = 9) reported a mean music-related dream frequency of .56 per week (SD = .73) with listening to music before bed. This difference was not significant according to an unpaired t-test (t(15) = 0.1544; p = 0.8793):

No Difference in Frequency of Music-Related Dreams in Musicians vs. Non-musicians After Intervention						
	N = M = SD = T-Test					
Musicians	8	.50	.76	<i>t</i> (15) = 0.1544		
Non-musicians	9	.56	.73	р = 0.8793		

Using the surveys sent after the first five days of the experiment (before intervention when subjects didn't listen to music) and the last five days of the experiment (after the intervention when subjects listened to music before bed) no significant results were found. Listening to music before bed did not increase nor decrease a subject's dream frequency or music-related dream frequency for either musicians or non-musicians. Overall, there was no difference in dream frequency between musicians and non-musicians before any intervention or after intervention.

### Discussion

Overall, there were no significant results in this experiment. Listening to music before bed had no effect on dream frequency or music-related dream frequency in either musicians or non-musicians. This experiment does contradict previous studies. Uga et al.'s study involving music-related dreams in musicians and non-musicians concluded that musicians were more than twice as likely to dream of music. Uga et al. concluded that music-related dream frequency did not depend on how long the musician played in his or her life, rather the age of commencement of playing an instrument or the study of voice. The earlier the age of starting to playing music, the more frequent their music-related dreams.

There were possible errors that could lead to inaccurate data. The small sample size did not encompass a very large group of people and the conclusions can only represent the subjects who participated in the study. The duration of the study may not have been long enough to obtain accurate results. Lastly, subjects did not always fill out required surveys which led to the collection of inaccurate data and was the cause for the varying sample sizes reported in the data section. The largest error factor was subjects not finishing their experiments on time. Subjects did not always fill out the survey on the days they were asked to, or failed to complete them. Subjects were asked to keep the two different sections of the experiment— five days without listening to music before going to bed and five days with listening to music before bed— consecutive. However, close to half of the subjects did not follow procedure because not everyone completed the experiment in ten consecutive days. Most of this was due to unreliability in some subjects, despite multiple communications with them. Therefore, some subjects continued the last five days of the experiment with a gap of a few nights in between the not- listening-to-music and listening-to music periods. These nights in between were not a part of the study and were not taken into account when collecting and analyzing data. The other subjects finished the experiment in ten consecutive days.

Another factor that could have resulted in inaccurate results is the length of the study. Five nights of listening to music may not have been enough for the brain to process the music and appear in dreams. This could be somewhat related to the dream-lag effect that suggests some events that occur during the day need a certain number of days before appearing in dreams in different stages of sleep. However, because subjects listened to music directly before bedtime, this was assumed to have a more direct effect on the brain and processing of the music without the need for taking the dream-lag into account.

To get more accurate results, certain changes to the study could include testing a larger sample size and testing over a longer experimental time. These changes would expand the experiment, involving more subjects and more time not listening and listening to music before bed which might yield better, more accurate results. Since there was no daily check-in with subjects and it was hard to know who was consistently keeping track of their dreams; the reconducted experiment could include sending out daily surveys. This would also keep track of subjects' dreams on a daily basis, making it even more specific. The type of music could also be controlled. Rather than letting subjects listen to music they chose, all subjects would listen to a certain genre of music to ensure that all variables are as consistent as possible. Another change would be to anonymously keep track of each individual subject to see how music affects their personal dream frequency, rather than generalizing this to all the subjects.

In conclusion, this study shows that listening to music before bedtime does not affect dream frequency. Listening to music before bed does not affect music-related dream frequency. Finally, there was no significant difference between the dream frequency and music-related dream frequency in musicians versus non-musicians.

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## An Assessment of HIV Education at Berkeley Carroll and The Biomarker Study

by Jacob Boehm

## Abstract

o assess how well Berkeley Carroll is educating its students about Human Immunodeficiency Virus (HIV), I conducted an in-house study that compared knowledge about how HIV is transmitted, the basic vocabulary/general knowledge surrounding HIV, and the effects of HIV between age groups who have taken the 10th grade Health and age groups who have not. To this end, a survey was issued to students in grades 8-9 (group 1) and 11-12 (group 2) that tested how much they know about HIV transmission, effects, and basic vocabulary/general knowledge. The results showed that there was a statistically significant difference between the age groups in overall scores (p=0.039) and HIV effects (p<0.01), so we must accept our alternative hypothesis in those two sections. However, in the general knowledge (p=0.36) and transmission (p=0.20) sections there was no statistically significant difference, so we must accept the null hypothesis.

## Introduction/Background

Reducing the transmission and lethality of HIV has the potential to save millions of lives. In fact, according to the World Health Organization, in 2015 alone 1,100,000 lives were lost due to HIV infection (World Health Organization). Despite decades of research, scientists are yet to devise a cure. The best way to survive HIV is to avoid contracting it in the first place, and education has been shown to be a key factor in reducing transmission (Krasnigi, 2014). A study conducted by the Department of Health Care in Elbasan, Albania found that there is a direct link between knowing about HIV and safer sexual practices (Krasniqi, 2014). Another study entitled "The Education Vaccine Against HIV" expanded on this concept finding that, initially HIV was actually more prevalent in affluent educated communities, but as scientists learned more about HIV, those with access to emerging information and research changed their sexual practices far more than the less educated individuals (Vandemoortele and Delamonica, 2000). As a result, HIV is now far more common in uneducated communities. Clearly, education can play a powerful role in reducing HIV transmission. For this reason, I attempted to assess the efficacy of tenth grade health within the Berkeley Carroll community by conducting a survey-based study. Ultimately, I hoped to use the previously established link between education and reduced likelihood of HIV contraction/transmission in order to gauge how much Berkeley Carroll is protecting its own students from HIV with the experimental question: "How does the amount Berkeley Carroll students know about how HIV is transmitted, the basic vocabulary/general knowledge surrounding HIV, and the effects of HIV vary between age groups who have not taken 10th grade Health and age groups who have?" My independent variable was the age group, and my dependent variables are the test scores.

Over the past two summers, I have worked with the Beth Israel Clinical Trials unit to conduct a study entitled the "Biomarker Study." In this study, I attempted to unearth biomarkers – here defined as a quantifiable or objectively measurable/diagnosable characteristic, infection, or development that acts as an indicator for a future alteration in the trajectory of a patient's recovery – by analyzing patterns in

various patients' information/notes. This multi-year nationwide study has thousands of participants and the potential to give doctors a way to predict the next disease or change in health a patient will develop before it happens. The results of the study are not yet available, as it spans across five years. However, a previous study "Immunological biomarkers predict HIV-1 viral rebound after treatment interruption" (Hurst, 2015) helps to put into perspective how influential the results could be. It found that by using biomarkers, we can predict how the virus will go from undetectable to detectable levels post-antiretroviral therapy.

## Methods

My in-house study used an anonymous survey that included questions designed to test how much participants knew regarding how HIV is transmitted, general knowledge and vocabulary surrounding HIV, and the effects of HIV. I sent the survey to 8th and 9th graders (group 1) and 11th and 12th graders (group 2). The 10th grade was excluded because they are in the middle of 10th grade Health. My method of sampling was coordinating with middle school science teachers and asking them to allow students to take a few minutes of class time to take the survey. Ultimately, I had 102 total responses.

In order to conduct the study, I had to operationalize independent and dependent variables. I made the independent variable the age groups, and the dependent variables the score. The only materials needed were electronic devices capable of taking the electronic survey (computer, iPads). The survey responses were scored in the following manner: I graded the transmission and effects session by adding a point for each correct answer and subtracting a point for each incorrect answer, then calculating what percentage of the total possible points the student achieved. For the general knowledge section, I did not subtract a point for incorrect questions because they were free response questions. I then ran a one-tailed independent t-test using a program called Vassarstats to determine if there was a significant difference in each subsection and the overall scores.

## Results

The average score and SEM (standard error of the mean) of the scores of the two groups are shown in the tables below.

8th and 9th Graders					
	Transmission	General Knowledge	Effects	Overall	
Average Score	58.621	16.810	32.466	35.966	
SEM	4.093	3.529	4.0657	2.752	

11th and 12th Graders						
	Transmission	General Knowledge	Effects	Overall		
Average Score	64.533	18.556	46.111	43.067		
SEM	5.841	3.476	3.969	2.864		

### **Scores on Transmission Section**











Ultimately, I found a statistically significant difference between the 8th and 9th graders' and the 11th and 12th graders' overall test scores (p=0.039) using a one-tailed independent t-test. Hence, we must accept the alternative hypothesis that overall 11th and 12th graders know more about HIV than 8th and 9th graders. However, in two of the three subsections (transmission and general knowledge) there was no significant difference between age groups. In the transmission section the p-value was p=0.19. Therefore, we must accept the null hypothesis that 11th and 12th graders know the same amount about how HIV is transmitted as the 8th and 9th graders. The general knowledge section also showed *no* significant results (p=0.36). We must accept our null hypothesis that group 1 and group 2 have the same general knowledge about HIV.

However, in the effects section, unlike the other two subsections, the older students did far better (p=0.0098). So, overall, we must accept the alternative hypothesis that the older students know significantly more about the effects of HIV than the younger students despite the fact that there was no significant difference in two of the three subsections.

## Conclusion

Ultimately, it appears that Berkeley Carroll is educating its students about the effects of HIV to some degree, but could certainly be doing more to educate them about transmission and general knowledge. It appeared that, in those two sections, students did not gain a higher level of understanding as they went through high school. This could have fairly major ramifications since sexual activity increases during high school (Krasniqi, 2014). Furthermore, in the general knowledge section, not only was there no statistical difference (p=0.36), but both groups scored, on average, less than 20 out of 100 (16.81 vs 18.56), which indicates that HIV is most likely not a topic of discussion in middle school or high school. This is supported by the response to the last question on the survey, "Do you feel Berkeley Carroll is doing enough to educate students about HIV and other Sexually Transmitted Diseases?" Students rated it from 1 to 5, 1 being the worst and 5 being the best. Group one answered 1.92 and Group 2 answered 1.91, which would indicate that the students are not content with how much Berkeley Carroll is doing to educate its students about HIV in both groups.

However, it is important to recognize the statistically significant difference in the effects section and overall scores. In the effects section, group two did far better (32.47 vs 46.11). This would indicate that Berkeley Carroll does integrate discussion surrounding this topic. This would mean, however, that the overall results, though significant, may have been skewed by the enormous disparity in the effects section.

There are other factors at play that may have skewed my results as well. The main one is that school is not the only source of information about HIV. Seniors have also been exposed to more television, social media, literature, and other sources. This is a major limitation in my experiment because there is no clear way to bypass the problem. Another difficulty is that a survey is limited in length, and a few general questions about HIV is not necessarily indicative of the students' overall knowledge. There is far more to know than can be assessed in a short survey. One implication of this is that many students received scores of zero, when, if I could include more questions, they would almost certainly score higher. Nonetheless, there was no statistically significant difference in two of the three sub-sections, and the students themselves say that Berkeley Carroll is not properly educating them about HIV. So the fact that Berkeley Carroll needs to be doing more to educate its students about HIV remains very much valid. The simple way to address this is to improve 10th grade Health.

To do so, I would recommend using a lesson plan taken from the Center for Disease Control titled "HIV/AIDS" by Heather Fogell and Lori Coles. The lesson plan is hands-on, would likely take multiple classes (about 2-3), and provide students with a plethora of resources if they want to learn more on their own. It begins by addressing misconceptions about HIV transmission. The results of my survey indicates that this is necessary, since the most common way students lost points was believing HIV could be transmitted in ways it cannot (e.g. public restrooms). It also goes beyond my survey and addresses social misconceptions such as the belief that HIV exclusively affects homosexuals. After students fill out a worksheet where they indicate their beliefs, the teacher gives a comprehensive lesson on the origin of HIV, the history of HIV, the symptoms and effects of HIV, and general knowledge surrounding HIV, stopping along the way to give students activities to keep them engaged. The lesson covers every question on my survey.

I would recommend that students take my survey one week after completion of this lesson, to test if they retained the information. They should be able to answer every question correctly. Some would have already taken the survey, but it would have been about one year before, so it is doubtful that many students would remember the questions.

However, it is still extremely important to cover HIV in classes besides health. This is especially true in terms of how HIV is transmitted, because if somebody does not know how HIV is transmitted, they cannot know how to avoid contracting it. Ultimately, further integrating HIV into the curriculum would almost definitely reduce the chances of students contracting the virus.

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## Making a Multiple Regression Mathematical Model to Predict the UEFA Champions League, Annually

by Liam Cryan

## Abstract

his experiment is based on the question: Is it possible to develop an effective model that can accurately predict the result of the Union of European Football Association's Champions League (UEFA) each year? The independent variable(s) is each statistic/variable used in the model(s); and the dependent variable(s) is the result (prediction) of each model. The experimental design is based on a linear mathematical multiple regression model. The multiple regression model assesses the combination of multiple variables to see how and to what extent they affect a certain outcome. In this model, a combination of six variables are used and set equal to y-values assigned to ending tournament places/results for each team. The stats used in the experiment were from public data hubs and information from other studies. Then this data was input into model after model. Each time a model was run, it was analyzed for successful patterns to find ways to improve the next model to make the final version as accurate as possible. The variables used included: cards per game (including both yellow and red), goal differential per game, shots on target per game, highest player rating per area on the field (averaged), percent possession per game, shots on target per game allowed by the defense, and a league weighting factor. This model was successful at predicting which teams will make it and be eliminated in the round of 16, and which teams will make it to the semi finals. However, it was less successful at predicting the winner, and it is pretty inconsistent at indicating how and why which teams are eliminated in the group stages and guarter finals.

## **Background/Introduction**

This study attempts to use a multiple regression model to predict the outcome for each team in the UEFA Champions League, more specifically, in what position these teams will finish in this tournament every year. This is done using a combination of six non-directly related soccer variables prior to the tournament. The data on each team is compiled from data on how each competing team did in their league in order to get into the Champions League.

In order to fully understand and conduct the study, scientific papers were read, and Berkeley Carroll teachers helped understand those papers. From, *More Probability Models for the NCAA Regional Basketball Tournaments*<sup>1</sup> (Schwertman, N. C., Schenk, K. L., & Holbrook, B. C., 1996), it was learned that competing teams need to be tiered, and a specific mathematical formula must be created in order to create a model. Through reading *Differentiating the Top English Premier League Football Clubs from the Rest of the Pack: Identifying the Keys to Success*<sup>2</sup> (Oberstone, J., 2009), it was learned that of all the possible variables to consider, the ideal combination is 6. The reasoning is that using a combination of six variables gives enough consideration to what makes a soccer team good without too much variation. Some of the six variables to consider were red cards, some form of goal scoring, and a

passing value. A multicollinearity test must be conducted as well. That is a test that determines if the independent variables being used in the linear mathematical multiple regression model are highly correlated, which is bad. This is bad because if variables are correlated, they influence each other's importance to the model. A variable can go from being worth one sixth of the model to being worth the entire model. This must be done when each model is finalized. A linear regression model uses this standard form:  $y = a + bx_1 + bx_2 + bx_3 \dots$  formula. Thus the variables identified from doing research on the UEFA Champions League would be put into a multiple regression system. This system would find each b value and indicate which b values needed to be multiplied by each variable  $(x_1, x_2, x_3, \text{etc.})$  For example, for every team, the b value would be multiplied with its corresponding possession variable. Then these values (products of b and x for each variable) must be added together. The next step is to see how close these added values are to the y value set for each team. The a value is 0 because each team starts from/is worth nothing at the beginning of each tournament in this model. Each y value set for every team is related to where they finish in the tournament. VassarStats was used to compute the model. The models were created by putting the combined variables and assigned y values into the system, and VassarStats then showing the corresponding b values. These new values are added up, with the highest value being the best team and the lowest being the worst.

Two more papers were read to solidify the reasoning of the methods and variables used in the experiment. *Statistical Modeling for Soccer Games: The Greek League*<sup>3</sup> (Karlis, D., & Ntzoufras, I., 1998) said that it's important to include a stage by stage/game by game calculation because teams can have high/good stats prior to the tournament, meaning they have a high chance of winning, but they can lose games in the tournament, and because of the knockout procedure in the UEFA Champions League that means elimination. Therefore, the prior tournament six-variable combination should be used during the tournament with UEFA Champions League. *Examining Influential Factors and Predicting Outcomes in European Soccer Games* (Magel/Department of Statistics, 2014), supported the reasoning of using yellow/red cards per game and goal differential variables: these two stats heavily influence or indicate how teams perform during games, and from game to game.

## Materials

*Mathematical Sources:* Google Sheets and VassarStats. *UEFA Champions League Data sources:* Wikipedia, Who Scored, Optapro, and UEFA Champions League site. Some variables from these sources were manipulated by the experiment to make new variables.

## Methods/Procedure

An excel spreadsheet was used to keep track of all the data and models. Y-values were made for each team: winner is 1, second place is .875, semifinal elimination is .5, quarterfinal elimination is .25, round of 16 elimination is .125, and getting eliminated in the group stage is 0. These numbers were picked because as the tournament progresses teams get better, and the assumption is that each round is twice as difficult as the previous one. First place is twice as good as the semifinal eliminated teams. Variables were gathered from UEFA Champions League sources and each competing team's league. A combination of variables were picked—4-6 variables per combination. Certain data was picked from specific sources based on variables that were found by the scientific papers to be important in a winning team, and by the patterns and data analyzed from each model in the experiment. For example, red cards are a "must-have" variable in any model. Losing a player in a game means playing with a man down, usually meaning teams who get a lot of red cards tend to lose more often. These variables were

set equal to the y-values selected for each team. These variables were put into the VassarStats multiple regression system. It got the b values for each variable from the VassarStats system. These b values were multiplied by each corresponding variable, these values were then added up together (the formula was:  $y = a + bx_1 + bx_2 + bx_3 \dots$  the a is 0 in this study). A weighting system for each team in the tournament was created. It was based on the maximum number of teams in the tournament per league: to get the weight, the number of teams from a certain league in the tournament was put in the numerator, and the greatest number of teams possible from a league (or leagues) was put in the denominator. This would get a decimal, and it would be multiplied by each team's predicted value from their stats from the combination of variables picked. This multiplied value was the sum of the b values which were multiplied by each of their corresponding variables. After doing this, trends were sought. Things such as consistency in the separation of tiers, meaning the clear separation of when each team is eliminated with values similar/replicated to the y-values already set, were looked for in each model. The tiers were the different knockout stages of the tournament. The highest sum being the best, and the lowest being the worst. The dependent variable(s) was the outcome/accuracy of each model. The outcomes for each team were tiered/separated between elimination round. For example, teams eliminated in the quarterfinals should all be around the same value, and are clearly worse than the teams eliminated in the semifinals, which should all also have their own similar value. The control variables are the results of each tournament that are being mimicked to verify the model's accuracy.

After examining some models, a variable and/or variables would be looked at in order to determine what are causing certain trends in the models. Variables were added and subtracted from the model to see how this impacted the accuracy of the model. This was done in the context of other models, scientific papers, prior knowledge, and the results of the tournament. These findings and other analysis would help create better models. This was done until an accurate model was found. A multicollinearity test was conducted to make sure no two independent variables were directly correlated. The test indicated everything was fine. This indicated there was not redundant/influencing variables in the model.

## **Results**

### Chart 1

Chart 1 shows the process of how the final model came about. When running baseline models, possession, goals scored, and a marquee player rating were part of each model's variable mix. Of these altered baseline models, models 3, 11, 13, and 14 are significant because they indicated which variables were and were not important towards creating a better model. For example, shots on target were added to model 3 and as a result it demonstrated more separation in tiers and the right descent in value for each team. Models 11 and 13 had a different kind of dribbling variable in each one of them, but because values from these models were lowered and tiering of teams became a bit off, these two models suggested dribbling variables were not good for indicating a Champions League winning team. From this realization, it was revealed that team stats are more effective at determining what makes Champions League winning team. Therefore, in model 14 one marquee player rating (Champions League winning teams usually have a team of the year player in them) turned into an average rating for the team--based on data from models 11 and 13. The amount of cards a team receives per game was another variable added to model 14. This variable was added to the model thanks to information discovered from one of the papers, Examining Influential Factors and Predicting Outcomes in European Soccer Games (Magel/Department of Statistics, 2014). Shots allowed by the defense became a variable in the final model because it became more clear a balance of statistics in offense and defense for each team is crucial. If all

statistics were taken from a defensive or offensive point of view, things could get skewed. A team with the best mix of defense and offense has a better chance of winning. These new variables were applied to model 14, the final model, because they prove to be most efficient at predicting how teams will do in the tournament. The final model consisted of average rating, cards per game, goal differential per game, average percent possession per game, shots on target per game, and shots on target allowed by the defense. After putting it in VassarStats, this was all weighted by the league relative weight for each team in the tournament. Model 14 demonstrated effective separation of tiers, descent in team value, and the closeness in competition (the difference in team values were very close).

Model Results	Model 0	Model 3	Model 11	Model 13	Model 14
FC Barcelona	0.2753	0.8884	0.320938	1.210996	6.108285105
Juventus	0.0929	0.7795	0.123222	1.1057915	5.773593632
FC Bayern München	0.2929	0.6799	0.33636	1.077045	6.074365
Real Madrid CF	0.183	0.6968	0.198196	1.058852	5.941702053
Club Atlético de Madrid	0.0777	0.2364	0.142834	0.658428	5.764260632
AS Monaco FC	-0.0074	0.392	-0.006656	0.737693	5.635704316
Paris Saint-Germain	0.1207	0.5223	-0.029827	0.8847385	5.689566263
FC Porto	0.2062	0.4118	0.2173779875	0.8458105688	5.661346439
Arsenal FC	0.1568	0.1822	0.020822	0.648089	5.615696947
FC Basel 1893	0.0385	0.2711	-0.1030073375	0.6327368563	5.49918366
Chelsea FC	0.1638	0.2318	0.194652	0.653624	5.430760789
Borussia Dortmund	0.15	0.2511	0.05945	0.59726	5.606558
Bayer 04 Leverkusen	0.042	0.2238	-0.109112	0.569336	5.495464706
Manchester City FC	0.082	0.2462	0.003364	0.579963	5.465914579
FC Schalke 04	0.1007	0.2479	-0.20701	0.67479	5.502211882
FC Shakhtar Donetsk	0.104	0.1709	0.0661926625	0.6503368563	5.49918366
AFC Ajax	0.045	0.1199	-0.056053	0.58588775	5.543466471
RSC Anderlecht	0.0497	0.0478	-0.0466073375	0.4578368563	5.49918366
APOEL FC	-0.0008	0.0833	-0.2158073375	0.3851368563	5.49918366
Athletic Club	-0.0087	0.0836	-0.068396	0.441553	5.55886
FC BATE Borisov	0.0064	0.0612	-0.4226073375	0.4435368563	5.49918366
SL Benfica	0.024	0.0065	-0.1022220125	0.4043105688	5.408519772
PFC CSKA Moskva	0.0293	0.0852	-0.119947	0.396791	5.348268667
Galatasary AS	0.0003	0.1101	-0.2774455	0.60029275	5.470625294
Liverpool FC	0.0481	0.1207	-0.137622	0.431326	5.463601316
PFC Ludogorets Razgrad	0.0299	0.0797	-0.1782073375	0.5121368563	5.49918366
Malmö FF	0.0239	0.0825	-0.2158073375	0.4344368563	5.483459216
NK Maribor	0.0014	0.1026	-0.1782073375	0.4541368563	5.49918366
Olympiacos FC	0.0725	0.0093	-0.0654073375	0.4494368563	5.49918366
AS Roma	0.067	0.1001	-0.128005	0.48389	5.439863316
Sporting Clube de Portugal	0.0871	0.0249	-0.0270220125	0.4002105688	5.473139772
FC Zenit	-0.0117	0.0379	-0.066889	0.469712	5.589917333

Color Key

= 1st Place = 2nd Place

= Semi-finals

= Quarter-finals

= Round of 16

= The Group Stages

## Chart 2

This is the result of the model run on UEFA Champions League from 2014 to 2015 to see if the model is accurate.

2014-2015 Affirmation	Best Player in Each Position Avg.	Cards PG	Goal Diff. PG
FC Barcelona	8.086666667	-1.921052632	1.763157895
Juventus	7.63	-1.894736842	1.5
FC Bayern München	7.956666667	-1.382352941	2.088235294
Real Madrid CF	7.83	-2.052631579	1.736842105
Club Atlético de Madrid	7.33	-2.631578947	1.342105263
AS Monaco FC	7.416666667	-1.684210526	0.8421052632
Paris Saint-Germain	7.496666667	-1.631578947	1.605263158
FC Porto	7.445632184	-1.465479815	1.066666667
Arsenal FC	7.546666667	-1.526315789	0.7105263158
FC Basel 1893	7.2466666667	-0.9117647059	0.955555556
Chelsea FC	7.53333333	-1.631578947	1.157894737
Borussia Dortmund	7.7366666667	-1.352941176	1.235294118
Bayer 04 Leverkusen	7.466666667	-2.117647059	0.5588235294
Manchester City FC	7.5566666667	-1.921052632	1.710526316
FC Schalke 04	7.53333333	-1.794117647	0.5882352941
FC Shakhtar Donetsk	7.2466666667	-0.9117647059	0.955555556
AFC Ajax	7.2466666667	-0.9117647059	1.205882353
RSC Anderlecht	7.2466666667	-0.9117647059	0.955555556
APOEL FC	7.2466666667	-0.9117647059	0.955555556
Athletic Club	7.2766666667	-2.184210526	0.7105263158
FC BATE Borisov	7.2466666667	-0.9117647059	0.955555556
SL Benfica	7.445632184	-1.465479815	1.333333333
PFC CSKA Moskva	7.3066666667	-1.333333333	0.7666666667
Galatasary AS	7.2466666667	-0.9117647059	0.7941176471
Liverpool FC	7.5566666667	-1.447368421	1.342105263
PFC Ludogorets Razgrad	7.2466666667	-0.9117647059	0.955555556
Malmö FF	7.2466666667	-0.9117647059	0.8666666667
NK Maribor	7.2466666667	-0.9117647059	0.955555556
Olympiacos FC	7.2466666667	-0.9117647059	0.955555556
AS Roma	7.43	-2.342105263	1.236842105
Sporting Clube de Portugal	7.445632184	-1.465479815	1.133333333
FC Zenit	7.52	-1.620689655	1.172413793

Avg. % Poss. During Season	Shots OT PG	Shots OT PG Allowed by the Def.	Y-Values	Relative League Weight	Results
63.7	6.9	-8.9	1	1	7.058557088
54.4	5.9	-10	0.875	0.5	3.308613079
71.1	7.6	-8.9	0.5	1	6.85751802
56.8	7.9	-10.9	0.5	1	6.509620368
49.2	5.2	-8.9	0.25	1	6.436521421
55	5	-9.8	0.25	0.5	3.260674254
61.8	6.1	-9.7	0.25	0.5	3.24317457
57.3137931	6.103448276	-10.54827586	0.25	0.75	4.777322967
55.7	5.6	-11.9	0.125	1	6.439795719
59.9	6.1	-10.2	0.125	0.25	1.55072468
53.9	6	-10.3	0.125	1	6.486227018
53.8	7.2	-9.8	0.125	1	6.593436608
50.3	5.5	-13.4	0.125	1	6.238037255
55.7	6.3	-9.4	0.125	1	6.532599877
50.4	5.4	-13.4	0.125	1	6.332378627
59.9	6.1	-10.2	0.125	0.25	1.55072468
59.9	6.1	-10.2	0	0.25	1.551300431
59.9	6.1	-10.2	0	0.25	1.55072468
59.9	6.1	-10.2	0	0.25	1.55072468
53	4.9	-11	0	1	6.282643982
59.9	6.1	-10.2	0	0.25	1.55072468
57.3137931	6.103448276	-10.54827586	0	0.75	4.779162967
51.6	5.7	-11.6	0	0.5	3.098943667
59.9	6.1	-10.2	0	0.25	1.550353373
54.8	6.8	-12.6	0	1	6.256094614
59.9	6.1	-10.2	0	0.25	1.55072468
59.9	6.1	-10.2	0	0.25	1.550520235
59.9	6.1	-10.2	0	0.25	1.55072468
59.9	6.1	-10.2	0	0.25	1.55072468
57	5.7	-10.8	0	0.5	3.179753342
57.3137931	6.103448276	-10.54827586	0	0.75	4.777782967
55	6.2	-12.4	0	0.5	3.150328759

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Color Key

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## Chart 3

This is the result of the model run on UEFA Champions League from 2015 to 2016 to see if the model is accurate.

2015-2016 Affirmation	-2016 Affirmation Best Player in Each Position Avg.		Goal Diff. PG
Real Madrid	7.916666667	-2.342105263	2.105263158
Atlético Madrid	7.39	-3.131578947	1
FC Bayern München	7.733333333	-1.147058824	1.823529412
Manchester City FC	7.7366666667	-2.131578947	1.184210526
FC Barcelona	8.0766666667	-1.86842421053	2.342105263
SL Benfica	7.3766666667	-1.934210526	2.058823529
Paris Saint-Germain	7.6066666667	-1.763157895	1.236842105
VfL Wolfsburg	7.5566666667	-1.352941176	1
Arsenal FC	7.603333333	-1.868421053	0.9210526316
Chelsea FC	7.61	-2.052631579	1.078947368
FC Dynamo Kyiv	7.3766666667	-1.934210526	1.36372549
KAA Gent	7.46	-1.720588235	1.36372549
Juventus	7.47	-2.105263158	1.263157895
PSV Eindhoven	7.65	-1.117647059	1.794117647
AS Roma	7.123333333	-2.921052632	0.6052631579
FC Zenit	7.456666667	-2	1.366666667
FC Astana	7.46	-1.720588235	1.36372549
FC BATE Borisov	7.46	-1.720588235	1.36372549
PFC CSKA Moskva	7.35	-1.105263158	1.333333333
GNK Dinamo Zagreb	7.46	-1.720588235	1.36372549
Galatasaray AS	7.27	-2.323529412	0.7352941176
Bayer 04 Leverkusen	7.496666667	-2.411764706	0.7352941176
Olympique Lyonnais	7.586666667	-1.710526316	1.026315789
Maccabi Tel-Aviv FC	7.46	-1.720588235	1.36372549
Malmö FF	7.46	-1.720588235	0.9333333333
Manchester United FC	7.373333333	-1.868421053	0.6578947368
VfL Borussia Mönchengladbach	7.473333333	-1.676470588	0.7941176471
Olympiacos FC	7.46	-1.720588235	1.36372549
FC Porto	7.3766666667	-1.934210526	1.794117647
Sevilla FC	7.013333333	-3.131578947	1.794117647
FC Shakhtar Donetsk	7.376666667	-1.934210526	1.36372549
Valencia CF	7.156666667	-3.078947368	1

Avg. % Poss. During Season	Shots OT PG	Shots OT PG Allowed by the Def.	Y-Values	Relative League Weight	Results
56.2	7.4	-11.9	1	1	6.527400351
49.4	4.9	-8.6	0.875	1	6.320517789
65.8	6.9	-7.5	0.5	0.8	4.886274667
57	6	-10.2	0.5	0.8	5.041416449
65.3	7.2	-8	0.25	1	6.58470993
56.95	5.43333333	-9.9	0.25	0.4	2.417771493
61.1	5.8	-10	0.25	0.4	2.437007467
54	6.1	-12.2	0.25	0.8	4.759362227
55.7	6	-10.7	0.125	0.8	4.889331256
54.1	5.5	-10.9	0.125	0.8	4.948787032
52.1	7.5	-9.9	0.125	0.4	2.397922003
52.1	7.5	-13.2	0.125	0.2	1.190895012
55.7	5.3	-10.6	0.125	0.4	2.436932084
52.1	7.5	-12.6	0.125	0.2	1.205538235
57.5	4.6	-10.3	0.125	0.4	2.371939396
55.8	5.2	-8.7	0.125	0.4	2.441447467
52.1	7.5	-13.2	0	0.2	1.190895012
52.1	7.5	-13.2	0	0.2	1.190895012
55.3	6	-9.1	0	0.4	2.320317053
52.1	7.5	-13.2	0	0.2	1.190895012
54.6	5.3	-13.8	0	0.2	1.175444024
51.5	5.7	-8.8	0	0.8	4.959134651
56.3	5.7	-10.7	0	0.4	2.428616435
52.1	7.5	-13.2	0	0.2	1.190895012
52.1	7.5	-13.2	0	0.2	1.183819365
58.8	4.7	-10.1	0	0.8	4.723694793
53	5.1	-15.4	0	0.8	4.71546309
52.1	7.5	-13.2	0	0.2	1.190895012
56.95	5.43333333	-9.9	0	0.4	2.409067964
49.9	4.9	-11.7	0	1	6.008719593
52.1	7.5	-9.9	0	0.4	2.397922003
50.8	4.2	-10.8	0	11	6.07171814

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Color Key

= 1st Place = 2nd Place

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### Chart 4

This is a prediction of which team will win this year's tournament. The teams in red are set to one because they have not been eliminated yet and have the potential of winning the tournament still. The other teams are set to 0 because they have been eliminated already, and that was the first round of the tournament. As already established, being eliminated in the first round for y values equates to 0.

2016-2017 UCL Predictions	Best Player in Each Position Avg.	Cards PG	Goal Diff. PG
Arsenal	7.62	-1.210526316	0.7631578947
PSG	7.653333333	-1.263157895	2.184210526
SSC Napoli	7.25	-1.921052632	1.263157895
Benfica	7.2066666667	-2.149122807	1.941176471
Barcelona	8.01	-1.763157895	2.184210526
ManCity	7.453333333	-1.605263158	0.7894736842
Atlético Madrid	7.53	-2.447368421	1.184210526
Bayern Munich	7.41	-1.470588235	1.852941176
Monaco	7.05	-2.315789474	0.1842105263
Bayer 04	7.193333333	-2.088235294	0.4705882353
Dortmund	7.223333333	-1.147058824	1.411764706
Real Madrid	7.85	-2	2
Leicester City	7.616666667	-1.421052632	0.8421052632
FC Porto	7.2066666667	-2.149122807	1.088235294
Juventus	7.486666667	-2.605263158	1.447368421
Sevilla	6.916666667	-2.868421053	0.2368421053
Lyon	7.343333333	-1.894736842	0.6315789474
Dynamo Zagreb	7.513333333	-1.75	1.411764706
Kobenhavn	7.513333333	-1.75	1.411764706
Club Brugge	7.513333333	-1.75	1.411764706
Sporting	7.2066666667	-2.149122807	1.705882353
Legia Warszawa	7.513333333	-1.75	1.411764706
Tottenham	7.523333333	-1.894736842	0.8947368421
CSKA	7.28	-1.9	0.8666666667
FC Rostov	7.1066666667	-2.533333333	0.7
PSV Eindhoven	7.723333333	-1.529411765	1.647058824
Celtic	7.513333333	-1.75	1.411764706
Borussia MG	7.386666667	-1.470588235	0.5
Beskitas	7.303333333	-1.970588235	1.176470588
Dynamo Kyiv	7.513333333	-1.75	1.411764706
FC Basel	7.513333333	-1.75	1.411764706
PFC Ludograts	7.513333333	-1.75	1.411764706

Avg. % Poss. During Season	Shots OT PG	Shots OT PG Allowed by the Def.	Y-Values	Relative League Weight	Results
56.9	5.6	-11.8	1	1	4.571251053
63.4	6.6	-9.6	1	0.75	3.538025132
59.3	6.4	-9	1	0.5	2.195572895
57	5.46666666	-10.5	1	0.75	3.494995991
62.9	7	-9.6	1	1	4.798916842
55.2	5.5	-8.9	1	1	4.567586316
48.7	4.4	-9.7	1	1	4.835514737
66.4	7.7	-7.5	1	1	4.364178824
48.7	4.4	-12.5	1	0.75	3.291367895
52	5.5	-10.6	1	1	4.260550588
61	6.3	-8	1	1	4.440918235
56	7.6	-11.3	1	1	4.13637
44.8	4.7	-13.6	1	1	4.331463684
57	5.46666666	-10.5	1	0.75	3.434159961
54.9	5.7	-8.9	1	0.5	2.339646053
49.6	4.7	-14.2	1	1	4.270929474
58.9	5.4	-9.4	0	0.75	3.540919342
54.85	6.65	-11.25	0	0.25	1.042369706
54.85	6.65	-11.25	0	0.25	1.042369706
54.85	6.65	-11.25	0	0.25	1.042369706
57	5.4666666	-10.5	0	0.75	3.478213638
54.85	6.65	-11.25	0	0.25	1.042369706
55.3	6.6	-11.1	0	1	4.186332105
56.4	5.4	-8.4	0	0.5	2.31091
47.9	4.3	-11.6	0	0.5	2.259461667
53.8	7.2	-11.7	0	0.25	1.003662794
54.85	6.65	-11.25	0	0.25	1.042369706
54.6	5.6	-13.4	0	1	4.301524118
55.9	6.1	-10.8	0	0.25	1.081076618
54.85	6.65	-11.25	0	0.25	1.042369706
54.85	6.65	-11.25	0	0.25	1.042369706
54.85	6.65	-11.25	0	0.25	1.042369706

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Color Key

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## Chart 5

A neater prediction of the 2016-2017 UEFA Champions League tournament. This shows Atletico Madrid winning, with Barcelona in second. Arsenal and Manchester City will finish in the semi-finals. Leicester City, Dortmund, Bayern Munich, Sevilla, look to be eliminated in the quarter-finals. The likes of Paris Saint Germain, Napoli, Benfica, Monaco, Bayer 04, Real Madrid, Porto, and Juventus look to be gone in the round of 16.

2016-2017 UCL Predictions	Results			
Atlético Madrid	4.835514737			
Barcelona	4.798916842			
Arsenal	4.571251053			
ManCity	4.567586316			
Leicester City	4.331463684			
Dortmund	4.440918235			
Bayern Munich	4.364178824			
Sevilla	4.270929474			
PSG	3.538025132			
SSC Napoli	2.195572895			
Benfica	3.494995991			
Monaco	3.291367895			
Bayer 04	4.260550588			
Real Madrid	4.13637			
FC Porto	3.434159961			
Juventus	2.339646053			
Lyon	3.540919342			
Dynamo Zagreb	1.042369706			
Kobenhavn	1.042369706			
Club Brugge	1.042369706			
Sporting	3.478213638			
Legia Warszawa	1.042369706			
Tottenham	4.186332105			
CSKA	2.31091			
FC Rostov	2.259461667			
PSV Eindhoven	1.003662794			
Celtic	1.042369706			
Borussia MG	4.301524118			
Beskitas	1.081076618			
Dynamo Kyiv	1.042369706			
FC Basel	1.042369706			
PFC Ludocrats	1.042369706			

### Color Key

= 1st Place

= 2nd Place = Semi-finals = Quarter-finals

- = Round of 16 = The Group Stages

## Analysis

The final model (model 14) is somewhat successful. For the most part, it keeps teams within the tiering, meaning the color/position of each team when the tournament finished is mostly in the right order. When looking at chart 1, the progression in accuracy amongst the models is clear. Teams are closer together in value in each respective tiering, and the separation in tiers is better. Model 14 being the final model, shows each team's value consistently descending in worth from Barcelona down. This final model is the best representation of the work completed so far because it has built upon indications of past models, and information from the papers read to be at its current success. It actually uses 6 variables to make a prediction, it encompasses stats in soccer that are important, and it uses stats that define the team as a whole successfully. On top of this, it tiers the competition well.

When looking at charts 2 and 3, the teams' values descend in the correct order. For 2014-2015, the tiering and values are correct from Barcelona down. For 2015-2016, the tiering and values are also correct but from Real Madrid down. This indicates the model is doing its job. It is successfully replicating results from the past, meaning the model is able to accurately predict tournaments in the future.

However, there are sometimes mistakes in the predictions, nothing major only minor things for which there can be adjustments. Like in model 2, it shows Arsenal should finish/be eliminated later than Benefia. This information from the models is an indication that two types of predictions for the UEFA Champions League will need to be done: a prediction prior to the tournament, and a prediction during the tournament right after the group stages end, but right before the knockout stages begin. This way there can be more accuracy as the tournament goes on, and it may be possible to see if variables that are important in winning a league are also important for winning a tournament. Instead of using league data to fill in for the variables, similar tournament data will be used instead. These values will be used to determine when head to head matches happen, which team will be eliminated, and which will succeed. A grand prediction needs be done at the beginning, and stage predictions need to be done too.

## Conclusion

It is difficult to determine a clear cut winner for the tournament, but it is easy to see where certain teams will finish. Teams in each tier are more or less the same quality, especially at the bottom half of my model's table. The problem currently faced is not determining who would not win, but who will win. If one looks at the top four teams of the model, there are times the model indicates the third and fourth place teams will do better than the second place team. Sometimes, these two lower teams do even better than the first place team. The one thing the model is good at doing is determining the top four teams of the tournament. Going forward, there is potential for analyzing how this data changes as the tournament goes on, and/or to create a separate model for the top four teams. This way there is a system that differentiates the quality of these teams and the potential of them winning the tournament. When teams are this close in quality, it is the finest of details that separate them. For example, instead of analyzing shots on target, why not a ratio of shots on target from inside and outside the box? It is this new data that may help best.

## Discussion

The limitation I had for this experiment was the amount of data available to me for free because even though there was a fair amount, my predictions can only be general as I did not have the specific details that make up a winning team. Good teams who are capable of winning the tournament are differentiated by those who are not by small meticulous things. Since this experiment is new, and I have been using information from one year and a variety of sources, my data may be too narrow and mixed up. If I had accessed and standardized more information, and tested my models more, I may have been able to find a better model; meaning, I would have found the right variables and patterns to indicate what makes a Champions League winning team every year.

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# Changes in Instant and Delayed Gratification by Age

by Nathaniel Dunn

## Abstract

his paper will attempt to explore how age affects the perceived value of delayed gratification. Delayed gratification is the ability to put off an immediate reward for a larger reward in the future. It is the opposite of instant gratification which is when someone takes an immediate reward instead of a larger reward available in the future. The experimental question will be tested by asking participants of different ages to complete a boring task in exchange for a reward. The participants are then told that the longer they stay, the bigger the reward they will receive. The independent variable in this experiment is the age of participants while the dependent variable is the amount of time the participants spend on the task. Thus far, there was not enough variety in the data, nor were there enough samples taken which prompted no significant conclusions to be made.

## Introduction/Background

Every human being is affected by gratification. Almost every decision we make in our lives is in some way impacted by our desires. In these moments of decision making, we usually make choices that fulfill our desires in either the present or the future. Therefore, our choices to achieve gratification have been divided by scientists into two categories: instant and delayed gratification. Instant gratification is making a choice that brings a person satisfaction in the present. This term is used for situations where choosing satisfaction in the present sacrifices greater satisfaction in the future. Delayed gratification on the other hand is defined as sacrificing pleasure in the present for greater pleasure in the future. An example of this would be if you were to offer someone the option to either receive a dollar now or 20 dollars tomorrow. A person who chooses the dollar would be classified as expressing instant gratification while the person who waited a day for the 20 dollars would be said to express delayed gratification. It is said that those who express delayed gratification have better judgement and are therefore more successful in life.

In the famous 1972 Stanford study, *Cognitive and Attentional Mechanisms in Delay of Gratification*, more commonly known as the "Marshmallow Experiment," Mischel (1972) found that children who expressed delayed gratification were much more successful later in life. In this study, children were given a marshmallow and told that if they waited ten minutes they would receive another marshmallow. The children who waited the ten minutes were said to have delayed gratification and were found to be more successful later in life than the ones who did not wait. This success was defined by higher SAT scores and higher college graduation and employment rates. An even more compelling side of the research around judgement is how it varies with age. Adolescents have particularly bad judgment because of their developing prefrontal cortex writes Caleza (2016). In some instances, such as the presence of peers, adolescents can exhibit worse judgement than younger children. In fact, adolescents are the only group of humans whose judgement is significantly impaired when in the presence of their peers. Adolescents are very likely to make risky decisions, that they would never make while alone, when they are with people in a similar age range according to Steinberg (2009).

This experiment aimed to continue the research done with regard to making decisions based on desire and how this differs based on age. Although there has been a great deal of research done on gratification and success (Stanford marshmallow experiment), less has been done on gratification at different ages, especially when comparing those solely under the age of 18. This experiment aimed to find out whether age affects one's ability to delay gratification. The alternative hypothesis was that as people get older, they are more able to delay gratification. The null hypothesis was that all ages exhibit equal ability to delay gratification. This hypothesis was tested by asking participants to complete a random task for a certain amount of time in exchange for a reward. After five minutes of doing the task, participants were offered the opportunity to stop and leave but in doing so, they would no longer be able to receive the reward. The longer the participants do the task, the bigger the reward would be.

The findings from this experiment have the potential to be of great use to both parents and educators. A stronger understanding of young people's ability to delay gratification could be tremendously useful when trying to assess someone's ability to do their work. It would potentially encourage new approaches to teaching if concrete evidence were found to support the idea that people at certain ages are incapable of delaying gratification. This question was addressed in this experiment as it asked participants to engage in a boring task in exchange for a reward.

### Methods

The experiment required three different age groups to be tested; lower schoolers (ages 5-9), middle schoolers (10-13), and high schoolers (14-18). Each group needed to have at least 20 participants and a slightly different experimental design to account for differences in age-related behaviors.

Although the experiment needed to be conducted with all three age groups, it was only conducted with the oldest age group. The oldest test group (age 14-18) was asked to sort white and brown rice for 30 minutes with the opportunity to receive rewards that increased at 5 minute intervals. The participants were not allowed to talk or do anything aside from sorting the rice. Every 5 minutes participants were given the opportunity to leave. If they left after 5 minutes they received no reward; if they left after 10 minutes their reward would be small and would grow for every 5 more minutes they stayed. After the experiment was finished a survey was sent to all of the participants asking why they stayed or left when they did. They were then asked if they left because they were bored, didn't want the reward or had to leave for another reason. Those who stayed longer were asked if they stayed because they wanted the reward, felt pressured to stay, wanted to be helpful, or if they stayed for another reason. Those whose reasons for staying and leaving were not because they wanted the reward or were bored were supposed to be discarded because their decision was not based on gratification. However, because the majority of the twelfth grade test group did not want the reward, the results of every participant were used to avoid having to remove the data of an entire age group.

Had the experiment been conducted with the younger age groups, a slightly different procedure would have been necessary. In the youngest age group (ages 5-9), participants would have been directed to sit in a room without doing anything for 10 minutes. They would have been given the option to leave at any point but also told that if they stayed for 5 minutes they could receive a prize of either a food or candy of their choice and that if they stayed for 10 minutes they would be given a second portion of that food or candy.

For middle test group (ages 10-13), the method would have been similar to the Lower School experiment with a few exceptions. Instead of sitting for 10 minutes students would have been asked to sort white and brown rice for 20 minutes and told that the experiment was testing productivity based on time of day to make sure they didn't try to show they have the ability to delay gratification. Their rewards would have increased at intervals of 5 minutes and would have been offered larger rewards at the 5, 10, 15 and 20 minute marks.

## **Results/Discussion**

Overall, few conclusions can be derived from the results of this experiment. Although this experiment aimed to find differences between judgement and age, due to the fact that only one reward (food) was allowed to be offered to students, the results are misleading. While Chart 1 indicates that twelfth graders spent the least amount of time on the task it is not because they necessarily have the least patience, rather it is because they did not have a desire for the reward. Although the method originally called for the results of those who did not want the reward to be discarded, it was decided this should not happen as there was already a shortage of data and participants. Had rewards such as school related privileges or even cash been offered, there might have been different results. The table and chart below show the outcomes for the experiment, including subjects' grade, time spent on task, reward chosen and why they decided to stop doing the task or continue doing it.

## Chart 1

### Average Time Spent on Task

Average time spent in room by each grade tested



### Table 1

Average time spent by grade and primary reason for ending task

Grade	Sample Size	Average Time Spent (minutes)	Measure of Spread (Standard Deviation)	Primary Reason for Leaving
9	5	20	8	Subject was satisfied with reward at their remaining time
10	7	20	5	Subject was satisfied with reward at their remaining time
11	14	17	8	Subject was satisfied with reward at their remaining time
12	4	8	55	Subject did not want reward

In the end, the greatest problem with this experiment was that it simply was not feasible given the environment. After the first trial with the oldest age group it was discovered that they were not capable of being in a room with peers. In three separate trials with multiple teenage participants, the participants either stopped doing the task or began using their phones and refused to follow instructions. After a trial was conducted with one participant, this problem subsided and therefore the remaining trials were all conducted with only one person at a time. Because of limited amounts of time, fewer trials were conducted than originally hoped for. Another setback for the experiment was the lack of rewards available for participants. Furthermore, for logicistal reasons the experiment could not be carried out with the younger test groups. When conducting the experiment there needed to be a place for the participants to go if they decide to opt out of the task. This was not available for the younger groups because the experiment was only allowed to be conducted during periods of time where participants would have had to go back to their class if they wanted to leave, something that might have in many cases been less preferable than the task itself. As a result, if the experiment was conducted it would be impossible to make any legitimate conclusions.

All and all, the experimental design has the potential to be carried out in the future. However, if this experiment is to be conducted again, two changes would need to be made. One, there would need to be more available rewards such a monetary reward, or in-school privileges. Furthermore, there would need to be a way to be able to conduct the experiment on younger participants while having them in an environment where, should they leave the task, they would be able to go to somewhere enjoyable to them.

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# Happiness at Berkeley Carroll: The Effect of Age and Academics on Happiness in Middle and High School Students

by Alessandro Getzel

## Abstract

iddle and high school students work hard in order to maintain satisfactory grades. This study was designed to determine if age and/or academic achievement impacted the happiness of middle and high school students. The study surveyed students, grades 5 through 11, in the Berkeley Carroll community – using the Oxford Happiness Index (from Mahmoud, 2012). The results of this study suggested that there is no relationship between grade level and happiness or grade point average (GPA) and happiness. However, the results suggested a strong correlation between perceived academic achievement and happiness: students who were pleased with their grades were happier than students who were not. Furthermore, there was a strong correlation between school division and happiness: students in the middle school were significantly happier than those in the high school.

## Introduction

A recent study conducted by Mahmoud et al. (2012) used a variety of systems, surveys, and scales – the Depression Anxiety Stress Scales (DASS-21), a Brain Computer Interface (BCI), the Brief Students' Multidimensional Life Satisfaction Scale (BSMLSS), and the SPSS statistic analysis program – to examine the results of a study taken of 1,700 students (age 18-24) from a public university in the Southwest. The researchers specifically examined these college students for depression, anxiety, stress, and life satisfaction. The experimenters found that, among other results, those with higher grades were happier than those with lower grades<sup>1</sup>. Additionally, older students were significantly happier than their younger counterparts<sup>1</sup>. Unfortunately, these findings were not consistent with other studies on the same subject.

A study conducted by Branko Slivar suggests that more academically motivated students might be at risk of exhaustion. Slivar examined a phenomenon known as burnout: "Burnout may be defined as a state of physical, emotional and mental exhaustion [resulting from] ...involvement... in situations that are emotionally demanding" (Pines & Aronson, 1981 qtd. in 2). The study examined a group of 1,868 students ages 15 to 18 who were given several questionnaires: the Offer Self-Image Questionnaire (OSIQ), the Spielberg Trait Anxiety Questionnaire, and the Maslach Burnout Inventory (MBI). The study found that even academically successful students could experience a high degree of burnout due to the sheer magnitude of their course work<sup>2</sup>. Furthermore, students with burnout were, on average, less engaged, more unhappy, and missed class almost 33% more often than their non-burnt-out counterparts<sup>2</sup>. This study highlights the importance of further study because even academically successful and self-motivated students can become extremely anxious and fall behind.

Another study surveyed two classes of 5th grade students from a northwestern U.S. city – the classes did not differ in size or makeup by gender, race, age, or well being. At the start of the year, subjects took cognitive and affective happiness tests – Student's Life Satisfaction Scale (LSS) and The Positive and Negative Affect Schedule for children (PANAS-C), and IQ tests<sup>3</sup>. These tests were used in order to examine how intelligence impacts happiness. In the spring, report card grades were collected and GPA's were calculated. The study concluded that students who earned higher grades were more likely to have a better mood and well-being (p = .04). Additionally, happier students were significantly more likely to earn higher final grades (p < .001). Furthermore, in their discussion, Quinn and Duckworth say that popular literature suggests "academically successful children are often construed as miserable, made so by their pursuit of achievement"<sup>3</sup>. However, similar to Mahmoud et al.'s study, this study pointed to the polar opposite: that grades are motivators that lead to happiness. Overall, there is virtually no consistent rule about how age and grades affect students. Without further examination of additional factors, it is impossible to get a concrete answer.

Pressures such as anxiety and stress are the focus of the next study which was a summation and analysis of 562 different studies that deal with the topic of test anxiety<sup>4</sup>. Test anxiety (TA) is an increase in stress caused by a major examination and often leads to overthinking, and in turn, worse performance on said examination<sup>4</sup>. Each study focused on a different variable and student samples ranged from pre-kindergarten to postgraduate. Hembree<sup>4</sup> found a significant correlation – regardless of gender, age, or race – that TA is caused primarily by "fears of negative evaluation, dislike of tests, and less effective study skills"<sup>4</sup>. This suggests a chain reaction of fear of negative evaluation causing additional stress and worse grades. Poor grades can lower the confidence of struggling students, resulting in a dislike of tests and poor study skills.

Given that a high degree of unhappiness was caused by academic pressures, those pressures could adversely affect the study of both higher and lower achieving students. The present study was designed to identify if pressures due to age and grade increased unhappiness in the Berkeley Carroll student body. A modified version of Mahmoud et al.'s' experiment was used which included middle and high school students rather than college students. They used an emotion survey called the Oxford Happiness Questionnaire (OHQ). The OHQ was selected because it is a relatively short survey and does not require extra questions, and is designed to see if the test taker is properly reading the questions. Additionally, the survey asks for the subjects' grade level and includes the question: "Do you believe your grades are an accurate representation of how hard you work?" Furthermore, the average grades of all of the students were double-blinded and compared with the survey results. The independent variables were the students' age, grades (first quarter high school grades), and grade satisfaction, while the dependent variable was the OHQ composite. The results were kept confidential and grade satisfaction, GPAs, ages, and OHQ composites were analyzed using a variety of statistical tests: analysis of variation (ANOVA), T-Test, and a linear regression test.

## Procedure

The study attempted to survey all students in the Berkeley Carroll school grades 5 through 11. The 12th grade was excluded due to an unusual amount of stress exerted on high school seniors from the college process. In the pilot study, only twenty students in each grade received the survey and had to complete it on three different occasions. Unfortunately, these results failed to yield statistically significant

results. However, since many subjects did not respond to the survey it was decided to try it again on a larger scale. In the actual study, a single survey was sent out to all students in grades 5 through 11. Although some students still did not respond to the survey, the study received 299 responses.

Surveys were sent to the middle and upper school through Google Forms. The tabulated results were quantified using a one-way analysis of variation test and subsequent t-tests. Lastly, the results were blinded and coupled with first quarter grades (for high school students only) and analyzed through a linear correlation and regression test.

### **Results**

Age:

The results of this experiment were extremely varied: some results were conclusive and others were not. On the one hand, there was a significant difference in happiness between divisions.

### Figure 1

### How Age Affects Happiness by School Division

Middle school students had an average OHQ composite of 4.5 while high school students had an average OHQ composite of 3.9. This suggests that middle school students are almost 20% happier than high school students (Figure 1). The fact that the error bars do not overlap coupled with a P-value < .0001 illustrate that these results are highly significant.



#### **OHQ Composite by School Division**

### Figure 2

### How Age Affects Happiness By Grade Level

However, the same did not hold true on a smaller scale. When examining the happiness levels of students in the same division (e.g. 7th grade students vs other middle school grades) there was no correlation between happiness and grade level. As can be seen in Figure 2, there is no significant relationship between grade level and happiness: all middle school and high school students seemed to be equally happy amongst their peers. The school divisions were each individually analyzed using

independent and unweighted Analyses of Variance (ANOVAs). Among middle schoolers, the p-value was 0.43787 and among high schoolers, the p-value was 0.990051: neither were significant.

In addition to the statistical backing for this information, there is graphical evidence as well: the overlapping error bars for grades 5 through 8 and overlapping error bars for grades 9 through 11.



### **OHO Composite by Grade**

### Academics:

## Figure 3

### **How Grade Satisfaction Affects Happiness**

The significant results were not limited to just age; there was a significant relationship between perceived academic achievement and happiness. Students who were satisfied with their grades yielded an average OHQ composite of 4.3 and students who were unhappy with their grades yielded an average OHQ composite of 3.9 It may seem that these results are close together, but because the questionnaire yields a score of 1-6, this difference is highly significant (p<.0001). Thus, students who were satisfied with their grades were almost 10% happier than those who were dissatisfied.



### **OHO Composite by Academic Satisfaction**

### Figure 4

### Scatter Plot of the Relationship between Happiness and Academic Achievement

Interestingly, the results suggest that satisfaction is much more important than actual grades when considering the happiness of a student. When comparing the double-blinded first quarter GPAs of high school students to the OHQ, the trendline was effectively flat. Furthermore, the coefficient of determination ( $r^2$ ) was 0.00079, which means that there is no significant correlation between grades and happiness in high school students.

Overall, in the first part of the experimental question (age), the alternative hypothesis (correlation between age and happiness) was accepted when dividing the groups by school division (middle and high school). However, the null hypothesis (no correlation between age and happiness) was accepted when dividing the samples by grade and comparing them to other grades in the same divisions. In the second part of my experimental question (academics), when examining the role of academic satisfaction, the alternative hypothesis was accepted (correlation between academic satisfaction and happiness). However, when examining high school students' first quarter grades the null hypothesis was accepted (no correlation between academic achievement and happiness).



### **GPA vs. Happiness**

## Conclusion

In summation, grade satisfaction and age (separated by school division) were the only (tested) factors that impact happiness in a Berkeley Carroll sample. One surprising result was that neither age nor academic achievement had any effect on happiness. This was especially surprising because in the study conducted by Mahmoud et al.<sup>1</sup>, both age and academic achievement had an impact on happiness. Another surprising result was that grade satisfaction had a more significant impact than the grades themselves. While it is true that different grades do not hold the same value for every student (for example a "B+" could be considered great for one student and horrible for another). Mahmoud et al. (2012) found that less academically successful students were significantly more likely to develop depression and thus be unhappy. Students who were pleased with their grades were happier. Younger students, who were likely under less pressure, were happier than older students. However, it was surprising to learn that grades had no impact on happiness because that conclusion is completely antithetical to the results of Quinn and Duckworth's study, Slivar's study, and Mahmoud's study.
## Discussion

Despite yielding significant results, my study was far from perfect. The surveys were sent to students in a variety of grades (including children as young as 11). As one middle school science teacher pointed out: the "double negatives and negative phrasing of the statements" were problematic. They suggested that "some students recorded the opposite of their actual opinions." In the future, it would be best to find a happiness questionnaire that had simpler language or fewer double negatives. Additionally, the study was originally supposed to include the grades of middle school students, but the Berkeley Carroll middle school runs on a trimester system. Therefore, there were no middle school grades from the 2016-2017 school year for me to analyze. Many worry that students place too much pressure on themselves to get good grades. Therefore, the impact of this study was evident: understanding what makes students unhappy is crucial to creating a positive learning environment where students can thrive.

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## Does Prompted or Unprompted Journaling Have an Impact on Positive and Negative Mood?

by Rachel Goluboff

## Abstract

his experiment attempted to determine if prompted journaling (a participant responding to a given prompt) or unprompted journaling (general journaling about one's day) has an effect on mood. In this experiment, the type of journaling is the independent variable while mood is the dependent variable. The study was conducted over four weeks with 15 participants. The impact of journaling on mood was tested by having participants fill out the Positive and Negative Affect Schedule (PANAS) survey before and after their four weeks of journaling. The data showed that the average mood scores for the prompted, unprompted, and control groups were not statistically different. Due to these findings, the null hypothesis was accepted, indicating that neither prompted nor unprompted journaling has an effect on mood.

#### Introduction/Background

In Harvard Health Publications (2005), the adolescent brain is discussed. This letter corroborates multiple studies done on adolescent behavior. The studies reveal that abstract reasoning, the ability to identify patterns, logical rules and trends in new data, integrating information, applying this information to problem solve, and the capacity to plan, are fully formed by the age of 15 or 16. However, adolescents are more likely to make decisions in a heightened emotional state. Teenagers have a harder time interrupting an action after it has begun. For example: before diving into water, teenagers are less likely to check how deep it is. If the water is too low, they could die. According to the many studies conducted, adolescents also have a harder time discerning between safe and risky options. Teenagers find it very difficult to resist pressure from their peers too. Studies cited in the Harvard Mental Health Letter have shown that adolescents are more likely to take additional risks when their friends are watching. Adolescents tend to live in a heightened emotional state. This makes their decision making more reactionary, and often times more dangerous. The emotional state adolescents live in can create many mood swings ("The adolescent brain: Beyond raging hormones," 2005).

Adolescents are notorious for their mood swings (rapid changes in mood). Teenagers' constant heightened emotional state can be explained by their intense hormonal changes during puberty (BBC

Science, n.d.). The BBC Science article, "Teenage Mood Swings" states that any change in hormones is likely to result in reckless behavior, irritability, depressive symptoms, and other negative behaviors. Girls during their adolescent years experience fluctuations in their estrogen and progesterone once they have started their period. Pre Menstrual Syndrome ("PMS") is known to cause intense irritability and mild depression in teenagers and adults who have their period. Teenagers experiencing PMS for the first time are less likely to control their emotional changes during this time due to the newness of the change in their hormones. BBC Science also discusses in this article that a teenagers' changing physical appearance also has a major effect on their mood. As puberty starts, the adolescent body changes, and teenagers are often unsatisfied with their changing appearance. The bodily changes that teenagers experience tend to make them far more self-conscious, which can contribute to their mood swings. Moodiness in adolescence passes with age and confidence increases. However, constant low moods persist in some teenagers rather than going away, and they are diagnosed with depression. Whereas it is highly unusual for a child (someone before puberty) to become depressed, teenagers are more likely to be diagnosed with depression due to the increase in their hormones and heightened emotional state. ("BBC Science | Human Body & Mind | Teenage Mood Swings," n.d). So the question remains: what is an easy and efficient way to combat teenage mood swings? A possible solution could be journaling.

Holloway and Nelson, from the University of Rochester, discuss the effects of journaling on mood in their medically reviewed article "Journaling for Mental Health". (Holloway & Nelson, "Journaling for Mental Health," n.d.). Their article states that writing down your thoughts and feelings can help you understand yourself more clearly. If a person struggles with stress, depression, or anxiety, keeping a journal can help that person gain control of his or her emotions while improving overall mental health. Journaling is a healthy way to process thoughts and emotions. Journaling helps control symptoms and improve mood by helping to prioritize problems, fears, and concerns. Journaling can help someone recognize triggers and learn ways to better self control. Journaling can also provide an opportunity for positive self-talk and identifying negative thoughts and behaviors. Holloway and Nelson also state that keeping a journal can clarify what is causing stress and anxiety. A *Psychology Today* article, "The Art of Journaling," (2015) echoes many of these sentiments and states that the possible positive attributes of journaling is being able to bring your emotions and motivations into perspective with your moral values. Journaling can also convert negative energy into creativity and personal growth, and can make you feel more human. Psychology Today also states that a possible negative attribute of journaling is that one can start to live too much in one's head, and this could make someone a passive observer of one's life. Journaling can make you self obsessed, or possibly cause you to wallow in negative experiences (Sumerson, 2015).

Unfortunately, there have not been many scientific studies done on the impact of journaling on teenage mood, so while doing research, I turned to a college student's dissertation for help. Jessica Rose Williamson's dissertation asks if repeated web-based self compassionate journaling has a more positive effect on depression, anxiety and stress than narrative journaling. (Williamson, 2014). In this graduate student's experiment, subjects completed baseline measurements assessing their levels of anxiety and depression. Participants were college and graduate students. They were then randomly assigned to either the self compassionate journaling group or the narrative journaling group. Self compassionate journaling is about humanity, human flaws, and being gentle and kind towards yourself. Narrative journaling is journaling about your day in a story-like fashion. The true control group just took the baseline survey twice without doing any type of journaling. Participants in this experiment were then provided a link for their web-based journaling. They were instructed to journal at least twice a week starting with one entry the day they signed up for the study, and for 4 weeks after, with both

journal entries to be submitted by Friday of every week. Participants were sent a general reminder on Wednesday and Friday each week to complete their entries by Friday. After the fourth week, participants completed the follow-up surveys. These surveys contained the same questions as the baseline survey. Williamson's experiment did not yield significant results, but I was intrigued by both the setup of the experiment and the question Williamson was attempting to answer.

The current study seeks to determine whether prompted or unprompted journaling is an effective way to improve adolescent mood. The experiment was based on Williamson's but used different prompts. In addition, this experiment utilized high school students in the Science Research and Design (SRD) program. Also, participants hand wrote their journals instead of journaling in a web-based capacity. The testing method used in this experiment was the PANAS Survey. The PANAS survey contains a list of emotions (equal parts negative and positive). Subjects are instructed to rank each emotion from 1-5 (1 being "mild" and 5 being "very"). From these rankings, subjects are given a negative score and positive score (Henry & Crawford, 2004). The current study is important because if significant results are found, it will indicate that journaling can be used as an effective way to help regulate stress and overall mood. The independent variable in this study is the type of journaling, and the dependent variable is the change in positive and negative mood. This experiment attempts to answer if journaling has an impact on positive and/or negative mood in adolescents.

#### Methods

The design of this experiment was a 4 week study where participants were given the PANAS survey to determine their baseline mood. The potential harm of this experiment was that severe symptoms could come up in the survey. If that were to occur, it would be the responsibility of the experimenter or the head of the SRD program to go to the school psychologist and ensure that the student got the help they needed. In order to get participants for the experiment, an email was sent out to all SRD students. Those who responded to the email participated in the experiment. The 15 subjects were split into 3 groups – gender and age were evenly spread throughout each group. A teacher assigned each group to either prompted journaling, unprompted journaling, or the control group, and then assigned them random numbers, so the group the participants were in was completely blind. The three groups in this experiment are: regular stream of conscious journaling (writing whatever is on your mind), prompted journaling (responding to specific prompts and/or questions), and those who do not journal at all (the control group).

#### The eight prompts given to the prompted journaling group were:

- 1. Who are your favorite writers and why?
- 2. Make a list of 25 things and people that make you happy.
- 3. Describe one of your earliest memories.
- Talk about a characteristic you admire in others and in which ways you possess that characteristic.
- 5. Write your life mission statement.
- 6. Describe a time you helped someone.
- 7. Write about 3 good things that happened today (or this week).
- 8. What is your favorite room or place? Why?

These prompts are designed to promote self-positivity and encourage participants to reflect on positive attributes in their life.

Participants in the journaling groups were expected to journal at least twice a week for 20 minutes total. They were instructed to complete a survey that assessed the amount of time they spent journaling. This process was repeated 4 times for a total of 8 entries and a complete journaling time of 80 minutes. The control group was told they would be participating during "phase 2" of the experiment. At the beginning of the fifth week, the participants completed the original survey again. These results were calculated by using the PANAS survey. The 20 emotions on the survey are broken up into 10 negative and 10 positive emotions. The minimum score for both the positive and negative is 10, and the maximum for both the positive and negative scores is 50. If after the four weeks of journaling the positive score increases, that indicates an increase of positive emotions. If the negative score decreases, that also means that overall mood has improved. While it is not ideal to rely on subjects' honesty, it was important in this study to protect the privacy of students. The experimenter did not read the participants' journals in order to respect their privacy.

## **Results/Discussion**

#### Graph 1

This graph indicates subjects' average positive mood before and after the four weeks of journaling. The error bars indicate the standard error of the mean (SEM) of the PANAS scores.



#### Averages of Positive PANAS Before and After 4 Weeks of Journaling

#### Graph 2

This graph indicates the change in average negative mood before and after the four weeks of journaling. The error bars indicate the standard error of the mean (SEM).



Averages of Negative PANAS Before and After 4 Weeks of Journaling

The results of the experiment support the null hypothesis: neither prompted nor unprompted journaling have an impact on positive or negative mood. While some of the participants reported that journaling helped them process their emotions, the overall results of the experiment were not statistically significant. Analyses of Variance (ANOVAs) compared the PANAS scores before and after the four weeks of journaling for each of the groups, and for the positive and negative scores separately. The p-value for the difference between the 3 groups was 0.223451 for negative mood, and 0.114799 for positive mood. All of the results were well above .05 meaning they were not statistically significant. Therefore, it can not be concluded that prompted or unprompted journaling has an effect on either positive or negative mood.

There were many limitations when it came to this experiment. Since my participants were all in high school, there were certain lines I could not cross. For example, I could not test for depression or anxiety, since the school would be liable for any type of harm to the students. My sample size was also quite small because I was only using students from the SRD program. People were also reluctant to volunteer to participate in my experiment. There were also problems with timing; not every participant got their journal on the same day, the weekly check-ins were not completed by every participant, and not everyone journaled for the full 20 minutes a week. All of these things could have interfered with my results immensely. Also, my experiment only lasted for 4 weeks, and participants were only required to journal twice a week for 10 minutes a day which may not be a sufficient amount of journaling.

If I were to conduct this experiment again, I would ensure that everyone receives journals and takes the baseline survey on the same day. I would only have two groups: prompted journaling and the control group, since prompted journaling indicated a larger positive shift in mood than unprompted

journaling. I would also make sure that everyone who is supposed to journal does so at least 3 times a week. I would ensure that the experiment does not fall at the same time as a large school event (e.g. the musical). Finally, I would make sure that my participants do not know what my experiment is or what I am testing. Unfortunately, I was unable to conduct the experiment a second time, due to the reluctance of possible participants.

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# Growing Cerebellar Neurons to Study the Efficacy of Cerebellar Transplantation on Restoring Motor Deficits in Patients with Cerebellar Hypoplasia

by Emily Gordon



## Abstract

his research focuses primarily on beginning to prove the efficacy of cerebellar transplantation as a cure for cerebellar diseases, disorders and defects by growing cerebellar neurons in a 3D functional brain model at Tufts University. The data confirms that these neurons can be grown successfully *in vitro*. This is essential to proving that cerebellar transplants can be a viable option in the future to cure symptoms associated with cerebellar dysfunction because these neurons are what allows for voluntary movements to be carried out. Without them, any attempt at a cerebellar transplant would not be successful.

## Introduction

#### The Function of the Cerebellum

The cerebellum is the part of the brain that controls and regulates voluntary motor movements in the body, such as coordination, posture, speech and balance. Signals from the spinal cord and other sections of the brain are sent to the cerebellum and the cerebellar neurons take these signals and transmit them via an electrical signaling process so the movement can be carried out. When the cerebellum is functioning properly, the result is accurate and there is fluid muscle activity, such as being able to walk normally. However, when the cerebellum plays a role in certain types of cognitive learning, such as language. A cerebellum that is not functioning properly would also lead to speech difficulties (Knierem, 2007).

#### The Composition of the Cerebellum

The image on the previous page is an illustration of the composition of the cerebellar cortex, which houses all of the neurons in the cerebellum. There are 3 layers: the molecular layer, the Purkinje layer and the granule layer, respectively. In the molecular layer there are Basket and Stellate cells, in the Purkinje layer there is a single layer of Purkinje cells, and in the Granule layer there are Golgi and Granule cells. Granule cells are numerous in the Cerebellum; their purpose is to receive signals from the mossy fibers in the cerebellar cortex and they send these signals to the Purkinje cells, which will be discussed later (Knierim, 2007). Little is known about the other 3 neuron types in the Cerebellum, but it is known that they are inhibitory neurons that work together and with the Purkinje cells (Swenson, 2006).

Purkinje cells are, perhaps, the most important neurons in the brain and are the focus of my research. They are inhibitory projection neurons that release a type of neurotransmitter called GABA (Gamma Aminobutyric Acid), which inhibits the actions of certain neurons and reduces the transfer of nerve impulses. Purkinje cells are important because they are the only signaling output source for the cerebellar cortex (Purves et al., 2001). Therefore, the Purkinje cells are able to control and regulate voluntary motor functions, and without them, severe motor deficits will occur.

IMAGE CREDIT TO PSYCHOLOGY TODAN



This is an image of Purkinje cells. There are many dendrites that receive a signal from either the outside environment or other neurons and then passes the signal to the cell body and finally to the axon. There is a long, single axon that branches out so that it can transmit the impulses to other parts of the cerebellum.

#### **Effects of a Defective Cerebellum**

When the cerebellum does not function properly, many symptoms can result. They can vary based on the specific disease, defect, disorder, injury, as well as additional factors, but they generally include:

- Uncoordinated and jerky movements
- Tremors and shakiness
- Dysdiadochokinesia, also known as the "impairment of the ability to make movements exhibiting a rapid change of motion that is caused by cerebellar dysfunction (Merriam Webster Dictionary)."
- Motor Learning Deficits (Knierem, 2007).

#### **Cerebellar Hypoplasia**

For the purposes of my research, I am focusing on studying a disorder called cerebellar hypoplasia, further referenced in this paper as 'CH'. It is a disorder that is most commonly found in cats and dogs and is generally caused when the pregnant female becomes infected with a parvovirus or a distemper virus which gets passed on to the babies *in utero*. This stunts the growth of their cerebella and as a result all of the Purkinje cells either die or regress, leaving little to no Purkinje cells behind (Akhtardanesh, Askari, 2014). As of right now, there is no cure for this disease, but it is not degenerative, so although it never gets better, it never gets worse. The external symptoms of CH are stated above and result in the animal having difficulty walking and frequently falling down. Therefore, there is a direct correlation between the external symptoms and the lack of Purkinje cells because the voluntary movements cannot be properly controlled and regulated.

#### **Possible Cure: My Proposal**

A possible cure for Cerebellar Hypoplasia is a cerebellar transplant because it would replace the cerebellum completely, and if it functions properly, correct the problem in its entirety.

While there has been, and continues to be, research on the effect of neural stem cell transplants in similar diseases – as seen in the article "Transplantation of Cerebellar Neural Stem Cells Improves Motor Coordination and Neuropathology in Machado-Joseph Disease Mice" – cerebellar transplantation is being proposed in this paper because of the nature of the disorder. In CH, when the cerebellum's growth is stunted, the Purkinje cells die (Armién, 2012). Although the direct connection between the two is unknown, it is believed that there is a reason why this happens and that the cerebellum cannot support the life of the Purkinje cells. This research is based upon the theory that if the cerebellum could not support Purkinje cell life before, then it would not be able to support their lives after a neural stem cell transplant, causing the Purkinje cells to die again.

Based on the knowledge acquired from this initial research, I hypothesize that there are other diseases, disorders or defects that a cerebellar transplant could help cure if it proves to be effective in the future; they are – and this is not an exhaustive list: autism, Parkinson's disease, Huntington's disease, and Cerebellar Abiotrophy.

#### **Beginning to Prove the Efficacy of Cerebellar Transplantation**

The first step in proving the efficacy of cerebellar transplantation is demonstrating that the necessary neurons are obtainable and sustainable. No matter where the host cerebellum comes from – whether from an animal or an artificial re-creation – there will likely be no viable cells. For this project, I am attempting to grow neurons found in the cerebellar cortex, extracted from Sprague-Dawley rats, in a 3D functional brain model. This will show that it is possible to obtain the neurons in the cerebellum that

would be necessary if one were to try and recreate a cerebellum to transplant it into a brain. These neurons have been grown successfully several times before at Tufts University – see "Bioengineered Brain Like Cortical Tissue" article for further information – so the results of cell growth are promising (Kaplan 2014).

## Methods

Note that this procedure is identical to that in the paper "Bioengineered Brain-Like Cortical Tissue," and has simply been paraphrased for the purpose of this paper. The only exception is that this method uses cerebellar neurons as opposed to cortical neurons. (Kaplan, 2014).

#### Scaffold Preparation

- 1. Place 10 pre-made, pre-cut, sterilized silk scaffolds in a 96 well plate.
- Add 0.1 mg/ml of Poly-D-Lysine Hydrobromide (PDL) solution into the well plates with the scaffolds. PDL is a solution that encourages and promotes cell attachment to the silk scaffolds.
- Aspirate PDL solution from the well plate and rinse the scaffolds with sterile Dulbecco's Phosphate Buffered Saline (DPBS) twice in order to remove all of the PDL. All PDL must be removed from the scaffolds because if it has not bound to the scaffold then it will act as a neurotoxin and compromise cell attachment.
- 4. Aspirate all DPBS from scaffolds.
- Add 200 micrometres of neurobasal culture medium to each scaffold and place in incubator at 37 degrees C (Celsius) for 1 hour before seeding the cells.

#### **Cell Isolation**

- Take 4 cerebella of embryonic day 18 Sprague-Dawley rats and place in a petri dish. Add 5 ml of warmed Trypsin-EDTA/DNase solution to the petri dish. Place in incubator at 37 degrees C – body temperature – for 20 minutes. The purpose of the Trypsin-EDTA/ DNase solution is to digest the tissue leaving a sort of "brain goo" behind, which allows one to easily isolate the cells.
- 2. After 20 minutes, remove the petri dish from the incubator and transfer the contents to a tube. Add Tryspin inhibitor to the tube to stop the digestion of the tissue. This prevents the over digestion of the tissue and prevents the cells from being damaged. Then, pipette the contents of the tube to ensure that all of the tissue is fully broken down.
- 3. Strain the mixture using a filter.
- 4. Spin this new, strained mixture in a centrifuge at room temperature for 5 minutes.
- Discard everything in the tube except for the cell pellet at the bottom. Resuspend the cell pellet in neurobasal cell medium.
- 6. Count the cells using a hemocytometer. The target cell count is about 1,000,000.
- 7. Place cells on ice until seeding, to preserve their viability.

#### **Cell Seeding**

- 1. Remove scaffolds from incubator. Aspirate all culture medium from the wells.
- 2. Move scaffolds to a new 96 well plate to ensure that cells attach only to the scaffolds.
- 3. Adjust cell concentration if necessary.
- 4. Add 200 micrometres of cell solution to each scaffold.
- 5. Place seeded scaffolds in incubator at 37 degrees C overnight.
- On the following day, aspirate all culture medium from wells. This will remove un-adhered cells. Move scaffolds to new 96 well plate and add culture medium.

#### Collagen

- Take a 15 ml conical tube on ice and add DMEM, sodium hydroxide, and collagen type I. Pipette a few times to mix the contents and then check to see if you have achieved the desired concentration (3 mg/ml). If not, then dilute until concentration is achieved.
- 2. Take a pH test strip and put collagen on it to ensure that the pH is neutral (7.4).
- 3. Aspirate the medium from the wells containing the scaffolds.
- 4. One by one, remove the scaffolds from the 96 well plate and place in new, dry wells. Before placing in the new wells, dab the scaffolds on a dry, sterile surface to remove all excess liquid.
- 5. Add 100 micrometres of the collagen solution to each scaffold.
- 6. Put the well plate with the scaffolds i to an incubator at 37 degrees C for 30 minutes to allow the collagen to gel.
- 7. Add 200 micrometres of culture medium to each well with a scaffold.

The cells were then taken care of (media was changed) at Tufts for a period of 1 month until September when imaging was set to take place. The fixing and staining of the scaffolds was also done in advance of the imaging. The images in the following section were taken on a Keyance microscope.

#### Results

Unfortunately, the staining performed on the cells that I helped to set up did not occur properly so it is unknown how well those cells grew. Based on previous studies (Kaplan, 2014) though, it is likely that the cells grew well and began forming neural networks based on previous studies that have been done with neurons and the silk scaffold at Tufts.

I was, however, able to take images of the cerebellar neurons that one of the PhD students, Will Collins, had seeded and been growing for 5 days prior to my visit to the lab at the end of September. I was also able to get images of pre-made 2D slides of cerebellar brain slices.





Cerebellar neurons grown in a 3D brain model. The green is the live cells and the red is the dead cells.



Cerebellar neurons grown in a 3D brain model. The green clusters are the live cells and the red is the dead cells.



Cerebellar neurons grown in a 3D brain model. The green clusters are the live cells and the red is the dead cells. However, some of the scaffolding also got stained with the dead stain so not as many cells as it looks like are dead.



Cerebellar neurons grown in a 3D brain model. The green is the live cells and the red is the dead cells.



Cerebellar neurons grown in a 3D brain model. The green clusters are the live cells and the red is the dead cells.



Axon region of Cerebellum as seen on 2D slides with slices of Cerebellum on them.



Axon region of Cerebellum as seen on 2D slides with slices of Cerebellum on them.



*Cell bodies of the Cerebellum as seen on 2D slides with slices of Cerebellum on them.* 

\*\*\*Please note that unfortunately I was unable to obtain images of the synaptic region of the Cerebellum.\*\*\*



This image shows the formation of a cerebellar neural network. Because the cells were only seeded five (5) days prior to this image, the network is not fully formed, but this is just the beginning. All of the green clusters are clusters of live cells and when these cell clusters begin to come together they form the cerebellar neural network, the purpose of which is to transmit signals among the neurons in the cerebellar cortex in order to allow for fluid movement, as was discussed in the introductory section of this paper (Knierim, 2007). In cerebellar hypoplasia the neural network can never form correctly because one of the five neuron types that are essential for forming this neural network is missing (the Purkinje cell).

## **Discussion and Conclusion**

The cells grew relatively well, considering that they were only seeded five days prior to imaging. Knowing that the cerebellar neurons can be grown *in vitro* is important for furthering the possibility of using cerebellar transplantation as a method to restore motor deficits since it is likely that there will be no viable cells available at the time of transplantation. This is because if the new cerebellar structure is made in a lab there will be no cells in it yet, and if the cerebellum comes from a brain-dead patient there will be no viable neurons since no electrical signal will be emitted from the neurons in the brain. Therefore, it is imperative that these neurons can be grown *in vitro* to be used to "recreate" a cerebellum to be used for transplantation to restore motor deficits in patients with cerebellar hypoplasia and other diseases, defects and disorders of the cerebellum.

There are several next steps in my research, the first of which is similar to growing the cerebellar neurons, which I have demonstrated in this paper. This first step is to determine how to recreate the cerebellum in its entirety, though there has not been any research on this that I could find. In addition, I would also need to investigate how to regenerate nerves, as well as how to actually perform a cerebellar transplant which involves disconnecting it from both the spinal cord and the cerebrum. Luckily, there has been a significant amount of research on this topic. The most promising studies have come from two neurosurgeons by the names of Dr. Zhigang He and Dr. Sergio Cavanero. Dr. He and his team of researchers at Boston Children's Hospital were able to figure out a way to regenerate the optic nerve by modulating the PTEN/mTOR pathway. Dr. Cavanero first proposed performing a human head transplant in 2013 and he has been working on doing this ever since; in fact, he has developed a method to perform the transplant which will take place in 2017 (Kirkey, 2017).

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# Is There a Correlation Between Frequency of Handwashing and Sickness in BC?

by Alice Lechtchinskaya

## Abstract

ashing one's hands plays a big role in an individual's health (CDC, 2016). Does frequency of hand washing correlate with missed days of school due to illness? While it is known that washing hands helps the prevention of illness and disease, it is not known whether or how often Berkeley Carroll students wash their hands. A survey was sent out asking how frequently individuals wash their hands and how often they have been sick enough to stay home since the beginning of the school year. After responses were analyzed, the results of students who were sick were compared to the results of those who were not and no correlation was found between frequency of handwashing and frequency of getting sick. With the implementation of this study, it will be known whether students in the Berkeley Carroll community wash their hands the recommended number of times per day.

## Introduction

It is believed by most that washing hands helps prevent the spread of disease and infection. According to *The Center for Disease Control and Prevention*, "Hand washing is like a 'do-it-yourself' vaccine – it involves five simple and effective steps (Wet, Lather, Scrub, Rinse, Dry) you can take to reduce the spread of diarrheal and respiratory illness so you can stay healthy. Regular hand washing, particularly before and after certain activities, is one of the best ways to remove germs, avoid getting sick, and prevent the spread of germs to others" (CDC, 2016). Not only is washing ones hands a step in the right direction towards good health and hygiene, but failing to do so is correlated with getting sick more often. *Health 24* states on its website that the failure to wash one's hands less than 7 times a day is a failure at basic hygiene, and that "People who wash their hands more than six times a day tend to suffer less frequently from infectious diseases" (Health 24, 2012).

A peer reviewed study conducted by researchers and published in the U.S. National Library of Medicine and National Institutes of Health called "Hand hygiene: Back to the basics of infection control" recognizes the magnitude of the healthcare associated infections problem and goes on to state that it is preventable. The study found that "There is now undisputed evidence that strict adherence to hand hygiene reduces the risk of cross-transmission (transfer of virus from one individual to another) of infections" (Mathur, 2011). Published in the Indian Journal of Medical Research, another study's focus was to figure out the impact of washing hands with soap on the risk of diarrheal diseases in a commu-

nity. Ultimately, the study found that "hand washing could reduce diarrhea risk by 47%." The researchers of this study also came up with "the potential number of diarrhea deaths that could be averted by hand washing at about a million" (Deobbeling, Stanley, Sheetz, Pfaller, Houston, Annis, Li, Wenzel, 1992). Another study, titled "Effect of washing hands with soap on diarrhoea risk in the community: a systematic review," found that compliance is usually estimated at <50% for healthcare workers' adherence to recommended hand hygiene practices. Promoting hand hygiene can be a challenge for infection control experts. "This review summarizes factors influencing lack of adherence by health-care personnel to hand hygiene procedures and suggests strategies for improvement" (Curtis, Cairncross, 2003). In *Oxford Journals* located under the category "Clinical Infectious Diseases" researchers found in a study that C. difficile spores [a forming bacterium that causes a symptomatic infection called Clostridium difficile (CDI)] survive routine environmental cleaning with detergents and hand hygiene with alcohol-based gels. However, "Thorough hand washing with chlorhexidine or with soap and water has been shown to be effective in removing C. difficile spores from hands" (Gerding, Muto, Owens, 2008).

All of these studies regarded one concept as paramount: washing hands prevents illness and promotes health. The current study investigates: do teenagers in the Berkeley Carroll Upper School community wash their hands enough? Or – is hand washing correlated with getting sick less? The study was conducted by a survey that was sent out to the Berkeley Carroll Upper School. Students' answers to the questions were later used to analyze the correlation between hand washing and number of sick days in Berkeley Carroll Upper School students. If the survey finds that students are not washing their hands enough, the school will be made aware of this issue and asked to remind students how essential it is to wash their hands more often in order to prevent sickness. The experimental question is: How does hand washing correlate to missed days of school? The dependent variable is the number sick days and the independent variable is: hand washing. While washing hands is a key step in maintaining good health, an article written by Brian McDonald and published on *Irish Examiner's* website states a survey found that "teens don't know how to wash properly" (Irish Examiner, 2014). Because of this study, I decided to determine whether Berkeley Carroll Upper School students fit this speculation.

#### Materials/Methods

A Google survey was sent out to each Berkeley Carroll Upper School student via their school email. The email asked participants to fill out the survey for a Science Research and Design (SRD) study and listed the survey that was to be completed. Emailing the survey was the simplest way to send a questionnaire, receive responses, and then analyze them. The survey was comprised of the following questions: "On average, how many times a day do you think you wash your hands?" (Choices ranged from none to more than 8) "When do you tend to wash your hands? (choices consisted of: after shaking/high-fiving someone's hand, after going to the bathroom, after blowing your nose, coughing, sneezing, after public transportation, etc). "Approximately how long do you think you wash your hands for?" (choices ranged from 0-2 min with 15-30 second intervals between each option). The last question was: "have you been sick enough to stay home from school this year?" to which the student answered "yes" or "no," and "If yes, how many days?" Answering these questions was the easiest way to generalize the frequency of each individual's hand washing routine and discern whether they have been out sick, allowing the researcher to compare and contrast handwashing frequencies with number of sick days. Responses were sent, stored, and analyzed in Google Forms and Sheets.

#### Results

- Out of the students who washed their hands 1-2 times per day, 50% missed school due to illness.
- Out of those who washed their hands 2-3 times per day, 43% missed school.
- Out of those who washed their hands 3-4 times per day, 27% missed school.
- Out of those who washed their hands 4-5 per day, 45% missed school.
- Out of the students who washed their hands 5-6 time per day, 50% missed school.
- Out of the students who washed their hands 6-7 times per day, 67% missed school.
- Out of the students who washed their hands 7-8 times per day, 50% missed school.
- Out of the students who washed their hands 8+ per day, 50% missed school.

The 50% of students that were sick in the group that washed their hands 1-2 times per day, washed their hands for 0-15 seconds, after going to the bathroom, after touching garbage, and before, during, and after preparing food. The other 50% (that didn't get sick) of the same group washed their hands for the same amount of time and at the same intervals (after going to the bathroom, after touching garbage, and before, during, and after preparing food).

Out of the individuals who washed their hands 2-3 times per day and were sick, 66% washed their hands for 15-30 seconds, while the other 34% washed their hands for 30 seconds-1 minute. 100% of individuals who washed their hands for 15-30 seconds washed their hands after going to the bath-room, while the others also washed hands before eating lunch, after touching garbage, and before, during, and after preparing food.

Of the 57% of students who washed their hands 2-3 times per day and did not get sick, 50% washed their hands for 0-15 seconds; 25% doing so after going to the bathroom, after touching garbage, and after public transportation, while another 25%, washed their hands after going to the bathroom, before eating lunch, after touching garbage, after public transportation, and before/during/after preparing food. The other 50% of students washed their hands for 15-30 seconds, with 25% of the students washing hands after going to the bathroom and after coughing/sneezing, and the other after going to the bathroom, after touching garbage, after public transportation, after handling animals, and before, during, and after preparing food.

50% of students who washed their hands 5-6 times per day ended up getting sick. Students who got sick washing their hands 5-6 times per day all washed their hands for 15-30 seconds – washing their hands after going to the bathroom, after blowing their nose, coughing, or sneezing, after traveling on public transportation, and after handling animals. One student however, was sick for half of a day, while the other who also washed his/her hands at additional intervals such as before eating lunch, after touching garbage, before, during, and after preparing food was sick for 2-3 days from school. The 50% of students who did not get sick washing their hands 5-6 times per day washed their hands for either 0-15 seconds or 15-30 seconds. All students in that group washed their hands after going to the bathroom, after touching garbage, before, during, and after preparing food. One of the respondents stated that they wash their hands after handling animals while the other additionally washed his/her hands after coughing, sneezing, blowing their nose and after a Physical Education class.

## Figure 1

Average number of days students were sick based on number of times hands were washed per day.



#### Frequency of Handwashing vs. Sick Days

## Figure 2

Scatter plot of frequency of handwashing and number of days sick with an *R*-squared value of 0.07262, indicating that there is no correlation.

## Frequency of Handwashing vs. Sick Days



## Conclusion

Although some individuals who got sick did not wash their hands as often as their peers, there was no direct correlation between frequency of handwashing and sickness. With an R-squared value of 0.07262, the scatter plot in Figure 2 shows that there is no direct correlation between sickness and frequency of handwashing in the Berkeley Carroll community. However, the collection of evidence of the tendencies of students can help analyze their hygienic habits and help the school to know whether there needs to be more education on that subject. Students who washed their hands 7-8 times a day had the greatest number of sick days and students who washed their hands 1-2 times per day had the least number of sick days, implying that my hypothesis was not supported and there is not a correlation between frequency of handwashing and sickness in Berkeley Carroll. The results become inconclusive for the groups that wash their hands 5 or more times per day. Questions for other contributing factors such as "When do you tend to wash your hands?" and "Approximately how long do you think you wash your hands for?" were taken into account and I compared for individuals in each group, which helped to analyze the frequency of their handwashing. Out of the 43% who got sick when they washed their hands 2-3 times per day, one individual did not tend to check off any periods of when he/she washed his/her hands, leading me to discount that piece of data. Those who listed number of days sick between two numbers were averaged. For example, those who were sick for 2-3 days were averaged to 2.5. While frequency of handwashing might not have a direct correlation to days missed due to illness among students from Berkeley Carroll, the results help us find how many students wash their hands the recommended amount per day and how many do not wash enough. Another survey can be sent out to students asking the way in which they wash their hands because one person may think rinsing with water is considered washing and someone else may think hand sanitizer is the equivalent to washing your hands with soap and water.

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# Simulating the Transit Method for Locating Exoplanets

by Xabi McAuley

## Abstract

n this experiment I tried to determine an accurate means to simulate the exoplanet discovery method called "transiting". In order to do this, I used a light-dependent resistor (LDR), a soccer ball, a tennis ball, an ammeter, and a spotlight. I positioned the different objects in front of the spotlight from varying distances (1 ft and 6 ft). I moved the objects by increments in front of the light, recording each reading after each move. My results showed that a tennis ball and soccer ball were able to successfully simulate the transiting method. The soccer ball served as a better teaching tool, and the tennis ball served as a more accurate example.

## Introduction

Exoplanets are planets that orbit host stars other than the Sun. These celestial bodies range from very big to very small, hot to cold, rocky to plain. There are millions of them in the universe, the majority remain unseen by the human eye. However, with advancements in technology humans have been able to expand their range of discovery and have employed several detection methods, including direct imaging, microlensing, transit, and radial velocity in order to learn more about exoplanets.<sup>1</sup>

Direct imaging involves taking an image of an exoplanet using a telescope. Direct imaging can give only loose constraints of the exoplanet's mass, which is derived from the age of its star and the temperature of the exoplanet through complex formulas and telescope readings. Only a small number of exoplanets have been discovered by direct imaging because of their relatively small sizes and large distances from Earth, and because the light from the host star usually swamps any signal from an orbiting planet.<sup>2</sup>

Microlensing takes advantage of a phenomenon that occurs when one celestial object passes in front of another from our point of view. The closer object's gravity bends and magnifies the light of the more distant object, causing the distant object to appear brighter than normal for a short time. By watching for a distant star's brightness to intensify twice, astronomers are able to find out whether the closer star has an exoplanet travelling with it.<sup>3</sup>

Transit uses shadows to find exoplanets. If an exoplanet's orbit around its star is angled just right, the exoplanet will regularly pass in front of its star, or 'transit', from our point of view. When it does, the exoplanet will block a tiny bit of its star's light for a brief period of time; the star actually gets dimmer. If the brightness of a star changes regularly and consistently, it could mean that an exoplanet is repeatedly transiting it. Transiting is the most common exoplanet detection technique and can be used to find the relative size of an exoplanet, its radius (if the host star's radius is known), and its orbital inclination.<sup>4</sup>

Radial velocity uses gravity to detect exoplanets. A planet is much smaller than its star, but it still exerts a tiny gravitational pull as it orbits. When an exoplanet is behind its star from our point of view, it pulls the star slightly away from us; when it is in front, it pulls the star slightly toward us. This causes the star to wobble back and forth, which can be detected with a spectrograph and powerful telescopes. A spectrograph separates light from a star into its component colors, producing a spectrum. Some of the starlight gets absorbed as it passes through the star's atmosphere, and this produces small, dark gaps or lines in the spectrum. As the star moves closer to us, these lines shift toward the blue end of the spectrum; as the star moves away, the lines shift back toward the red end of the spectrum. These back-and-forth motions of the lines in a star's spectrum indicate the presence of an exoplanet.<sup>5</sup>

Unfortunately, the experimental techniques used to identify exoplanets remain relatively unknown by the public, due in part to their complexity. As such, this study aims to test whether or not one of the techniques, transit, and the data it produces, can be simulated using readily available and/or common materials. If data can be obtained, the different exoplanet characteristics (fast or slow, large or small) will be investigated.

#### Procedure

To begin, we must define what a light-dependent resistor (LDR) is. The LDR is a circuit element whose resistance (ohms) decreases in the presence of light. So as light intensity increases, the resistance then decreases, and visa versa. The LDR, in this experiment, and ammeter (a device which measures electric current) were positioned 10 feet away from a spotlight in dark room. The LDR was attached to a power source emitting 4.5 v; the ammeter was set to read 20mA. An initial light intensity reading was obtained.

To simulate the transiting of a large exoplanet, a soccer ball was placed 1 ft in front of the spotlight, so that 14 cm of the ball obscured it; then a light intensity reading was obtained. Moving the ball in 14-cm increments, additional 1 ft readings were made until the ball had completely "passed" the spotlight. These steps were also repeated at a distance of 6 ft from the spotlight.

To simulate the transiting of a small exoplanet, a tennis ball was placed 1 ft in front of the spotlight, so that 1.5 cm of the ball obscured it; then a light intensity reading was obtained. Moving the ball in 1.5-cm increments, additional 1 ft readings were made until the ball had completely "passed" the spotlight. These steps were also repeated at a distance of 6 ft from the spotlight.

## Data

## Chart 1

Soccer Ball 1 foot Away		Soccer Ball 6 foot Away	
Distance Covering Light (cm)	Resistance (ohms)	Distance Covering Light (cm)	Resistance (ohms)
0	4581	0	4598
14	4741	14	4653
28	5241	28	4732
14	4658	14	4608
0	4457	0	4512

## Graph 1



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## Chart 2

Tennis Ball 1 foot Away		Tennis Ball 6 foot Away	
Distance Covering Light (cm)	Resistance (ohms)	Distance Covering Light (cm)	Resistance (ohms)
0	4576	0	4581
1.5	4581	1.5	4581
3	4586	3	4583
4.5	4586	4.5	4584
6.55	4593	6.55	4589
4.5	4589	4.5	4588
3	4583	3	4586
1.5	4579	1.5	4582
0	4578	0	4579

## Graph 2

Tennis Ball Light Curve



#### Graph 3

#### Transit Light Curve

Transit light curve for TrES-2 with a fit line overlaid in blue. Data obtained from Wesleyan University's Van Vleck Observatory. The y-axis exhibits the normalized flux and the x-axis exhibits the days from center of transit.<sup>6</sup>



## Discussion

After completing the trials you can see how for each data set the resistance (ohms) goes up when a larger percentage of the ball is covering the spotlight. This means that the LDR is detecting a presence of an object and experiences more resistance since there is less light coming towards it. For the soccer ball trial there is a larger deviation/difference in numbers when the ball is 1 ft away from the spotlight than 6ft away. This is because the ball is obstructing more of the spotlight and less light can pass the object. When the ball is 6ft away from the spotlight there is still a significant difference in the numbers, but not to the same degree as the first data set. This is a clear indicator that the second set is further away from the "sun"/spotlight than the first, therefore successful simulating a transit method trial. The tennis ball trials get a bit trickier since the difference between the numbers is very little/insignificant. Nonetheless you can still note that the LDR registers the presence of an object passing by. Additionally, it registers a greater change in light when the ball is closer to the spotlight than when it is farther away, just like the soccer ball trial. Between both trials you can see how the LDR is accurately perceiving a change in light, just as I had intended.

This experiment suggested to me that an LDR and various circular objects can serve as an accurate model to simulate an exoplanet transit detection method. This can be seen in the way the resistance fluctuates depending on the percentage of object obstructing the light towards the LDR. It seems as though the better circular object to demonstrate this method would be the soccer ball over the tennis ball due to a larger and more evident fluctuation in the ohms. A more pronounced and smooth light curve can be seen in those trials over the tennis ball trial, in which both curves (at 1 ft and 6 ft) are very close together. The tennis ball trial, however, would serve as a more authentic representation of what a real light curve looks like. This is due to the greater amount of data points, which serve to show how even a slight movement of the object can be detected and accounted for. All in all, between all data sets you can clearly see that the LDR and circular objects have served as an accurate means to simulate the concept of transit exoplanet discovery.

Although the experiment seems rather simple, it took a long time to complete because of the topic. Astronomy in general is a complicated and intricate subject and familiarizing oneself with the terms and events encompassed in this field can take some time. Furthermore, exoplanets, and particularly life on exoplanets (a topic I was once interested in pursuing), requires materials that are only possessed by professionals. That said, if I were to repeat this experiment I would try to obtain more data points, rather than just five for one and nine for the other. This would greatly increase my accuracy and provide more points to plot on a graph. However, I still believe my conclusion and experiment would remain the same, thus doing this would only be to increase the experiment's credibility. Additional next steps would include trying to determine more information with the information I derived. I could try to find out the size, radius, orbital period (the time it takes for a planet to complete a full orbit around the host star) of the items I used in the experiment. The reason I could not do so in this experiment is due to the complex formulas which require inputs derived from actual transit scenarios. This means that I could not input the distance from the ammeter to the ball in order to determine the size of the ball because the formulas for such discoveries only work for planet-to-planet distances. Also, most of the formulas required information that I was unable to acquire due to lack of resources.

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# The Effects of Fidgeting on Comprehension and Concentration

by Grace Morales

## Abstract

idgeting is defined in this study as making small repetitive movements, usually of the hands and feet. It is frequently seen wherever there are human interactions, e.g. public transportation, school, restaurants, and the workplace. It is understood that fidgeting is a result of boredom, agitation, or nervousness<sup>1</sup>. Therefore, there should be a relationship between fidgeting and concentrating in school (specifically during class). To determine if a correlation exists between fidgeting and concentration, subjects were observed for fidgeting identifiers such as tapping a foot or fingers, biting nails and playing with fingers. Of the 40 subjects, only 6 were motionless through the whole trial. However, there was no significant correlation between fidgeting and concentration. Though this is a small sample size, this study is aiming to establish appropriate environments for different types of learning styles in the future – especially for those individuals that have the tendency to move more than others.

## Background

Some individuals are cognizant of the amount of fidgeting they engage in, while others do it subconsciously. Every person reacts to social situations with different body language and movement, and this is an aspect of life many tend to overlook.One specific example of a movement that can affect social situations is fidgeting. Fidgeting is considered a small repetitive movement,<sup>2</sup> whether that be tapping your feet, pencil, fingers, or even playing with an object. This specific topic of fidgeting was honed in on from an original myriad of topics such as movement and health. The process began with reading articles about all different types of movement from sports to hobbies, and articles about motionless activities as well. These articles provided examples as to how health risks are directly correlated with motion during a professional day at work, such as health risks associated with a desk job. Various studies throughout the past decade have found that sitting at a desk or sitting in general for more than half of a day doubles the risk of both diabetes and cardiovascular disease<sup>3</sup>. It can also lead to other risk factors such as obesity. This suggests that if students can avoid sitting for the majority of the day, this may be a saving factor. Fidgeting is something the majority of society does all day whether that be in class, during a test, or simply talking to someone.<sup>4</sup> Moreover, my personal experiences with fidgeting have been positive. However, many may disagree and claim that fidgeting is a distraction to not only oneself but also to those around them.

An article that propelled me to my experiment was titled *"Sitting Time, Fidgeting, and All-Cause Mortality in the UK Women's Cohort Study.*"<sup>3</sup> This study was conducted with 12,778 women from the UK between the ages of 37-78. These women had a job that involved excessive amounts of sitting (i.e. a desk job) and had to score themselves on a scale from 1-10 on the amount of fidgeting they did daily. Throughout the test their diets, physical activity, alcohol consumption, and smoking status were monitored, to take personal health into account. Furthermore, these participants were tracked for mortality over a 12-year time span. The results stated that fidgeting modified the risk associated with sitting time (p=0.04 for interaction). The results also showed that fidgeting can, in fact, lower the risk of death due to excessive amounts of sitting. Therefore, this study concluded that fidgeting is a health benefit because it avoids lack of movement which provokes health risks and has extremely adverse long term effects. However, the results of this test may not be that conclusive because the scoring system was self-assessed and subjects may have not properly scored themselves.

When researching fidgeting, much of the available information is about how hyperactivity largely correlates with Attention Deficit Hyperactivity Disorder (ADHD) and Attention Deficit Disorder (ADD). In fact, an article titled: "When ADHD Kids Fidget: Better Focus Through Multitasking"<sup>5</sup> states that: "body affects the brain as much as the brain affects the body" which in turn suggests that fidgeting is, in fact, a helpful resource for people diagnosed with ADHD. This led me to the question of whether that applies to typically developing children as well. One example of this is an article titled: "A trial-by-trial analysis reveals more intense physical activity is associated with better cognitive control performance in attention-deficit/ hyperactivity disorder."6 This article is about 44 children from the ages of 10-17 who were either diagnosed with ADHD or who were "typically developed" and had no form of learning disability. The test was to see the rate of physical activity in correlation with cognitive control (which is one's reaction to processing information). Each child wore an actometer on their ankle, which measured physical movement while they took the flanker paradigm (a test which assesses if you can have the appropriate response in the right context). Scientists were testing this to see if the movement had a correlation to the performance of the flanker paradigm test. The conclusion of the article was that "excessive motoric activity associated with clinically significant ADHD symptoms may reflect compensatory efforts to modulate attention and alertness." Though this article concluded positive results for humans diagnosed with ADHD, it did not address whether fidgeting helps concentration in TD (typically developing) humans. This article inspired the experimental question of the current study: does fidgeting affect concentration? In this study, participants were given images to memorize and later asked to demonstrate their knowledge with a brief exam. Both during memorization and during the time they take their exam, the amount of physical activity they engaged in was measured and scored. My independent variable was the amount of fidgeting during the trial and my dependent variable was the test scores. The importance of the topic is that some people cannot control their fidgeting,<sup>7</sup> and it is a common misconception that fidgeting is a distraction like doodling.<sup>8</sup> This experiment may address the common myth that fidgeting distracts not only the person fidgeting but also others around them as well.

## **Materials and Methods**

The first step in designing the experiment was to figure out how to quantify fidgeting. This was determined by sending out a survey to the entire Berkeley Carroll Upper School with a multiple choice questionnaire asking: Which do you most consider fidgeting? The options included: tapping your leg/moving it back and forth, playing with your fingers, biting nails/cuticles, tapping pencil, and other. If a student selected the "other" box, they then had to indicate what they had in mind. Student responses to the "other" section included responses such as: playing with hair, biting hair, stretching, and moving torso around. Out of a total of 133 responses, the first option: tapping your leg/moving it back and forth received the most votes (84.2%). This questionnaire was used to make a scale that was used throughout the rest of the experimental process. Since there were five options in the survey, a scale of 5 was used, 5 being the highest (which in this case was "tapping your leg/moving it back and forth") and 1 being the least (which was the motions listed under "other").

This study was conducted with a total of 38 subjects. There were three separate trials – two were conducted in the spring in 2016 and one conducted in the fall of 2016. The third trial was a modified version of the first two trials conducted in the Spring.

Trial one consisted of 10 students who were all sophomores. These subjects had to memorize 12 cartoon pictures in ten minutes. Then they were quizzed on the for another consecutive ten minutes. The quiz had all 12 cartoon pictures on it and a blank line under each cartoon for the name that they just saw as they were memorizing. As they were both memorizing the cartoon images and taking the quiz on this content, they were being observed (by me and two assistants) and scored by the scale from the questionnaire form. Trial two was almost entirely the same as trial one with minor modifications. They were the same group of subjects plus two new subjects making a total of 10 rather than 12. The modification in terms of the procedure was that there were now 25 cartoon images to memorize and five minutes for the quiz following rather than 10 minutes.

The third trial was modified immensely from the first two trials. There were 38 subjects sitting in front of a whiteboard with cartoon pictures hanging. They also had a ten question quiz. This quiz included visual, written and geometric brain teasers and riddles. The scoring system, however, remained the same. Each quiz was numbered from 1-38 and each subject had a sticky note with the number that correlated to their exam in front of them. Thus to avoid writing the name of each person, their number and the amount they fidgeted in relation to the original 1-5 scale was recorded. This was accounted for when subjects repetitively moved for a significant amount of time which was considered 5 seconds or more. Once they came to a complete stop, they were scored using the 1-5 scale. At the end of each trial, all the numbers recorded for each individual were added together, and each person received their own score. Throughout the trials, these scores ranged anywhere from 0-40.

## **Results**

## Figure 1

shows the relationship between fidgeting and the test scores for all three trials. Trials 1 and 2 were conducted with a much smaller sample size in comparison with trial 3. None of the R-values yielded conclusive results as they were all relatively close to 0. R-values were 0.436, 0.321, and 0.409 respectively.



Amount of Fidgeting

## **Discussion/Conclusion**

The conclusion that can be drawn from the data is that there is no direct correlation between fidgeting and concentration. In figure 1, it is the most difficult to make any actual connections between the scattered points because all 9 subjects scored above 80%. The hypothesis was that the score was that high in trial one because the subjects were allotted too much time to memorize the images and take the quiz after. Figure 2 has 10 total subjects, but there is more variation in the data with many scatter data points above and below the trendline. While physically there are more data points in figure 3, there still is not a strong direct correlation because all the subjects that performed the best (50 and above) vary widely in how much they fidget.

However, after doing a literature review and much research, there may be another way to test this experimental question. Since some of the subjects being tested are going through the pass-fail course of the Science Research and Design program, it is possible that there is less sincerity in participating in the study which could alter the results. Also, it is possible that grades are not the best possible representation for a subject's concentration. Specifically in trial 3 it is possible that a subject who scored a 0% concentrated more than the subject who scored a 79%. Moreover, fidgeting is not the only variable that affects concentration in a classroom setting. Distractions from other things in the other students, noises, and technology may also have an effect. Thus, to find a relationship between concentration and fidgeting there has to be a different way of isolating fidgeting as a distraction and quantifying concentration rather than a grade.

This study is important because there could be a breakthrough in the future which encourages institutions to pay more attention to students that fidget more. Though this study does not prove that such a change should be made, there are students all across the globe that deserve to learn in what is the best fit for their learning style. For instance, there could be a classroom setting that offers a putty or stress ball for students who feel they comprehend and focus more on the classroom content when moving. This may help students participate more or even increase exam scores.

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## Molecular Biology Techniques in the Classroom: Site Directed Mutagenesis of the Green Fluorescent Protein

by Kellen Penner Coxon

## Abstract

luorescent proteins are naturally occurring molecules that absorb light and re-emit it at lower frequencies. They are responsible for fluorescence in some species, mostly cave- and water-dwelling animals and plants. Since their discovery in the 1960s, fluorescent proteins have been used as molecular tags to label proteins inside living cells for biological research. Because the proteins glow under certain wavelengths of light, attaching a fluorescent protein to another protein allows the movements of the protein of interest within a system to be monitored. As a result, biologists have created fluorescent proteins of varying characteristics (photosensitivity, color, pH sensitivity, etc.) to suit their specific needs. Using site directed mutagenesis, I attempted to produce a variant of the Green Fluorescent Protein that fluoresces a different color.

## Background

The Green Fluorescent Protein (GFP) was discovered in the Aequorea victoria jellyfish in 1961 (Shimomura, 2005). Though the researchers were unsure of the reason, this species of jellyfish was bioluminescent (Figure 1). In their attempts to isolate the compound causing this luminescence, the researchers found that two molecules were responsible: Aequorin, and GFP. Aequorin, named after the species in which it was first found, is a chemi-luminescent protein, meaning it emits light as a result of

#### Figure 1

The Aequorea victoria jellyfish fluorescing.



(SHIMOMURA ET AL.)

a chemical reaction. This triggers GFP's fluorescence, as it absorbs the blue light from the Aequorin and emits it as lower frequency green light (Shimomura, 2005). The team continued to study both proteins, and were able to predict GFP's structure. Their prediction was later confirmed in a 1993 study using X-ray Crystallography (Cody et al., 1993).

The portion of the protein responsible for its fluorescence is called the chromophore (or sometimes the fluorophore). The chromophore is comprised of three adjacent amino acids, almost always containing a tyrosine and a glycine (Figure 2). When excited by light at certain frequencies (the protein's excitation spectrum), the chromophore will undergo a conformational change, and emit a light at a lower frequency (its emission spectrum). Since the protein's fluorescence is activated by light, no additional and potentially harmful substances need to be added to the organism for it to function. Fluorescent proteins also have a ß-barrel structure that makes them extremely stable (Figure 3). The chromophore and supporting residues are located on the inside of this barrel, protecting them from changes in the environment (e.g. pH levels) that could potentially cause damage to the molecule, and water that could quench the fluorescence. Finally, each molecule of fluorescent protein is composed of a single polypeptide chain. The N and C termini of the chain are found at either end of the molecule, which makes it easier to use as a molecular tag. Tagging a protein is done by inserting the gene for a fluorescent protein next to that of the target protein. During transcription and translation, the proteins are made together as one continuous polypeptide, without disturbing the mechanism of the chromophore or target protein (Figure 4) (Zimmer, 2002).

#### Figure 2



#### Autocatalytic Flourescent Protein Chromophore Formation

The GFP chromophore and its maturation

#### Figure 3

#### Architecture of Aequorea victoria Green Flourescent Protein

The beta barrel structure of GFP



#### Figure 4

An illustration of a molecular tag



(ZIMMER, "GREEN FLUORESCENT PROTEIN - THE GFP SITE.")

Fluorescent proteins' relatively robust structure gives biologists room to modify them to suit various needs. For example, researchers led by Dmitry Shcherbo and Ekaterina M Merzlyak, developed a far-red spectrum fluorescing protein that they called Katushka (Shcherbo et al., 2007). Their goal was to create a fluorescent protein that could be used for deep tissue imaging in animals. The spectrum for effective imaging through layers of tissue is 650 to 1,100 nm, due to photon absorbing molecules like water and melanin. At the time, no proteins that fluoresced in that range were bright enough to facilitate this type of imaging. Starting with a protein called TurboRFP (itself a derivative of the Red Fluorescent Protein discovered in the Discosoma striata sea anemone), the researchers used a PCR Random Mutagenesis Kit (Clontech) to generate a large library of mutants, which they then screened for qualities such as increased brightness and decreased emission frequencies. The kit is used for Error-Prone PCR. Increasing the Magnesium in the PCR solution and changing the balance of nucleotides causes random errors in the replication of template DNA. When bacteria were transformed to express these mutants, the researchers could check for the desired qualities, then sequence the genome to discover what mutation(s) caused them. They then used that information to design Katushka (Figure 5) (Shcherbo et al., 2007).

#### Figure 5

Frog embryos expressing mPlum (another red-spectrum fluorescent protein) and Katushka in their muscle cells. Katushka's superior brightness allows for better imaging.



(SHCHERBO ET AL.)

With such a great variety available, fluorescent proteins can be used for imaging in living organisms at all levels of organization, from organelle to tissue to organ. For instance, one group of researchers used two colors of fluorescent proteins to observe neuron development in mice (Zimmer, "Green Fluorescent Protein – The GFP Site."). They first engineered one strain of mice to express blue fluorescent proteins in their neurons, and another strain to express green fluorescent proteins. Then they crossed the lineages. In the resulting offspring, the researchers could observe the blue and green neurons as they grew and made connections (Figure 6).

#### Figure 6

The neurons of a mouse expressing two colors of fluorescent protein.



(ZIMMER, "GREEN FLUORESCENT PROTEIN - THE GFP SITE.")

Fluorescent proteins can also be used to test promoter function (Chudakov et al., 2010). Promoters are regions of DNA responsible for initiating transcription, and thus gene expression. By using the same methods as for imaging, scientists can test the effects of varying environments on the promoter function. For example, cells with the GFP gene inserted after a promoter of interest can be put in environments of varying pH, which itself has little effect on the protein's fluorescence (depending on the variant of GFP). If in one pH solution the cell fluoresces, and in another it does not, the researchers have evidence that pH has an effect on the action of that promoter (Chudakov et al., 2010).

## Replication

My goal was to modify the color of a fluorescent protein. I chose to start with GFP, since the school already has access to the gfp gene in our supply of pGLO plasmid (BioRad Laboratories). This plasmid is used to genetically modify organisms to express GFP.

While random mutagenesis is an effective strategy in large labs, it is simply too resource-intensive and time-consuming for a high school setting. Thus I turned to site-directed mutagenesis. This technique involves causing specific mutations that lead to a variation in fluorescence range based on known sites on the protein's gene. I attempted two versions of this experiment: green to orange fluorescence, and green to yellow.

PCR (Figure 7) was used to insert mutations into the pGLO plasmid. To isolate the sections of DNA with our mutations, and prepare them for ligation back into the plasmid, we used the restriction enzymes Ncol, Xhol, EcoRV and BstBl. For the Green to Orange mutation, a substitution at nucleotide 1538 (C G) made the amino acids of chromophore identical to those of mKusabiraOrange, a red-spectrum fluorescent protein found in the *Fungia concinna coral* (Kikuchi et al.). The forward primer designed was 5' – CTGTTCCATGGCCAACACTTGTCACTACTTTCTGTTATGGTGTTCAAT – 3', and included both the restriction site for the enzyme Ncol and the nucleotide substitution (Figure 8) The reverse primer was 3' – TAACTAAAATTTCTTCTGTTATGAGCACATGTT – 5', including the restriction site for Xhol. The restriction sites and corresponding enzymes were necessary to successfully subclone

#### Figure 7





(PCR BASICS)
the amplicon (PCR product) into the plasmid vector in the next steps. For Green to Yellow, the mutation required three nucleotide substitutions at 1960-3 (ACA $\rightarrow$ TAT), in order to change the 203rd amino acid, one of the residues that interacts with the chromophore, from a Threonine to a Tyrosine. In YFP (Yellow Fluorescent Protein), this tyrosine has a  $\pi$ -stacking interaction with the tyrosine on the chromophore, slightly increasing its emission frequency (Figure 9). This time, the mutation was on the reverse primer, which also had the restriction site for BstBI: 5'- GTCGTATCAATCTGCCCTTTCGAAAG - 3'. The reverse primer was 5'- CGCTGGCGATATCAAAATTGCTGTC - 3', and had the restriction site for EcoRV. While the colors of GFP and YFP are more difficult to distinguish than GFP and mKusabiraOrange, the more similar structure of the two fluorescent proteins (YFP was developed as a variant of GFP) gave this mutation a better chance of success. Both trials produced PCR product.

## Figure 8

Nucleotide sequences for the first trial. The chromophore sequence is in blue, with its amino acid sequence written below. The mutation is in red. The restriction site for Ncol is in pink.

GFP	CTGTTCCATGGCCAACACTTGTCACTACTTTCTCTTATGGTGTTCAATGCTTT Phe-Serv-Tyr-Gly
mКО	GTGTTCTGTTACGGCCACAGAGTATTTACTAAATATCCAGAAGAGATACC Phe-Cys-Tyr-Gly
Fwd Primer	CTGTTCCATGGCCAACACTTGTCACTACTTTCTGTTATGGTGTTCAAT Phe-Cys-Tyr-Gly

## Figure 9

# Chromophore Modification Effects on Flourescent Protein Emission Spectra

The  $\pi$ -stacking of Tyrosines 66 and 203 in YFP is shown in the bottom right. On the left, emissions spectra of a few GFP derivatives.



The PCR products were put through gel electrophoresis to check their size. The Green to Red amplicons and plasmid vector were digested with the Ncol and Xhol enzymes (New England Biolabs). The resulting segments, the insert likely containing a mutation and the vector, were ligated (Figure 10) with the Quick Ligation Kit (New England BioLabs), forming a new plasmid. *E. coli* HB101 cells were then transformed to express the protein. In this trial, only the control plates showed significant growth. For Green to Yellow, the PCR product and plasmid were digested with the EcoRV and BstBl enzymes before ligation and transformation. This time, the results were inconclusive, because neither the controls nor experimental group were expressing GFP.

### Figure 10

#### Plasmid Cloning by Restriction Enzyme Digest (aka Subcloning)

An example of ligation of an insert and plasmid vector.



### Discussion

The Green to Orange mutation was chosen because it was a dramatic color change for a single nucleotide replacement. Unfortunately, a few flaws in the design hindered this trial. First, the primer and template DNA ratios in my PCR were not optimized. In experiments with more time and resources, many calculations and trials of PCR are run to find the ratio that will maximize the PCR product. I, however, had to approximate the best I could. As a result, much of the primer may have annealed to other primer molecules rather than the template DNA, resulting in primer dimers, which cannot amplify the target sequence. Second, the amplicon produced by PCR was rather small, only about 270 bases long. This made it difficult to distinguish from the roughly 100 base primer dimers in the gel (Figure 11). For whatever reason, only the control groups showed noticeable growth and fluorescence (Figure 12).

The primers for the Green to Yellow trial were designed to provide a larger amplicon, to avoid the issues with Green to Orange. With this larger amplicon, the PCR process went more smoothly, and it was easier to distinguish between the amplicon and the leftover template DNA and primers (Figure 13). Yet once the bacteria were transformed, none of the groups expressed the protein. This could be because the HB101 strain is not reliable enough for research. It is used in school demonstrations, and during these transformations, requires double the amount of plasmid used in this experiment. For research, it is better to use strains that have higher transformation efficiency, which respond better to lower plasmid concentrations. It may also be that the window of logarithmic growth, the ideal time to

The PCR products of the first trial after gel electrophoresis.



## Figure 12

The far left (p?  $\rightarrow$  Fingers crossed) is the experimental group, exhibiting practically no growth. The middle and right are controls using the pGLO Plasmid.



transform bacteria, was missed due to time constraints. Finally, a few days after results were collected, the bacterial plates exhibited signs of a fungal contamination. Competing with the fungus for resources likely affected the bacteria's ability to express the proteins of interest.

This type of experiment has many variables that need to align for success, not least of which is the time it takes. The second trial, Green to Yellow, seemed to be on track until the transformation and expression phase. Next steps for this experiment would include re-attempting both versions, paying special attention to the ratios of components during PCR, and using a type of bacteria more suited to research.

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# Powering Wireless Sensors By Harnessing Vibrations From 181 Lincoln Place

by Luis Peromarta

## Abstract

ately, alternative energy production has had quite a spike in popularity (Gallup, 2016). Environmentally friendly alternatives to fossil fuels are becoming more widely used throughout the world (Gallup, 2016). This experiment aims to find a use for a new emerging technology, piezoelectric ceramics. In this study, various locations around 181 Lincoln Place were tested as possible locations to generate power through the use of these ceramics. This acquired power was compared to WSNs, wireless sensor networks, to see if the power generated is enough to constantly power these sensors. This study's results point towards the null hypothesis that not enough power could be generated.

## Introduction

We humans have always had a need for more money, more land, more control over our lives. However, in this day and age the only limiting factor in our progress is power or electricity. We have built great machinery to harness the power of materials such as coal and oil, but soon those resources will end (Ecotricity 2017). Recently, more and more advances have been made towards renewable sources of energy (Ecotricity 2017). Solar, wind, and hydroelectric power are only a few examples of renewable sources of energy, but this paper focuses specifically on an emerging technology, piezoelectricity, which, like most other forms of renewable energy, translates mechanical energy into electrical energy. Piezoelectric materials generate a current whenever they are bent or deformed in any way, as long as they are not broken. The interesting fact about these materials is that they work much like a dynamo motor, capable of both generating energy when mechanical stress is applied, and generating mechanical energy or movement when an electrical current is applied (Woodford, 2016). For that reason, these materials are used throughout many industries. They are used as engine knock sensors, hydrophones, and high precision speakers (APC, 2015). But there is still an untapped potential here. This paper focuses on the work done by three research groups in trying to obtain power generation from such materials.

The first paper in the research is *Energy Harvesting via Piezoelectricity*, by Tanvi Dikshit, Dhawal Shrivastava, Abhijeet Gorey, Ashish Gupta, Parag Parandkar and Sumant Katiyal (Dikshit, T., Shrivastava D., Gorey, A., Gupta A., Parandkar A., Katiyal S., 2010), which rather than conducting an experiment focused on giving an overview of the many different ways that piezoelectric power generation could be applied. It referred to appliances ranging from power generating shoes to self-charging computer key-

boards and mice. The focus of this paper was to present their proposal of a piezoelectric windmill, which translated rotatory force into an up-down movement, which was then used to generate power through the use of a piezoelectric sheet. It divided most power generation in these two groups: micro and macro. Macro power generation is what we usually think of when we think of power generation: large power plants generating tremendous amounts of power. Micro on the other hand, is the complete opposite. It's the generation of small amounts of power for much smaller applications, such as key-boards and mice. These definitions helped me narrow down the research topic from overall piezoelectric power generation to the much more manageable micro power generation.

In *A Novel Approach to Recycle Energy Using Piezoelectric Crystals*, (Arjun A.M., Sampath, A., Thiyagarajan S., Arvind V., 2011) researchers focused on a way to create a 'feedback loop' of sorts, a charging battery via piezoelectric generators that would alert whenever it was filled, and thus waste very little energy. However, instead of focusing on the effect that different vibrations had on the material, and different ways to stress the material, they focused on the material being used, changing the number of piezoelectric sheets used and the connection between them. Their results were that a series of 5 sheets produced the highest voltage, and thus the most power. This paper was helpful in gaining much needed background on the topic, but the experiment in the current study more closely revolved around the next paper.

*Piezoelectric Energy Harvesting Devices: An Alternative Energy Source for Wireless Sensors,* (Nechibvute A., Chawanda A., Luhanga P., 2012) was the inspiration for the current study. The goal, similar to the previous paper, was to see how much power could be generated using piezoelectric ceramics. This study took it one step further and examined if it would be possible to power a WSN (Wireless sensor network) with it. What was different about this paper when compared to the rest was its analysis of vibrations, a variable that the two previous ones did not take into account. This is what truly drove the research behind the current project.

The idea is to explore the possibilities of generating power inside of the Berkeley Carroll School by using piezoelectric ceramics, and to then see if a small WSN could be powered using that generated electricity. The independent variable in this study is the ceramic's position. Power generated by the vibration frequency are dependent on the position of the ceramic sheet.

## Procedure

The experiment was conducted in various places around the school: the cafeteria, the 181 Lincoln Place gym during a game, and the boiler room. In all three places, the procedure was the same. The piezoelectric sheet itself, as shown in figure 1, was bought from Piezo.com, in the form of a small energy harvesting kit. Its specifications are as follows:

#### Mechanical

Outline Dimensions	2.0" Long x .55" Wide x 0.7" High
Mounting Holes	.085" Diameter, 4 Places
Weight	14 Grams (0.5 Ounces)
Input/Output Cables	6" J1 Connector, 6" J2 Connector

First, the piezoelectric sheet was mounted on a small wooden block to act as a cantilever. It was mounted using glue-tack and duct tape, using the least amount of material possible to reduce the amount of dampening. Next, the apparatus was placed in different areas. In the gym, it was placed high up on the bleachers during a game of floor hockey. The height of the bleachers allowed for more vibra-

tions, and thus more power, to be created. In the cafeteria, the block was set on a table near the entrance as the students arrived. And in the boiler room, the block was placed near the water pumps, the place with the most noticeable vibration. Once these were all set, they were left there for an hour. Every 20 minutes, the capacitors' charges were checked and recorded.

### Figure 1



### Data

Even though this experiment has only been conducted in a few locations in the school, the data suggests that there might not be enough or strong enough vibrations in the school to generate nearly enough power. The experiment was conducted in two different places in the cafeteria to try and find the best place to generate vibrations. But even though the data shows that sufficient power may not be generated, I conducted a second experiment to test for the ceramic's natural frequency, the frequency at which it will vibrate the most and thus produce the most power. This was conducted by sticking the piezoelectric sheet on the backside of a speaker using the same method of adherence to the wooden block (glue tack and thin strips of duct tape), and playing different frequency vibrations through it. The speaker, a Bose Soundlink Generation I, was plugged into a computer and using the szynalski online tone generator, various different tones, with varying frequencies, were played. The sheet was then left

### Figure 2

Each column is a different location, and each row is a different 20 minute interval. Units displayed in the first chart are displayed in microvolts. Units in the second chart are in volts.

	Boiler Room	Gym (Hockey)	Cafeteria 1	Cafeteria 2
Initial Capacitor	0	0	0	0
20 Minutes	0	3	4	5
40 Minutes	0	6	8	8
1 Hour	0	10		

in place for 15 minutes with the sound going through the speaker. The capacitors were then checked to see how full they were and their output was tested. Using this data, a future study could be conducted in which the vibration at a location is first tested before placing the piezoelectric apparatus on the location, thus saving all the waiting time that it takes to see if the capacitors charge or not.

## Figure 3

	50hz	54hz	55hz	56hz	60hz	65hz
Current Output	0.4	22.5	22	22	10.5	0
Voltage Output	0.05	0.43	0.55	0.45	0.17	0

### Figure 4

### **Frequency Test Bar Graph**

The output is measured in volts.



# Figure 5

Frequency Test Bar Graph

The output is measured in milliamps.



### Conclusion

As previously stated, the only conclusion that can be drawn from this data is that not enough power can be generated inside of the school to power a WSN.

The least powerful WSN that I could find, the Digi International XB24-AWI-001 moisture sensor, needed at least a supply of 2.8 volts and a current of 50 milliamps, many times higher than anything that could be produced inside of the school (Digikey Electronics 2017). With further trials in different locations maybe one would have been found to produce enough power. However, mostly due to the ongoing construction and renovation in 181 Lincoln Place, many of the yet untested areas, such as the ventilation system, were completely closed off. For instance, before beginning this study, the top floor ventilation room was closed off, and thus preventing the experiment from being conducted in what is arguably the best location in the entire school. Lastly, due to scheduling, the experiment could only be conducted at very specific times, which in total added up to too few trials.

This was the biggest problem in the experiment. The lack of trials yielded relatively few results. This data yielded the null hypothesis – that not enough power can be generated. However, some difference in power generation was noticed during testing, and with that in mind a second study could and should be conducted. For that study, this same experiment could be replicated but each trial could be conducted multiple times to increase the chance for significant data. Lincoln Place construction is scheduled to end in 2018, and that might be a perfect opportunity to conduct the experiment with more varied locations around the school.

This paper made it possible to discover a method for finding this ceramic's natural frequency. The ceramic was attached to a speaker cone and various tones were played through the speaker while the output was recorded. A small range of frequencies were found (between 54hz and 55hz) that produced very promising voltages. With this in mind, maybe the next experiment can focus on analyzing the frequency of vibration of a given surface before testing the piezoelectric ceramic.

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# Effectiveness of Current Teaching Methods of First Aid Education

by Dmitry Pokushalov

# Abstract

henever there is an extreme situation of a person requiring first aid assistance, how effectively can someone access their first aid skills? This study simulates the conditions of an online first aid class, which was largely based on lectures, using Berkeley Carroll students. Participants listened to a lecture and then completed comprehension tests, one right after the lecture and the second one 20 days after the lecture. The results of a one-tailed correlated t-test significantly showed (p-value=0.0072395) that participants scored higher on the first test than the second test, suggesting a problem in the approach to teaching first aid. This suggests the need to reevaluate the ways first aid is taught and perhaps add more practical activities to the curriculum.

# Introduction

In a situation where one's knowledge of first aid can play a huge role in saving lives, can one always fully recall everything that has been taught in first aid classes? Humans have two different types of memories: short term and long term. Short term memories are memories retained for 20-30 seconds and the region responsible for their storage is the prefrontal lobe of the brain (Mohs, n.d.). Long term memories, however, are anything longer than 30 seconds and multiple regions of the brain are involved in retaining them with the hippocampus serving as a catalyst ("Parts of the Brain Involved in Memory," 2011). Since there is a huge discrepancy between the amount of time information is retained with each type of memory, an important question arises: are first aid students retaining their knowledge in the form of short term or long term memory?

Surprisingly, the process of obtaining a first aid certification is not complicated. It is possible to become certified simply by completing an online course which is structured similarly to a fact-based lecture (Online CPR Certification and First Aid Certification, 1999). The form in which the material is presented to students lacks practical experience or follow up memory refreshers. It was hypothesized that this style of learning is detrimental to a student's ability to retain first aid information in their long term memory. The broader question of students remembering information solely based on facts has been addressed many times in the scientific community. A study titled *Long-Term Retention of Basic Science Knowledge: a Review Study* looked at medical school students and their long term retention of

fact-based scientific knowledge. Over the course of four years, the same students took a test which evaluated their knowledge of fundamental biological and anatomical facts. Researchers observed the trends of how well students would retain that factual information. The study concluded that after one year approximately 66 to 75 percent of knowledge was retained and after two years, slightly less than 50 percent was retained (Custers, 2010).

Studies have also tested people's knowledge of first aid and how it changed after initially learning the information. Swedish researchers in their *First-aid training and bystander actions at traffic crashes—a population study*, conducted a study where they looked at car crashes and percentages of bystanders who were able to provide adequate first aid (Larsson, 2002). They found that in their randomly sampled group across ages 18-74 and all genders, 39 percent of people had received first aid training at least once. However, when it came to applying their knowledge, out of the 14 percent of people that responded and who had first aid training, only 20 percent were able to provide adequate first aid to a victim of the crash, with 80 percent of them being first aid certified.

Similarly to the Swedish study, a different population-based survey in New South Wales, titled *A population-based survey of knowledge of first aid for burns in New South Wales,* also aimed to find out the randomly sampled population's knowledge of a specific area of first aid, burn treatments. Out of the 7,320 respondents, fewer than 10 percent knew the optimal treatment for burns and 80 percent had a mix of false and correct treatments (Harvey, 2011). The above studies seem to showcase a pattern of people who had received first aid training but failed to apply their knowledge.

The purpose of my study is to simulate first aid class conditions using the lecture-based teaching method to determine its effectiveness. Students' knowledge was assessed over various periods of time to determine whether the decrease in their scores over time was significant. The null hypothesis of this study is that there is not going to be statistically significant differences between the students' scores at different time periods, while an alternative hypothesis is that the initial score would be significantly higher than the scores obtained later. In the study, time between the first aid lecture and a test was measured and manipulated as an independent variable expressed in days. The dependent variable was students' average score on each of the tests. An extraneous variable was students' prior knowledge of first aid and the material covered during the lecture. To keep participants' conditions similar certain control variables were introduced which are going to be discussed later.

### Methods

#### Subjects

The experiment was conducted on volunteers from the Berkeley Carroll's 10th grade Science Research and Design class. Students from the tenth grade were picked because they were able to complete both stages of the experiment and had already taken the required health class which would signify a lack of major difference in initial knowledge of the material. In total there were 10 participants in the study. Since it was important to keep conditions as close to an actual first aid class as possible, there were no factors that could have limited and excluded certain students from participating in the study.

#### Variables

The dependent variable was students' average score on each of the tests. To keep control variables and participants' conditions similar, the same lecturer was used for both of the groups, the lecture was written to be as similar to an actual first aid lecture as possible, all of the students received the same tests, and the number and type of questions in both tests was kept constant.

### Procedure

A Berkeley Carroll Science Research and Design teacher read out a lecture which covered common emergency situations such as: frostbite, burns, bruises, nosebleeds, poisonous bites, etc. (Derived from Mayo Clinic). Once the lecturer finished, students were given the first test containing questions based on the lecture. Prior to the experiment, the participants signed a permission slip and were informed of the intentions of the study. The types of questions presented on the test fell into one of the three categories: multiple choice, short answer(requiring 1-2 sentences to answer) and long answer (requiring 3 or more sentences to answer fully). Students were given 20 minutes to complete their tests. After that, their tests were collected and graded on a scale where a correct answer on a multiple choice guestion received 1 point, a correct response on a short answer question received 2 points, and a fully correct response on a long answer question received 5 points. Meanwhile, incorrect answers resulted in 0 points. Partial credit was given on long and short answer guestions and multiple choice guestions which had more than one correct answer, where it was deemed appropriate. The largest potential score participants could have obtained was 25, while the lowest potential score a subject could have obtained was 0. After 20 days, the same students received a different test which covered similar areas and topics that were discussed in the lecture. However, this test had different questions. The total number of the questions and the proportion of different types of questions were kept the same. Similarly the potential highest and lowest scores, test location and general time of the day when the test was administered remained constant. Students were given the same amount of time to complete the second test and their answers were graded on the same scale.

### Data

Both tests were graded on the scale discussed above. The tests were separated into two groups based on when they were taken. Average scores for each of the two groups have been calculated. A correlated one-tailed t-test was performed in order to see if the decrease between the scores on the first test and the second test was significant.

### **Results**

The results of each participant on both of the tests were computed and organized. As evident from Graph 1, after a period of 20 days the results of most of the participants decreased, except for participant 4 and 7. A correlated, one-tailed t-test was conducted in order to find out the statistical significance of the difference between the average scores. The average scores of the participants are illustrated in Graph 2. The results proved to be statistically significant with p-value being <0.05 (p-value=0.0072395), meaning that the alternative hypothesis has to be accepted. Although we assumed that Berkeley Carroll students are valid representatives of people who want to be first aid certified, nonetheless the conditions of the experiment were kept close to an online first aid certification course. Thus it can be concluded that the lecture format for teaching students first aid for certification purposes is actually ineffective. These findings suggest that there should be a reevaluation of methods for obtaining certification.

### Graph 1

# Test Difference in Scores between the First Test and the Second Test



# Graph 2





### Conclusion

The study showcased that the lecture based format for teaching first aid for certification is ineffective. Students who participated in a replica of an online first aid class lost a statistically significant amount of their gained knowledge after only twenty days. A potential pitfall in the design of this experiment is that despite replicating the conditions of an actual test, the test subjects, high school students, are not an accurate representation of groups that seek to obtain first aid certification. Since the participants did not have a personal need of obtaining first aid certification, their scores could be low due to the lack of motivation to do their best. It is important to note that even after the initial lecture the average score on the test was approximately 50% which could itself mean that the lecture method of obtaining first aid certification is flawed. Additionally, it is crucial to acknowledge that the sample size of this experiment was extremely small (10 students) which, despite having significant results, still means that the study should be replicated with a larger sample size.

The presentation of this essential information in a fact-based format is simply ineffective at helping subjects remember the presented information over longer periods of time. It would be interesting to continue this research on the effectiveness of first aid education by performing a similar study on participants of different age groups, which could perhaps indicate that first aid education is tailored towards a particular age group. In addition, to find out if the problem with the certification lies in the lack of practice, results over time of students who received strictly verbal and fact-based instructions could be compared against those of subjects who had received a practical component in addition to the fact-based instructions.

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# Life in Color: Increasing Informational Retention Rates Using Blue Font

by Darrell Pona

## Abstract

n today's society, one looks for the most efficient way to do everything. In order for students to succeed, educators continue to search for ways to revolutionize and simplify learning. If certain colors help students memorize information, it would be important to find the most effective color for informational retention. In this experiment, participants were given tests of historical events in either red, blue, green, black, or a combination ("multi"). After time to memorize, subjects were given a test to show information retention based on the color. Scores were compared by a one-way ANOVA (analysis of variance) for four independent sample groups. The lowest p-value for this experiment was .72, which is significantly higher than .05, indicating that the results were not statistically significant.

# Background

For educators, efficiency not only means the fastest way to teach their students material but also the way that will help their students retain the maximum amount of information in a short period of time. I assume that when teachers focus on "the way they present the information," they mostly think of how they can deliver material in an intriguing activity that will engage their students, but often end up for-getting the literal sense of their phrasing. Many studies have shown that presenting information in certain colors increases learners' retention rate. Retention rate is the amount of the information that can be recalled verbally or in writing. Another way to say that someone memorizes information is information retention. Information retention rate is percentage of information memorized. Therefore, if there were questions after certain information was given, the retention rate would be the number of correct answers over the total number of questions. In one study testing the effect of text color and background color on memory, scientists found that having a blue font on a white background resulted in the highest memory retention (Cousins, 2013). In a second study testing the same thing but on a website, scientists found that, once again, blue fonts had the highest information retention rate (Dzulkifli, 2013). Another experiment on the effect of color on dyslexic and autistic learners' memories found that colored fonts allowed for a higher retention rate than fonts in black and white (Pitman, 2012).

However, many would say that because red is a vibrant color it would yield the highest retention rate of given information. For example, according to the University of California, Berkeley, cue dependency, or the accessibility of a memory given the informational value in the brain, if manipulated can explain why certain colors help people learn more effectively (Kihlstrom, 2013). The color blue could help in memory retention because the color blue is a cooler, but more recognizable and distinguished color, and this information is prioritized during the storage phase of memorization (Kihlstrom, 2013).

Although it is still unclear why blue or red may be more effective color choices for people, it is better understood and more important to figure out which color helps students memorize and learn more efficiently. This experiment tests which font color allows for students to retain the most information: red, green, blue, black, or a combination. This is especially important in all schools, including Berkeley Carroll, in pursuit of the best ways to educate students. In this experiment, the font color (independent variable), will affect the memory or retention rate of learners (dependent variable) to determine the most effective and efficient color to present information in to hopefully increase the quality of education for Berkeley Carroll students. I believe, despite the common belief that red is the most retainable color, that it is most probable that information written in blue will produce a higher retention rate than red, green, or black fonts given past experiments. In order to test this, groups of subjects were given the same information rate would correlate to the font color that most effectively helped students memorize the most information.

### **Procedure**

In this experiment, there was a list of eight historical events that were most likely unknown to Berkeley Carroll students based on what I remember learning through my Berkeley Carroll courses and education. The historical events included the Chernobyl Disaster, Rwandan Genocide, The Jamestown Massacre, Tunguska Explosion, The Lost Colony of Roanoke, The Winter War, Pax Romana, and the Manhattan Project. Each historical event was accompanied by a short summary of the occurrence. Each test, although containing the same information, was administered in different colors. The test colors were red, blue, black, green, and multi-colored. The multi-colored test was simply a test with two sections of information per color.

### Participants of the study were given the following instructions:

"You have four minutes to memorize as much material on the other side of the top sheet. I will time you and give you fifteen second cues for the first two minutes. I recommend that you spend fifteen seconds on each section (which will become clear once you flip your test). You do not have to follow this recommendation. After those two minutes, you will be given another two minutes to review and memorize as much as possible. There are no other instructions other than to memorize as much of the material as possible. Are there any questions?"

If there were questions, repetition of the instructions or a sentence of the instructions was given. Once there were no more questions, the test was started. Every fifteen seconds, participants were advised "you may move on" and participants, given their choice to follow directions, followed or memorized in their own way. The reason this step was included was to ensure that all sections were given equal memorization time. This could alter the results of the multi-colored tests by having a more attractive color retain the attention of the participants, as opposed to actually helping them memorize more. Once eight rounds of fifteen second intervals elapsed, participants were warned about two minutes of remaining memorization time. After the two minutes were complete, the facilitator then collected all information sheets. Afterwards, the participants were instructed to read the instructions on the top, and begin the test on the second administered paper.

All tests were the same and in black font. The instructions written were "Please place a check next to the statements that are TRUE about the events that precede. Your score is out of three. One point for each correctly filled, one point for each correctly left blank." To avoid confusion, participants were also told that they could check more than one statement per section. The color of the test was determined by matching the subject number on both the information page and test page. The questions on the test page asked about the event and even the incorrect answers were worded similarly to the summaries to ensure actual memorization. The tests were then scored out of three points per question. The only materials used in this experiment were the information pages, tests, and pens.

To collect data, each correct answer marked with a check was given a point and each incorrect answer left blank was given a point. There were eight sections, each with up to three points to earn, resulting in 24 points to potentially earn. This score was then divided by eight to find the retention rate score. For the multi-colored test, the two scores for each color were added, then divided by two, to get the retention rate score for that color. There were three one-way ANOVA variance statistical analyses run on the collected data. The first included retention rate scores for all data collected, including retention rate scores for the multi-colored tests. The second excluded multicolored test scores, because there was the option to ignore the 15 second recommendation, meaning that colors that stood out had an advantage. The third test focused only on the multicolored test results.

## Results

In test one, there was no significant finding that any color drew a higher retention rate because the p-value was 0.8179 – much higher than 0.05. In test two, there was no significant finding that any color drew a higher retention rate because the p-value was 0.9021, again too high to show significant results. In test three, there was no significant finding that any color drew a higher retention rate because the p-value was 0.7208.





### Graph 2





Graph 3 Multi Only Retention Rates



## Discussion

With p-values exceeding .05 in all statistical analyses of the data, the null hypothesis – that there is no difference between any specific color and higher retention rates – must be accepted. The largest limitation in this experiment was the number of subjects available. There may have been different results had the study been conducted with 60-80 subjects as initially planned. In future attempts, it will be important to work around subjects' schedules so they have time to take the test. It will also be important to limit the test to the two colors that had higher retention rate scores in this experiment: red and blue. It also seems that the tests were not challenging enough for Berkeley Carroll students because retention

rates scores were much higher than the expected two out of three. Although there was an effort to avoid previously known topics, it seems as if participants already knew a few of the historical events from previous knowledge. It is also possible that I gave participants too much time to memorize the information. These tests could also have been too simple because the questions were extremely straightforward and worded similarly to the summaries themselves. In future attempts, adding another question or two to the test page would significantly increase difficulty and also vary the retention rate scores. It might also make the experiment more controlled if subjects were required to memorize each section separately for 15 seconds. Limiting memorization time might also increase difficulty.

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# Geometric Analysis of Three-Way Junctions in RNA Structures

by Sneha Punukollu

# Abstract

fter dozens of RNA structures and their 3-way junctions were reviewed, three types of comparison graphs were created to identify trends among families, coaxial stacking, helices, and bend/torsion angles. The goal of this analysis was to identify patterns in existing RNA structure to work towards eventually being able to predict the characteristics of new structures. The individual length of helices were compared among families first. This was followed by a comparison of the stacked and unstacked bend and torsion angles in one dimensional plots. After the completing of this process, a cumulative graphing was conducted to seek out trends among the number of residues within specific strands, compared to their corresponding bend and torsion angles. Multiple minor trends were identified but did not prove to be consistent throughout all of the junction examples. The primary characteristic identified was among the stacked and unstacked bend and torsion angles which conveyed the lack of constraint for the unstacked junctions with respect to those which were stacked. Additionally, the stacked bend angles across all families were found to be within the strict range of 0 to 45 degrees and 90 or 135-180 degrees.

## Introduction

When it comes to the functional aspects of ribonucleic acid, it is known that the polymeric nucleic acid molecule is composed of nucleotides. Within each nucleotide in a strand, there are also the bases Adenine, Uracil, Cytosine, or Guanine. The base pairs form hydrogen-bonded sections which form stems and all of the unpaired bases form loops and junctions (Schlick, 2015). But aside from knowing its role in processes such as gene regulation, transcription, and protein synthesis, a lot is still unclear about RNA's structural role and properties. This is especially true for the prediction of novel RNA structures. The RNA chain is made up of single stranded folds on itself in various ways, and these folds can form both secondary and tertiary structures. The secondary structure is a 2D structure which conveys the helices, also called the stems, consisting of the base pairs formed. This type of structure also includes loops which can be of different types (hairpin loops, junctions, regular loops). These are found within structures which are formed from unpaired bases (Schlick, 2015). RNA As Graphs (RAG), a database used to classify existing RNAs by their topological characteristics in attempt to predict the structures of novel RNA, depicts these secondary structures through tree graphs with simplistic depiction of the structure using edges and vertices. In these tree graphs, each loop in the secondary structure counts as a vertex and the helices/stems in the secondary structure are the edges, which are drawn as lines connecting each of the vertices together. The tree graph also helps convey the type of junction (e.g. 3 way or 4 way) the structure has by showing how many stems are coming from the junction vertex. RNAJAG, a junction explorer software, is a program used to predict the 3 way and 4 way helical arrangements

and coaxial stacking of RNA structures. Using sampling, the 2D planar graphs of 3 way and 4 way junctions were analyzed by their bend and torsion angles. This analysis was done using knowledge based (from previously existing structures) statistical potentials. Candidate graphs were chosen based on which had the lowest score (meaning a closer feature resemblance to solved RNAs). Finally, all atom models (which are detailed in contrast to tree graphs) were able to then be constructed.

Using pre-existing structures of RNA, 3-way junctions in a specific family and coaxial stacking were analyzed to identify patterns in the bend and twist angles they formed in relation to the number of residues in each strand. Follow up plots were also created to look for further trends in these relationships. Finding these patterns provided a step forward in learning how to classify existing structures in the process of predicting novel ones.

## **Methods and Materials**

In this process of computation, junction prediction and Monte Carlo/Simulated Annealing (MC/SA) sampling was used. Junction prediction is done through running the program database RNAJAG to determine the coordinate location of junction vertices. Using the Random Forests data mining approach, RNAJAG can predict 3 and 4 way junction topologies and coaxial stacking of the RNA (Kim N. et al, 2004). Using the collective training set of previously known junctions, 3 way junctions were split into 3 families whereas 4 way junctions were split into nine families. MC/SA sampling was used to determine the orientations between the helices of 3 way or 4 way junctions. Using sampling, the 2D planar graphs of 3 way and 4 way junction to determine how close or far off these angles were, we aimed to alter the bend and torsion angles of the junction without changing the family of the junction. This process occurred after junction and coaxial stacking prediction and prior to MC/SA sampling.



## **Results**

After comparing patterns among the bend and torsion angles of structures of the same coaxial stacking and families, comparisons were also drawn between those of different coaxial stacking and families. It was observed that there were no significant distinctions or characteristics between the angles and the residue numbers, the families and coaxial stacking, or between the angles and the strand length. Relationships between these factors were found in only a few groups among the dozens of observed structures and thus could not classified as representative of all structures. A few examples of this lack of pattern which were observed within the same family and coaxial stacking are depicted below:

### Graph 1

### Coaxial Stack H1H3, Family C

Comparing number of residues in strand 1 to the bend angle between strand 1 and 2



### Graph 2

### Coaxial Stack H1H3, Family C

Comparing number of residues in strand 2 to the bend angle between strand 2 and 3



Next, it was tested to see if there were similarities or distinct comparisons between the bend and twist angles for specific families and coaxial stacking. This revealed a slight trend showing that as the number of residues increase in strand 2, the bend angle between strands 2 and 3 decrease but the results were not statistically significant (Schlick, 2016).

## Graph 3

### Coaxial Stack H1H3, Family C

Comparing number of residues in strand 3 to the bend angle between strand 1 and 3



### Graph 4

### Coaxial Stack H1H3, Family C

Comparing number of residues in strand 3 to the bend angle between strand 1 and 3



## Discussion

The results of this experiment were conveyed through three different types of graphs to look for correlations among structures of a specific coaxial stacking and family: 18 graphs for each family (6 for each coaxial stacking). Both the bend and twist angles were plotted on the Y axis against the number of residues in each strand. In total there were 54 2D graphs on this type. Moving forward, one dimensional graphs were created to compare the strand length within a specific coaxial stacking and family. Finally 3D graphs were formed using the residue numbers of both of the strands that form the angle and either their bend or twist angle. After observing and comparing the patterns among the bend and torsion angles of structures among the same coaxial stacking and families as well as the comparisons between each other, we observed that despite there being a couple of relationships between these factors, they were only found among a few groups of the dozens of structures and thus could not be named as representative of all of the structures as a whole. Looking at these structures within a specific coaxial stacking and family and establishing any patterns would have served as a big step forward in being able to analyze and classify these structures for structure prediction: the initial role of RAG.

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# Analysis of Methodologies Applied to Direct the Differentiation of Stem Cells for Use *in vivo*

by Toluwani Roberts

## Abstract

tem cell transplantation is the insertion of stem cells into a subject's body. It has been explored as a method to restore tissue function. Difficulties in stem cell transplantation can arise from the unpredictability of stem cell differentiation. Stem cells are defined as a population of undifferentiated cells capable of both indefinite self-renewal and the generation of specialized cells<sup>3</sup>. Differentiation is the development of stem cells into mature and adult cell populations. This paper analyzes different methods of guiding stem cell differentiation in vivo. It concludes that stem cell differentiated and engraftment of stem cells in host tissue is most successful when the cells are pre-differentiated and then inserted into the host. The host biological microenvironment and specified fate of stem cells helps to direct differentiation.

# Background

Stem cells are found throughout the body, and have different proliferative properties and functions. There are many different types of stem cells that will be explored in this paper. Embryonic stem cells (ESCs) are pluripotent stem cells, meaning they have the ability to give rise to any of the hundreds of cell types in the human body<sup>1</sup>. Human mesenchymal stem cells (hMSCs) are stem cells that give rise to mesenchymal tissues, the body's connective tissues, such as bone, cartilage, and fat<sup>4</sup>. Hematopoietic stem cells (HSCs) are stem cells with the ability to self-renew and differentiate into all mature blood lineages<sup>3</sup>. Scientists have been studying how stem cells differentiate in their hosts, specifically by conducting experiments where different types of stem cells in various states are inserted and observed. Stem cell differentiation can occur *in vitro, in vivo,* or both. *In vivo* means taking place in the body of the animal subject, and *in vitro* means taking place in a dish. The goal of this paper is to summarize different methods of differentiation that have been used and answer the question, what is the best method for scientists to direct the differentiation of stem cells *in vivo* animal models?

## **Methods of Differentiation**

Researchers have studied how stem cells best engraft in the host body by comparing the insertion of undifferentiated stem cells into the host to the insertion of pre-differentiated stem cells into the host. Toma et. al have explored how hMSCs differentiate into a cardiomyocyte phenotype in the adult murine heart<sup>4</sup>. The goal of the study by Toma et. al was to test whether hMSCs may undergo 'milieu dependent differentiation', which is differentiation based on biological environment, or "home." In other words, the goal was to assess the ability of hMSCs to engraft and differentiate in the adult myocardium.

hMSCs were first isolated from the adult bone marrow. Early passage cells were tagged with beta galactosidase ( $\beta$ -galactosidase) by infecting cells with the gene *lacZ*, which reports the presence of  $\beta$ -galactosidase. Tagging cells with this gene is important because  $\beta$ -galactosidase allows researchers to identify which cells they have injected into the adult myocardium amongst the cells previously present. A volume of cell suspension containing about 500,000 to 1 million cells was then injected into the left ventricle of adult male mouse hearts with a needle. These mice were immunodeficient, so cells in their immune system lacked the ability to kill the stem cells that were inserted in the body.

hMSCs were engrafted into myocardium of SCID/beige mice. Mice receiving intracardiac injections of *lac-Z*-labeled hMSCs were killed 30 minutes to 2 months later (Figure 1: row A, 4 days; B, 1 week; C, 1 month; and D, 2 months). At 4 days, engrafted cells were found dispersed throughout the myocardium as ovoid cells (row A). Ovoid cells are cells shaped like an egg. With time in situ, cells began to take on the morphology of surrounding cardiomyocytes (row B, 14 days). At 1 to 2 months (rows C and D), there was a change in engrafted cell morphology to rod shaped (C, 1 month; D, 2 months).

The hearts of the sixteen mice in the experiment were harvested at 30 minutes (one mouse), and 4 days (3 mice), 14 days (3 mice), 21 days (2 mice), 30 days (4 mice), and 60 days after surgery (3 mice). Staining for  $\beta$ -galactosidase in the mice hearts showed that hMSCs were dispersed in the myocardium as individual cells at 4 to 60 days in 12 of the mice, as shown in Figure 1. Human mesenchymal stem cells were not identified in 4 out of the 16 mice – one mouse which was harvested 30 minutes after surgery, and the other three which were harvested 14-20 days after surgery. This may be due to technical difficulties associated with injecting cells into the beating myocardium. Amongst the hearts harvested four days after surgery, which involved the injection of 500,000 hMSCs, about 2200 hMSCs were found to have survived in the left ventricle. Over two months, or 60 days, the  $\beta$ -gal+ cells became morphologically indistinguishable from the surrounding cardiomyocytes. In addition, all identified hMSCs were positive for desmin expression at 60 days after surgery. Desmin is a muscle specific protein, showing that the hMSCs had successfully differentiated into cardiomyocytes.

These data suggest that hMSC transplantation may be successful because the cardiac environment may provide the necessary signals to induce cardiomyocyte differentiation. In addition to the cardiomyocyte microenvironment that the hMSCs were placed in, part of their stem cell fate was to differentiate into cardiomyocytes. hMSCs are specialized stem cells that give rise to connective tissues, which includes muscle. A similar study explored how stem cells engraft into their host environment using unspecialized cells.

A study by Caspi et. al. explored the transplantation of human embryonic stem cells (hESCs) into infarcted rat hearts, which are hearts with tissue death<sup>2</sup>. hESCs have a wider cell fate. They are undifferentiated stem cells from unfertilized embryos with the potential to give rise to any differentiated cell type<sup>1</sup>. The goal of this study was to find if the insertion of hESCs into an *in vivo* cardiac environment would enhance hESC differentiation into myocardium. Another goal was to determine if hESCs that were differentiated into cardiomyocytes *in vitro* survived, proliferated, and integrated with host tissue after insertion into the infarcted rat heart. Male rats underwent surgery for the transplantation of hESCs into the heart. Round one of surgery was to cause heart infarction in the male hearts. The hearts were ligated, meaning the heart arteries and/or vessels were tied up. After 7 to 10 days of round one of surgery, 150,000 undifferentiated hESCs were also transplanted into the infarcted area at four different sites. 150,000 undifferentiated hESCs were also transplanted into uninjured hearts. This study also included additional rat groups. It included another experimental group of injured and healthy rats in which human embryonic stem cell derived cardiomyocytes (hESC-CMs) were transplanted.

### hMSCs Engrafted into Myocardium of SCID/beige Mice

Mice receiving intracardiac injections of lac-Z-labeled hMSCs were killed 4 days to 2 months (row A, 4 days; B, 1 week; C, 1 month; and D, 2 months). At 4 days, engrafted cells were found dispersed throughout myocardium as ovoid cells (row A). With time in situ, cells began to take on morphology of surrounding cardiomy-ocytes (row B, 14 days). At 1 to 2 months (rows C and D), there was a change in engrafted cell morphology to rod shaped (C, 1 month; D, 2 months).



The second experimental group, in which hESC-CMs were transplanted, was included to answer the study's experimental questions by providing a comparison group for the undifferentiated hESC transplantation. The hESCs in this group were differentiated *in vitro* to give rise to cardiomyocytes.

Researchers were able to identify transplanted cells through tagging and staining techniques, shown in figure 2. This included labeling hESCs with a fluorescent cell tracer and with genetic markers, such as a green fluorescent protein. They also stained rat hearts for human specific antigens to further identify hESCs in the rat hearts. These rat hearts were harvested four weeks after stem cell transplantation. Undifferentiated hESCs were found to be grafted in the left ventricular myocardium of healthy and infarcted rats. However, the hESCs did not differentiate into the cardiac lineage of all hearts studied. Instead, what resulted was the formation of teratoma-like structures in 6 of 10 healthy rats and in 3 of 6 infarcted rats. Teratomas are a type of germ cell tumor. The *in vivo* cardiac environment did not enhance undifferentiated hESC cardiomyogenesis, which is the development and differentiation of hESCs into cardiomyocytes.

# *In Vivo* Transplantation of Undifferentiated hESC Results in Teratoma-like Structures

(A) Hematoxilin and cosin staining of teratoma within the infarcted area. Note the presence of early stage hyaline cartilage (right, top) and gastrointestinal-like columnar epithelium (right, bottom). (B) Immunostaining for the pluripotent markers Tra-1-60 (top) and Tra-1-81 (bottom). Note the positive staining of undifferentiated human embryonic stem cells (hESC) colonies (left) and the absence of staining in cells isolated from the contracting embryoid bodies (EBs). (C) Troponin I immunostaining of cells isolated from the contracting EBs.



hESC-CM transplantation was more successful. Evaluation of healthy hearts injected with hESC-CMs four weeks after surgery revealed the presence of grafted cells and lack of teratoma formation. The cell grafts appeared to have undergone some ultrastructural maturation. hESC-CM transplantation results were similar in the infarcted rat heart. Evaluation of these hearts also revealed the presence of grafted cells and lack of teratoma formation. Cell grafts were shown to align with host cells through staining, shown in figure 3. The viable cardiomyocyte area was determined by immunostaining for Tnl. Tnl (Troponin I), a protein that signals for cardiac muscle damage<sup>9</sup>. The area that did not show Tnl was the viable cardiomyocyte area. This area was stained to identify the transplanted human cells.  $25 \pm 6\%$ 

### Transplantation of hESC-CMs in the Infarcted Heart

(A) Identification of the grafted hESC-CMs at the scar's center using antienhanced green fluorescent protein (green, left) and antisarcomeric **a**-actinin (red, middle) antibodies. (Right) Superposition of both images. The scar was identified using antcollagen antibodies (blue). (B) Immunostainings of the transplanted hESC-CMs at the infarct border zone using antienhanced green fluorescent protein (green) and antitroponin I (red, right) antibodies.

(C) Identification of the grafted hESCOCMs with antihuman leukocyte antigen antibodies. (Top) Immunohistochemistry results. (Bottom) Immunofluorescent staining using antihuman-human leukocyte antigen (green) and antitroponin I (red) antibodies. (D) Development of gap junctions (Cx53 immunostaining, white) between the grafted cells (prelabeled with Vybrant-CFDA) (green, left) and host cardiomyocytes (arrows). Cardiomyocytes were identified using antiproponin I antibodies (red, middle). Abbreviations as in Figure 2.







of the infarcted area was comprised of viable cardiac tissue. Within the viable cardiac tissue,  $45 \pm 12\%$  stained positive for human specific antigens, showing the presence of differentiated hESCs.

These data show that the group of human cells that successfully engrafted without teratoma-like structures was the hESC-CMs. This demonstrates that biological microenvironment is not the only factor in the differentiation of stem cells. The specialization of stem cells and their microenvironment may be two necessary factors in guiding the differentiation of stem cells. The following study supports this finding.

Hillyer et. al. studied if Hematopoietic stem cells could differentiate into hepatocytes, which are liver cells, *in vivo* to restore biochemical function of a damaged liver<sup>10</sup>. They first isolated HSCs from the bone marrow of normal adult male mice. The type of HSCs used had surface markers c-kit<sup>high</sup>Thy<sup>low</sup>Lin<sup>-</sup>Sca-1<sup>+</sup>, also known as KTLS HSCs. HSCs were identifiable because they could also be stained for CD45, an antigen found on nearly all cells of hematopoietic origin. These HSCs were then injected in small amounts intravenously into adult female mice deficient in fumarylacetoacetate hydrolase (FAH-/-). Deficiency in this enzyme causes the mice to develop liver disease and damage<sup>18</sup>. Two months after KTLS HSC transplantation, researchers tested nucleated blood cells of the

#### Table 1

### **Detection of Donor-derived Cells after HSC Transplantation**

Hematopoietic donor-derived cells were detected in blood, spleen and bone marrow (BM) by fluorescence-activated cell sorting using the FDG fluorogenic substrate<sup>10</sup>. Data represent percent nucleated donor-derived cells found in the tissue and correspond to an average of two samples. Three mice in the first 2 months and eight mice during the next 4 months died and were not analyzed. < 1, no detectable engraftment. B, B cells; M, myeloid cells. Cells were identified by B220, CD3 and GR-1 + Mac-1 antibodies in combination with FDG staining. Mice died after their cage flooded. +, donor-derived hepatocytes (for liver engraftment).

Marria	Number of HSCs	Time after Transplant				
Number	2 x 10 <sup>3</sup> FAH ÷ BM Cells	Blood (%)	Blood (%)	Spleen (%)	BM (%)	Liver (%)
1	10	dead				
2	10	1.0 B, T	dead			
3	10	2.0 B, T, M	dead			
4	10	< 1	dead			
5	10	< 1	dead			
6	50	6.8 B, T, M	dead			
7	50	2.8 B, T, M	dead			
8	50	< 1	dead			
9	50	3.1 B, T, M	dead			
10	50	3.2 B, T, M	1.3	2.8 B, T, M	1.0	+
11	100	0.9 B, T, M	2.7 B,T, M	1.9 B, T, M	6.7	+
12	100	10.3 B, T, M	13.0 B, T, M	8.3 B, T, M	8.5	+
13	100	7.6 B, T, M	3.7 B, T, M	1.7 B, T, M	3.3	+
14	100	16.1 B, T, M	alive			
15	100	16.5 B, T, M	7.8 B, T, M	4.5 B, T, M	9.2	+
16	1000	dead				
17	1000	dead				
18	1000	58.7	48.6 B, T, M	50.2	72.1	+
19	1000	32.7	17.3 B, T, M	24.0	18.1	+
20	1000	42.1	9.9 B, T, M	18.5	39.0	+

experimental mice for hematopoietic engraftment. Nucleated blood cells are blood cells that contain a cell nucleus, and in this case, the HSC nucleus. Most of the mice were engrafted, with 10- 1,000 KTLS HSCs in their blood, as shown in the table. Mice were then sacrificed six months after HSC transplantation. Eight of the mice had died before the six month period, so they were not tested. Within the group of sacrificed mice, their bone marrow, blood and spleen were analyzed for donor-specific multilineage reconstitution. This means researchers were looking to see if HSCs from the male mice—the donors—engrafted into the bone marrow, blood, and spleen of the recipients. Researchers used fluores-cence-activated cell sorting in this analysis, confirming that the hematopoietic systems of the surviving female host mice were engrafted with the donor male HSCs. The results of this study are also shown in Table 1.

Further analysis was done to determine if HSCs engrafted in the host liver. This was done by staining for  $\beta$ -galactosidase activity around the liver to detect any nodules. Nodules were classified in this study as small and discrete colonies of hepatocytes present on tissue sections of the liver lobe. Researchers also stained for FAH enzymes within the hepatocytes and for the appearance of male donor cells, specifically, their Y chromosome sequences. Findings were that hepatocytes stained  $\beta$ -galactosidase positive, coexpressed FAH protein, and were Y chromosome positive. This shows that transplanted hematopoietic stem cells were engrafted and derived from the male donor KTLS cells.

This study inserted HSCs, an already specialized stem cell, into a microenvironment that matched its cell fate. This further supports the hypothesis that to direct stem cell fate, stem cells must be pre-differentiated and inserted into an environment that matches their cell fate. There are various methods of pre-differentiating stem cells, also known as directing stem cell fate *in vitro*.

Some stem cells already have a specific stem cell fate based on where they originate. Hematopoietic stem cells are derived from bone marrow. They are specialized undifferentiated cells that will become bone marrow cells, and other types of blood cells. This applies to hMSCs, which are also derived from bone marrow. When it comes to unspecialized stem cells (hESCs) guiding cell pathways is a method of determining cell fate. The process of pre-differentiating stem cells usually happens *in vitro*.

### Methods of Differentiation in vitro

In vitro stem cell research is carried out with cells cultured, or grown, on a flat artificial surface. To maintain the undifferentiated state of ESCs, cells are cultured in plastic petri dishes with leukemia inhibitory factor (LIF) as one of the feeder-cell-derived molecules<sup>12</sup>. Feeder-cells are used to nourish ESCs and keep them alive<sup>13</sup>. When the factors that keep ESCs in their undifferentiated state are removed, ESCs will differentiate. They will produce progeny from the three embryonic germ layers: mesoderm (derivatives include blood, heart, skeletal muscle), definitive endoderm (liver, pancreas, lung), and ectoderm (skin)<sup>12</sup>. Methods of *in vitro* development are shown in Figure 4. One method of development is to allow ESCs to aggregate and form embryoid bodies<sup>12</sup>. Embryoid bodies enhance cell-cell interactions as a result of their three-dimensional structure, promoting the differentiation and development of ESCs. Other methods of development can occur with more artificial involvement. In co-culture experiments, two cell types are grown together<sup>11</sup>, resulting in one cell influencing the development of the other, like embryoid bodies do. Petri dishes can also be coated with collagen on hydrogels made from naturally derived extracellular matrix proteins<sup>12</sup>. The extracellular matrix determines the rigidity of tissue. Cells cultured on either a softer or stiffer matrix will give rise to different types. For example, the rate of adult skeletal-muscle stem-cell proliferation increased with matrix stiffness<sup>11</sup>, being that skeletal-muscle cells make up more rigid tissue.

#### **Three Different Protocols Used for ES Cell Differentiation**



Researchers have tested these various methods of ESC differentiation *in vitro*. Co-culture experimentation has been tested through directed differentiation of hESCs into intestinal tissue *in vitro*<sup>14</sup>. Researchers directed differentiation by using a series of growth factor manipulations to mimic embryonic intestinal development<sup>14</sup>. In this paper, hESCs are referred to as human pluripotent stem cells (hPSCs)<sup>15</sup>. Researchers first used activin A to promote differentiation of hPSCs into definitive endoderm, which sets the cells up to differentiate into intestinal cells. The results showed that up to 90% of the hPSCs co-expressed markers of definitive endoderm cells – SOX17 and FOXA2. Co-culture is further supported in this same study when researchers worked to specify the definitive endoderm cells, specifically, to promote hindgut and intestinal specification. Researchers used FGF4 and WNT3A, whose signalling pathways are required for promoting endoderm formation into the midgut and hindgut. High concentration of these factors, after cells were exposed to them for 96 hours, resulted in stable CDX2 expression. CDX2 expresses in hindgut cells.

Matrix elasticity is another method of directing stem cell differentiation *in vitro*, being that it mimics a cell microenvironment. A study by Engler et. al. demonstrates the importance of matrix stiffness in the fate of stem cells<sup>11</sup>. The study used naive mesenchymal stem cells (MSCs), which would be shown to specify lineages and commit to phenotypes that show extreme sensitivity to tissue level elasticity<sup>16</sup>. MSCs were placed on soft, collagen-coated gels that mimic brain elasticity. The majority of MSCs adhered, spread, and exhibited a filopodia-rich form. Filopodia are thin cell membrane protrusions that function as antennae for cells to probe their environment<sup>17</sup>. Presence of filopodia shows that MSCs began to mimic primary neurons on matrigel-coated gels – a type of artificial collagen. Once embryonic stem cells have been specialized and demonstrate proper function, they can be transplanted into *in vivo* animal models.

### Discussion

Guiding stem cell differentiation is a developing study in stem cell research. This paper supports the method of using specialized stem cells in an *in vivo* biological microenvironment to control stem cell fate. The first study analyzed showed the development of specialized stem cells inserted into the adult murine heart. These stem cells engrafted into the heart 30 to 60 days after their transplantation. The conclusion drawn from this study was supported by a study by Caspi et. al. Unspecialized embryonic stem cells (hESC-CMs) did. A third study by Lagasse et. al. further supports the above method of differentiation by studying the development of hematopoietic stem cells into hepatocytes in mice livers. HSCs were shown to be engrafted in the livers of eight of the ten surviving mice.

This paper has shown that the best way to guide the differentiation of stem cells is to first differentiate unspecialized stem cells *in vitro* or to harvest specialized stem cells. The harvesting process of stem cells depends on the type of stem cells that are being harvested. Hematopoietic stem cells, for example, would be harvested from bone marrow. These specialized stem cells are then transplanted into a biological microenvironment that matches their stem cell fate. This explains why HSCs were transplanted into the damaged livers of mice; HSCs would best engraft and help repair this organ. Stem cell transplantation is particularly important in repair of injury and cancer research.

Despite the necessity of specialized stem cells in stem cell research and transplantation, it is still important to take advantage of the pluripotency of embryonic stem cells. This paper shows that ESCs are useful when previously specialized stem cells are scarce. ESCs can be specialized *in vitro* and give rise to all types of cells. Stem cell transplantation can help to restore tissue function, and can be used in cancer therapy. Stem cells have the potential to save lives. It is also important to continue to research *in vivo* differentiation, to ensure that the mature cell populations that develop in these cultures display appropriate functional properties when transplanted into appropriate animal models<sup>12</sup>.

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# Mental Toughness on and off the Court, Field, and Rink

by Dean Ross

# Abstract

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have always admired the mental toughness of professional athletes and I've wondered if the ability of athletes to succeed and remain calm under pressure can be applied to other aspects of life. More specifically, are athletes able to deal with stress and perform better under stress than nonathletes? Using the device called the E-Sense Skin Response System,<sup>5</sup> I measured conductance levels in the unit µ siemens as a way to observe changes in stress levels while I administered the Trier Social Stress Test (TSST)<sup>5</sup> to induce stress as well as measure performance. Conductance measures stress because stress causes sweaty palms, which increases conductivity. For the purpose of this paper conductivity can be considered synonymous with stress levels. A sample of 19 students tested yielded a significant difference in performance on the math section of the Trier Social Stress Test between athletes and non-athletes, with a one-tailed p-value of 0.0209625. There was no significant difference in the change in average stress levels between athletes and non-athletes, with a one-tailed p-value of 0.0618165.

# Introduction

Research has been done regarding different aspects of stress in athletes, from physical stress (injuries) to differences in psychological anxiety.<sup>1</sup> Scientists have yielded evidence supporting various hypotheses such as the relationship between age and stress in athletes, and the effects of mental stress on injury.<sup>1</sup> However, not much has been done specifically in the area of maintenance of mental toughness in athletes off the court, field, rink.

Most of the data gathered looking at mental toughness and athletes has been done in the form of surveys.<sup>1</sup> Lavallée, Lynn, and Flint of York University looked at the role of stress, competitive anxiety, mood state, and social support in the occurrence and severity of athletic injury. This study concluded that stress, competitive anxiety, and mood state were all directly proportional to athletic injury and severity.

A second study, *A Cognitive-Behavioural Analysis of Mental Toughness in National Rugby League Football Teams,* conducted by Golby *et al.* of the University of Teesside and the University of Strathclyde, sought to identify a relationship between mental toughness and a team's performance in the Rugby World Cup.<sup>4</sup> Mental toughness was measured through the use of a series of questionnaires. It was discovered that the teams that had greater mental toughness overall were more likely to have success in the tournament.

A study performed by Koivula *et al.* of Stockholm University explored how an athlete's idea of self-perfectionism affects personal standards, doubt about actions, and concern over mistakes.<sup>2</sup> In this study, researchers used a series of studies in order to find out that lower personal standards, higher doubt about actions, and higher concern over mistakes increases as a result of an unrealistic idea of self-perfectionism.

Another study found a substantial disparity of mental toughness between levels of achievement, gender, age, years of experience, and sport type.<sup>3</sup> The researchers used the Mental Toughness Questionnaire to measure mental toughness in 677 different athletes, as well as a series of surveys that included more personal information. While these studies looked at mental toughness in athletes, none of them address the difference in mental toughness between athletes and non-athletes. They also depended on questionnaire-based self-reporting to measure mental toughness.

The current study tested the hypothesis that the experience in high pressure situations afforded to athletes in their respective sports allows them to remain calmer and function at a higher level under pressure than non-athletes. Do athletes handle and perform better under stress than non-athletes? In order to answer this question stress levels for athletes and non athletic students at Berkeley Carroll Upper School were measured using the eSense Skin Response system to measure stress levels. The eSense Skin Response system measures skin's electrical conductance. The skin's electrical conductance varies directly with its moisture level, and moisture level is directly related to stress. An increase in sweat has been shown to be connected to an increase in stress.<sup>5</sup>

The independent variable in this experiment is whether or not the subject is an athlete. The dependent variables are the differences in conductance levels as a result of and performance on the TSST. I attempted to control the variables of stress unrelated to my study as well as disturbances during my study such as phone alerts, people entering the space I was in, and more. I looked to minimize the effect of these control variables by finding a quiet space and engaging the subject in the study.

### **Methods**

In order to establish a change in conductance based on increase stress, an initial baseline reading needed to be recorded. Subjects were allowed to do whatever they wanted on their phone while their stress levels were recorded. During the initial study, I noticed spikes in the stress levels when the participant came across various items on Facebook. Therefore, I began to provide a soothing YouTube video of scenery with calming music for my subjects to watch while the baseline reading was being gathered.

### **Procedures**

The Trier Social Stress Test and the E-Sense Skin Response tool were used to induce and measure stress. The baseline reading took five minutes, while the TSST took about 10 minutes. The E-sense skin response system app automatically calculates average stress levels per minute, and average, minimum, maximum, and range of stress levels were recorded for each subject. After the Baseline was established, the TSST was administered. This test is done in two parts. The first part asks subjects to tell a story. The subjects are given no further instructions and are timed for five minutes. For the second half of the TSST the following instructions were read. "During the five-minute math portion of this task you will be asked to sequentially subtract the number 13 from 1,022. You will verbally report your answers aloud, and be asked to start over from 1,022 if a mistake is made. Your time begins now." If the participant made a mistake, then I would simply say: "That is incorrect, please start over from 1,022." I measured stress levels during the five minute math part, recording subjects' average stress levels each
minute, minimum and maximum stress level, range of stress levels, as well as number of mathematical errors by the subject. I then compared the athletes and non-athletes change in stress levels between the pressured and unpressured situations, as well as the number of mistakes made on the TSST.

# Results

I conducted a one-tailed t-test comparing the change in average stress levels in the pressured and unpressured situations between athletes and non-athletes. The one-tailed t-test yielded a p-value of 0.0618165, which means the difference in stress levels was not statistically significant. I also conducted a one-tailed t-test comparing the number of math mistakes made by athletes versus non-athletes. This one-tailed t-test resulted in a p-value of 0.0209625, deeming this data significant.

Baseline Average	Baseline Average	TSST Average	TSST Average
Conductance	Conductance	Conductance	Conductance
Non-Athletes	Athletes	Non-Athletes	Athletes
3.56	3.43	6.46	3.75

Mistakes on Math (Non-Athletes)	Mistakes on Math (Athletes)	
4.9	2.5	

# Discussion

The results from my study are not significant as a whole, but they do give me hope that future similar studies could produce truly notable data. The results of the differences in conductance levels between the study and the baseline are not significant. On the other hand, the difference in the math performance under stress of athletes versus non-athletes indicates statistically significant data, and should be further explored.

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# Race and Fouls: Is There Racial Bias in Number of Fouls Allocated to Players of Color

by Leah Ross

# Abstract

his study tested racial bias among referees in the NBA against players who can be visibly categorized as People of Color (POC). The data suggested that white players average more fouls per minute, and have a significant positive correlation with fouls per minute. This study also suggests that race is not necessarily a major factor in determining how many fouls a player receives. Position may have a greater impact on fouls received.

### **Background Section**

Racial bias has continued its impact on collegiate and professional sports. In 2003, an interview with Shaquille O'Neal, a player considered to be one of the greatest centers of all time, showed his frustration with the refereeing in the NBA.

**Reporter:** "I know you were frustrated at how the officiating went down the stretch there, but you guys pulled it out and it was a big win."

**Shaquille O'Neal:** "If you ever started wondering why the league is losing money, that's why. People pay good money to come watch these athletes play and they (the referees) try to take over the f\*\*\*\*\*\*\* game." **Reporter:** "Shaq we're on live."

Shaquille O'Neal: "I don't give a s\*\*\*."

The current study attempts to answer the question: is there racial bias among NBA referees in number of fouls called against players who can be visibly categorized as POC? The independent variable is race and the dependent variable is rate of fouls called. Background information relied heavily on the findings of several articles that research other kinds of racial bias. While these articles do not particularly pertain to the research question they do help with a general understanding of racial bias in sports.

The article *Driving While Black: Bias Processes and Racial Disparity in Police Stops* explores racial profiling in police stops on the road. The study concluded, "We find only weak evidence of racial disparity in stops by officers of the state highway patrol but stronger evidence in those made by local

police officers" (Zingraff, 2006, p. 1). While a wide range of studies has researched bias in betting, ratings, and media coverage, few have explored racial bias in number of fouls called.

*Racial Bias in the NBA: Implications in the Betting Markets* looks at the impact of race on the betting spread of NBA games. The researchers were able to conclude, "in the games where the majority of the officials are white, betting on the team expected to have more minutes played by white players always leads to more than a 50% chance of beating the spread." (Prince, 2008, p. 8). In simple terms, a spread in betting is the predicted amount by which a team will beat another team. One wins by betting above or below the point spread accurately. In this case, when the majority of officials are white, betting on the team that plays white people more, gives the bettor a more than 50% chance of winning their bet.

The third article looked at implicit bias in viewers of the NBA. Their study showed, "the size of television audiences viewing NBA games is positively correlated with increasing participation by white players in NBA games. This result indicates the presence of consumer discrimination in the market for NBA players" (Funk, 2001, p. 1). Racial bias is not only prevalent in betting and viewership of basketball but in sports media coverage of collegiate basketball.

Biased Voices of Sports: Racial and Gender Stereotyping in College Basketball Announcing analyzed language used by commentators to determine whether there was a bias in reporting. It found, "Black men players tended to be stereotyped as naturally athletic, guick, and powerful, while White men players continued to be touted for their hard work, effort, and mental skill" (Eastman, Billings, 2015, p. 1). The final article is fairly similar to the research question and provides insight into the possible outcomes of the experiment. This study was also attempting to find racial bias in refereeing in the NBA. Price and Wolfers' study determined, "We find - even conditioning on player and referee fixed effects (and specific game fixed effects) - that more personal fouls are called against players when they are officiated by an opposite-race refereeing crew than when officiated by an own-race crew." (Price, Wolfers, 2007, p. 5). While the findings are important, the controversy sparked by this study may have the biggest impact on the experiment. After circulations through popular media, the article attracted both the attention and criticism of David Stern, the NBA commissioner at the time. As described by, "It is possible that, since the release of their results, the behavior on the part of referees has changed" (Prince, Wolfers, 2008, p. 8). The NBA may have become more conscious of race relations between players and referees in response to the article. As a result, racial bias in fouls could not be as obvious or just not be there. Through these three articles, there is an unfortunate common theme of racial bias in collegiate and professional basketball. Whether or not it exists in fouls called against black players is what needs to be determined, but it is still present in other facets of the sport.

### Procedure

The initial step of performing the experiment focused on finding data. A large data set that could be exported and easily manipulated needed to be found. After looking on Google at a variety of websites, a website called "nbaminer.com" provided all the data needed. The data was then exported and rearranged in Excel. The name of the team that each player played for was attached. Then, all of the players who had played 29 games or fewer were discarded. This was to ensure that players who had signed onto teams with 10 day contracts or even multiple 10 day contracts would be excluded from the final roster. Typically, players who have been signed to 10 day contracts produce statistics that differ quite drastically from the normal spread of NBA players with full time spots on a roster. Including them in the data set would have produced an inaccurate picture of the average NBA player's performance.

Next, each player was categorized by visible race. They were sorted into two categories, POC and white. For each player, a picture of them was Googled in order to determine, visibly, which category they fell into. This was done in order to replicate the quick decision making that referees have to make when assessing fouls to players. After sorting by race, the total personal fouls per player per team, average total personal fouls per season per team, fouls per minute per player, and average personal fouls per team was calculated. This procedure was copied individually for white players and POC players. In order to calculate correlations, the data set was run through Statistical Package for the Social Sciences, a statistics program. Race was operationalized by assigning white the number 0 and assigning POC the number 1. Fouls per minute were used to determine any correlations between race, rebounds, blocks, and steals.

## Data

### Graph 1





\*Please note: Data points overlap when multiple players received the same number of fouls per minute.

# Table 1

Correlations						
		Race_Num	Fouls_ Minute	Rebound	Blocks	Steals
Race_Num	Pearson Correlation	1	164**	041	.021	.183**
	Sig. (2-tailed)	N/A	.001	.428	.685	.000
	N	379	379	379	379	379
Fouls_ Minute	Pearson Correlation	164**	1	.031	.196**	307**
	Sig. (2-tailed)	.001	N/A	.540	.000	.000
	N	379	382	382	382	382
Rebound	Pearson Correlation	041	.031	1	.745**	.334**
	Sig. (2-tailed)	.428	.540	N/A	.000	.000
	N	379	382	382	382	382
Blocks	Pearson Correlation	.021	.196**	.745**	1	.111*
	Sig. (2-tailed)	.685	.000	.000	N/A	.030
	N	379	382	382	382	382
Steals	Pearson Correlation	.183**	307**	.334**	.111*	1
	Sig. (2-tailed)	.000	.000	.000	.030	N/A
	N	379	382	382	382	382

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

# Table 2

Report					
Fouls_Minute					
Race_Num	Mean	Ν	Std. Deviation		
White	.09655161	98	.028439071		
Person of Color	.08641388	281	.026100596		
Total	.08903525	379	.027054067		

### Table 3

Highest Number of Fouls Per Minute			Lowest Number of Fouls Per Minute				
Race_num	Position	Player	Fouls_ Minute	Race_num	Position	Player	Fouls_ Minute
White	Center	C. Aldrich	0.173	Person of Color	Guard	R. Butler	0.021
Person of Color	Center	J. Thompson	0.17	Person of Color	Guard	K. Walker	0.039
White	Center	T. Hansbrough	0.167	Person of Color	Guard	D. Rose	0.041
White	Center	J. Nurkic	0.164	Person of Color	Small Forward	T. Prince	0.042
Person of Color	Center	A. Payne	0.161	Person of Color	Guard	G. Robinson	0.044
Person of Color	Center	A. Ajinca	0.158	Person of Color	Guard	J. Jenkins	0.045
Person of Color	Center	T. Black	0.157	Person of Color	Guard	N. Batum	0.046
Person of Color	Power Forward	J. McAdoo	0.156	White	Small Forward	D. Gallinari	0.046
Person of Color	Center	D. Dedmon	0.156	Person of Color	Guard	N. Young	0.047
White	Center	A. Bogut	0.155	White	Guard	P. Connaughton	0.048
White	Center	N. Collison	0.151	Person of Color	Small Forward	L. Deng	0.049
Person of Color	Small Forward	K. Oubre	0.15	Person of Color	Guard	D. Williams	0.05
White	Small Forward	M. Miller	0.148	Person of Color	Guard	J. Butler	0.051
White	Power Forward	N. Bjelica	0.145	Person of Color	Guard	W. Ellington	0.052
Person of Color	Center	N. Hilario	0.141	Person of Color	Guard	D. Wade	0.052
Person of Color	Center	R. Hollins	0.14				
White	Center	A. Varejao	0.138				

# **Results**

Graph 1 is a scatter plot graph that illustrates number of fouls per minute during the 2015-2016 NBA regular season. It shows fouls incurred by white players versus fouls incurred by players of color. Table 1 represents a test for correlations. Any statistically significant correlation is double starred. There are seven significant correlations: Fouls per minute and race (-.164), steals and race (.183), fouls per minute and blocks (.196), fouls per minute and steals (-.307), rebounds and blocks (.745), rebounds and steals (.334), and blocks and steals (.111).

For the purpose of this experiment, the important correlations to understand are fouls per minute and race, fouls per minute and blocks, fouls per minute and steals, and steals per minute and race. The first correlation implies that if you are a player of color you get fewer fouls per minute. The second correlation indicates that the more blocks you get, the more fouls you receive. The third correlation says the fewer steals you get, the more fouls you receive. The final correlation suggests that if you are a player of color you get more steals.

Table 2 is a table of results after calculating the average number of fouls per minute. The mean number of fouls per minute for players of color is .0864 and for white players is .0965. The "N" in the column heading represents the sample size. In the data set there were 98 white players, 281 players of color, and 379 total players.

Table 3 and Table 4 are charts that list the players with the highest number and the lowest number of fouls per minute, respectively. Another column includes their race as well.

## Discussion

In interpreting this data, the most obvious piece of information is that white players average more fouls per minute than players of color. However, race did not seem to be the most influential factor is determining number of fouls a player receives. That is allocated to position. Evidence for this claim can be found in Table 3. The players with the highest number of fouls are almost exclusively centers. This position involves protecting the basket and much more physical contact. In contrast, players with lowest number of fouls are almost exclusively guards. Their position does not force them into a role where they would have a greater opportunity to be called for a foul. Another bit of evidence that fouls are contingent on position rather than race can be seen in Table 3. All but two players on the list are players of color and twelve out of fifteen are guards. Instead of claiming that there is some sort of racial bias in refereeing, it may be more accurate to argue that guards tend to be players of color and because guards do not foul as often, there is significant negative correlation between race and fouls per minute. One could also argue that there may be more white centers in the NBA which translates to more fouls per minute for white players because centers tend to receive more fouls.

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# Are High School Soccer Players More Likely to be Injured with Increased Playing Time?

by Albert Rubin

# Abstract

he topic of this paper is: *Does more playing time increase the chances of getting injured in soccer*? In order to answer this question, an in-house study was conducted on 15 soccer players from the Berkeley Carroll varsity soccer team in the fall of 2016. Over the course of the season, total playing times were monitored along with injuries that each subject sustained. At the end of the season, it was found that more playing time did significantly increase the chance that females would sustain an injury. However, there was no significant data to support the conclusion that more playing time increases a male's chance for getting injured.

# Introduction

Soccer is one of the most popular sports across the globe (*Swanepoel, Surujlal & Isabirye, 2015*). During events such as the World Cup, most soccer starters are constantly playing, which potentially leads to the overuse of their muscles. When players overuse their muscles, they are more likely to suffer pulled or (in extreme cases) torn muscles (Physio Works, 2017). While it is relatively easy to rationalize why injuries might occur in soccer, it remains difficult to predict when a soccer player might get injured (or even what type of injury they may sustain), making it hard for soccer coaches to know when to rest their players. The three articles this study used for its background research on were: "*Sports injuries in adolescents' ball games: soccer, handball, and basketball" ("Article 1")* by J. Dye and A.B. Nielsen (1990); "Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players ("Article 2") by E. Witvrouw and L. Daneels (2003); and, "Acute injuries in soccer, ice hockey, volleyball, basketball, judo, and karate: analysis of national registry data" ("Article 3") by U. Kujala and S. Taimela (1995).

In Article 1, Dye and Nielsen (1990) analyzed sports injury data collected at the Danish Sports Club from athletes of varied ages. They found that soccer players mostly sustain injuries in their legs, whereas in handball and basketball, players mostly sustain injuries in their arms and fingers. They also found that there are fewer ball-to-foot injuries in handball or basketball.

In Article 2, Witvrouw and Daneels (2003) studied the acute injury profiles of soccer, ice hockey, volleyball, basketball, judo and karate athletes. They concluded that differences in acute injury risks due to gender were small, but that differences due to age were significant. Compared to younger athletes,

players aged 20-24 years had the highest risk of sustaining an injury. They reasoned that this is because training and competition is most intense for athletes of those ages. They also found that competitions tend to have a higher risk of injury per hour than training does, and that out of the six sports they monitored the overall injury risk was highest in the sports with the highest rates of bodily contact.

In Article 3, Kujala et al. (1995) investigated whether muscle tightness is a risk factor for the development of muscle injuries. They found no significant statistical difference between the amount of time spent in training and games between injured and uninjured players. This suggests that playing time does not have a significant impact on the risk for sustaining an injury.

In addition to the background research, a preliminary study was conducted on professional soccer players in the Barclays Premier League and the German Bundesliga. The experimental question was: *Does more playing time increase the chances of getting injured in soccer*? All injuries and total playing times for each player were carefully recorded in a google spreadsheet. One of the conclusions drawn was that players who are close to their 1500th minute of playing time have a significant chance of getting a hamstring injury. The preliminary study and the in-house study were essentially the same, except for testing different players. Both studies aimed to answer the experimental question: *Does more playing time increase the chances of getting injured in soccer*?

## Methods

The participants of this study were the players on Berkeley Carroll's 2016 boys and girls varsity soccer teams. Overall, 7 boys and 8 girls participated. This study was observational because no variables were manipulated during the course of the study. The variables accounted for were: total amount of time played; total number of soccer injuries; and type of soccer injury. The study began after the first game of each team's season. After each game, all participants received an email asking them:

Did you play in the game? This question could only be answered in two ways: yes or no.

**If you played in the game, how many halves did you play in?** This question could only be answered with 0, 1, or 2 halves. 0 halves rounded to 0 minutes of gameplay; 1 half rounded to 40 minutes of gameplay; 2 halves rounded to 80 minutes of gameplay. At the end of the season, the total amount of time played for each player was based on the number of halves they played.

If you played in the game, did you get injured during the game? This question could only be answered in 1 of 2 ways: yes or no.

**If you got injured in the game, what type of injury did you sustain?** Subjects had to either consult with the soccer trainer (or with a doctor) to figure out the diagnosis of their injury, or conduct a self-diagnosis (an educated guess for the injury they had sustained) to answer this question.

If you didn't play in the game, was it due to an injury? This question served as a follow up to the first question. If a subject missed a game, their total playing time would decrease because of an injury or an outside event.

At the end of the season, the estimated sum of total time played for each subject was calculated. This data was analyzed in conjunction with the injury data.

# Data

# Graph 1

This figure demonstrates all of the different injuries that Berkeley Carroll soccer players sustained over the course of the 2016 soccer season. Analysis is based on subjects' descriptions.



## Graph 2

# Correlation between Playing Time and Number of Injuries for Girls

This figure shows the correlation between playing time and number of injuries on the girls varsity soccer team. The correlation between the two variables represents a moderate, positive, linear pattern (R = 0.52).



### Graph 3

# Correlation between Playing Time and Number of Injuries for Boys

This figure shows the correlation between playing time and number of injuries on the boys varsity soccer team. The correlation between the two variables represents a weak, positive, linear pattern (R = 0.32).



## Graph 4

### Correlation between Playing Time and the Number of Injuries for All Players

This figure shows the correlation between playing time and number of injuries for all of the varsity soccer players. The correlation between the two variables represents a moderate, positive, linear pattern (R = 0.49).



### Discussion

Since none of the R-values were close to 1, it can not be concluded that an increase in playing time causes an increase in injury rates. However, when comparing this study to the previous studies referenced in the introduction, the rules of soccer (a more foot-heavy sport compared to handball and basketball) account for the high number of leg injuries compared to upper body injuries. If a person wants to play a sport where they have a decreased chance of getting an upper body injury over a lower body injury, it would be better for this person to take on soccer rather than a sport that requires constantly using your arms or hands.

Due to difficulties in getting subjects, one of the major limitations of this study was that the sample size was too small. If it had been greater, the correlations may have been more accurate, which would have made it easier to determine the overall trends amongst graphs 2, 3, and 4. Because not all players who sustained injuries this season participated in this study, it was very hard to compare the injury status of the boys and girls soccer teams. Another issue was the anomalous result of subject X, who was injured before he had any playing time. The decision was made to exclude his data from the graphs because it wasn't fair to keep him in the study when he did not even get a chance to get any playing time. Subject X got injured in the 1st game, but because the playing time was not recorded for any of the subjects in their 1st game, it was decided to exclude subject X from the study since he technically did not acquire any playing time at the start of the study. Another problem that occurred was when surveys were sent after each game, subjects were not given guidelines to help them determine the type of injury they sustained. They had to mostly go by their gut feeling. This was a highly inaccurate way of identifying a subject's diagnosis. It might have been better to have the trainer diagnose injuries rather than have the subjects conduct a self-diagnosis. Since playing time was determined based on how many halves each subject played, the amount of time that each subject played was also very inaccurate because each soccer half is 40 minutes. If the study were re-done, the soccer coaches could monitor each player's playing time individually to get more accurate results.

Because of the very small sample size of this study, there is not a clear conclusion that can be drawn. However, because graph 2 has a higher R-value (0.52) than graph 3 (0.32), it can be seen that there is a greater correlation between injuries and playing time amongst the girls over the boys. But since these R-values are not very close to 1, additional research is needed.

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# Mood and Food — A Study of Nutritional Psychiatry

by Ananda Sahihi

# Abstract

his study addresses whether or not there is a correlation between nutritional choices and mental health. In this case the nutritional choice observed is vegetarianism. The question was tested using the Positive and Negative Affect Schedule questionnaire (PANAS)' to gather information about the subject's mood over the course of a week. This was done with sixty-five high school students. Students were asked whether they were vegetarian, non-vegetarian, or if they follow an alternative diet. This data was correlated with their positive and negative scores on the PANAS. The data showed no significant difference in average positive and negative scores for each group. The results suggest that vegetarianism does not have an impact on mental health. However, these questions do bring up the consideration of other types of diets and nutritional choices and their effects on mood.

# Background

Like an expensive car, your brain functions best when it gets only the premium fuel to keep it running. Eating high quality foods that are rich in vitamins, nutrients, and minerals help to nourish and protect the brain. Unfortunately, the opposite is also true. The brain can be damaged if it does not receive this "premium food", which can lead to impaired brain function. Impaired brain function can be in the form of depression and similar conditions, which are a huge burden in the modern world. Current treatment strategies generally focus on biological and psychological pathways, largely ignoring the role of lifestyle as outlined by Anxiety and Depression Association of America<sup>2</sup>. Nutritional psychiatry researches nutritional approaches for the prevention and treatment of mental disorders. While it is a newer area of research, the following studies and others similar to them are bringing attention to nutritional psychiatry.

The study that initially inspired mine looked at how the change to a Westernized diet of more processed and pre-made foods has affected the mental health of circumpolar people, who are people living in areas around the Earth's poles.<sup>3</sup> The researchers took an observational approach. They looked at statistics from electronic resources such as ISI Web of Science and PubMed, which are online databases for biomedical literature. Using keywords such as arctic, circumpolar, diet, omega-3 fatty acids, mental health, seasonal affective disorder, and suicide, scientists sought to identify a correlation between suicide and depression rates, and obesity and heart disease. Their results showed that a change in traditional diets led to increased health problems, such as obesity, cardiovascular disease, and diabetes. Additionally, the mental health of circumpolar peoples showed a substantial decline, characterized by increased rates of depression, seasonal affective disorder, anxiety, and suicide.

Another study that supports the correlation between diet quality and depression examined dietary patterns and the volume of the hippocampus in adults.<sup>4</sup> The hippocampus is part of the brain thought to be the center of emotion, memory, and the autonomic nervous system. In this study,

researchers assessed whether diet is associated with differential rates of hippocampal atrophy, or deterioration, over time.<sup>4</sup> They did this by focusing on a sample of Australians aged 60-64 years. Everyone in the group completed a food frequency questionnaire that recorded caloric and nutritional intake, and underwent two magnetic resonance imaging scans (MRI) approximately 4 years apart. Magnetic resonance imaging is a medical technique used in radiology to image the anatomy and the physiological processes of the body. They then assessed the association between dietary factors and hippocampal volumes. The results showed that every point increase in the score from the food frequency questionnaire was associated with a 45.7 mm<sup>3</sup> larger left hippocampal volume, while higher consumption of an unhealthy "Western" dietary pattern was associated with a 52.6 mm<sup>3</sup> smaller left hippocampal volume. This led to the conclusion that lower intakes of nutrient-dense foods and higher intakes of unhealthy foods are each independently associated with smaller left hippocampal volume. Although this study had similar results when performed on animals, this was the first human study to demonstrate a connection between diet and hippocampal volume.

With all the evidence that a nutrient-poor diet can have a negative impact on mental health and cognitive issues, can the impact can be reversed? There is some evidence showing that if you improve your diet later on in life, your mental health improve. This idea was tackled in a study where scientists attempted dietary intervention for adults with serious depression.<sup>5</sup> Around 200 adults with Major Depressive Episodes (MDE) were randomized to receive either the dietary intervention or social support for the condition. A Major Depressive Episode is a period characterized by a primarily depressed mood for two or more weeks and a loss of interest or pleasure in everyday activities. Participants in both groups completed mental health assessments prior to their programs, at program completion (3-months), and at a 6-month follow-up. The results showed, through shorter rehabilitation and hospitalization periods, that a dietary intervention for depression, as a supplement to standard care, has the potential to be cost-effective and widely applicable to cases of Major Depressive Episodes. This approach may lead to improve doutcomes for individuals with MDE and reduce the public health burden of psychiatric illness.

My preliminary research focused on the short-term diet change of 20 Berkeley Carroll students and observed the transition from an omnivorous diet to a vegetarian one and how it affected their mental health. 10 of the subjects were in the control group and did not change their diet while the other ten were in the experimental group and tried vegetarianism for two weeks. Both groups took the Profile of Mood States questionnaire twice over the course of the study to get an idea of their mood. The results showed no significant difference by in mood state, but had interesting trends that led to the alterations of this study.

The phrase "you are what you eat" is ingrained in the minds of many, whether or not they choose to live by this saying. The phrase reminds us that what you eat determines your health. It is commonly believed that mental health and physical health are strongly correlated. When you improve one, you can improve the other. In light of this, the question approached in this research was: Do the dietary decisions of teenage students affect their mental health? And if so, to what extent? By asking students what diet they already followed, I did not account for transition time as I assumed that their bodies and minds were used to their standard nutritional intake.

# **Materials and Methods**

The first step in designing the experiment was choosing the correct questionnaire for mood. This questionnaire needed to focus on the subject's general mood in the past week rather than momentary mood. The Positive and Negative Affect Schedule (PANAS) was an appropriate fit to do this. It asks the subjects to think about the past week in response to a series of adjectives that they are given (for example, anxious, hostile, attentive) and rate how they feel on a scale of 1 to 5 according to the following descriptions:

- 1: Very Slightly or not at all
- 2: A Little
- 3: Moderately
- 4: Quite a Bit
- 5: Extremely

The scoring of the PANAS is usually self-calculated (see Figure 1). I designed an efficient survey that asked the students about the diet they followed prior to the PANAS to prevent self-calculating and optimize participation. The very first section of the survey was to identify whether the subject was vegetarian, non-vegetarian, or followed an alternative diet. This then sent them to the next appropriate section in order to keep the scores separate. I gathered the data of students from two New York City high schools. Once provided with the input from each group, I could then calculate each subject's positive and negative score using the guidelines provided by the PANAS.

### Figure 1

### **Classic Formatting of the PANAS Questionnaire**<sup>1</sup>

This figure indicates how the Positive Affect Negative Affect Schedule (PANAS) psychometric scale is classically formatted to measure the independent constructs of positive and negative affect both as states and traits. Directions are provided to self-score, but my survey mimicked the format without students having to self-score. Only weekly scores were considered in the results.

### **PANAS Questionnaire**

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word. Indicate to what extent you feel this way right now, that is, at the present moment *OR* indicate the extent you have felt this way over the past week (circle the instructions you followed when taking this measure)

1 Very Slightly or Not at All	2 A Little	3 Moderatel	4 y Quite a Bit	5 Extremely
1. Interested	6. G	uilty _	11. Irritable	<ul> <li>16. Determined</li> <li>17. Attentive</li> <li>18. Jittery</li> <li>19. Active</li> <li>20. Afraid</li> </ul>
2. Distressed	7. Sr	cared _	12. Alert	
3. Excited	8. H	ostile _	13. Ashamed	
4. Upset	9. Er	nthusiastic _	14. Inspired	
5. Strong	10. I	Proud _	15. Nervous	

### **Scoring Instructions**

**Positive Affect Score:** Add the scores on items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19. Scores can range from 10 - 50, with higher scores representing higher levels of positive affect. Mean Scores: Momentary = 29.7 (SD = 7.9); Weekly = 33.3 (SD = 7.2)

**Negative Affect Score**: Add the scores on items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20. Scores can range from 10 - 50, with lower scores representing lower levels of negative affect. Mean Score: Momentary = 14.8 (SD = 5.4); Weekly = 17.4 (SD = 6.2)

# **Results**

### Figure 2

### **Comparison of PANAS Scores**

(a) Represents the average negative scores of vegetarian and non-vegetarian students. The average negative score of the vegetarian students was 25.6 and the negative score of non-vegetarian group was 30.7 average. The scores range from 10-50. As lower scores represent lower levels of negative affect, on average the non-vegetarian group experienced greater negative affect, but the difference was not significant. We can be sure of this because the standard error bars overlap. (b) Represents the positive scores of vegetarian and non-vegetarian students. The average positive score of the vegetarian students was 29.2 and the positive score of non-vegetarian group was 29.9 average. The scores range from 10-50. As higher scores represent higher levels of positive affect, on average the non-vegetarian group experienced greater positive affect, but the difference was not significant. We can be sure of this because the standard error bars overlap.



#### (a) Negative PANAS Scores



# / E. CD / 5 $\bigcirc$

### Figure 3

#### Average Positive and Negative Scores of Alternative Diet Students Compared

The students who indicated on the survey that they follow an alternative diet had negative and positive scores that hovered around a similar range of 25-30. The negative score average was 31.4, while the positive score average was 28.4. The alternative diet results are shown on a separate graph because the subjects were never asked to specify what an "alternative diet" means to them. We don't know how they fall in terms of meat-consumption, and therefore a direct comparison of the three would be unwarranted.



### **Alternative Diet PANAS Scores**

### Figure 4

### Summary Table of Results

Displays the positive and negative p-values from the input of the 65 individual averages in an independent two-sample t-test of vegetarian compared to non vegetarian. They are greater than 0.05 which means there is no significant difference.

	Positive (Vegetarian vs Nonvegetarian)	Negative (Vegetarian vs Nonvegetarian)	
P-value	0.212740	0.339622	

# **Discussion/Conclusion**

As the PANAS score is on a range of 10 to 50, it is interesting that the averages of both the positive and negative scores of all three dietary groups fall between 25 and 31 on the scale. The lowest is the negative average of the non-vegetarian group (25.6) and the highest is the average of the alternative negative score (31.4). Although the averages fall in the same range, the table of individual scores of all 65 participants shows that there was a much greater variety of scores. The range of independent scores was 14 to 49. The accuracy of the averages would sharpen, the range would increase, and the standard deviation of the results would narrow with a larger sample group. In addition, because the PANAS is

self-reported, there is no universal standard average score. The numbers reported in the graphs above must be looked at as relative to each other rather than the entire school community.

There are important factors to consider that would make a study like this more successful in the future. Closer information on dietary choices, such as daily calorie, water, and sugar intake, could help to decipher individual scores. Theoretically, the perfect study would control for all the factors that can affect a teenager's mood in a week including hormones, but those would be very difficult criteria to maintain. In this study the anonymity and safety of the participants was made a priority. A student's mental health history could play a huge role, but accessing this kind of personal information was beyond the scope of this anonymous survey.

Although the difference in averages between the two dietary groups was not substantial enough to draw complete conclusions, the data is full of trends and provides leading questions for future studies. For example, how do the individual effects of nutrition on mood come about? And how might self-confidence and body image come into the conversation? Nutritional psychiatry is an evolving area of research and there is much more to explore.

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# Testing Self Segregation in the Berkeley Carroll Community

by Lauren Tinglin

# Abstract

his study aims to test whether the students in the 7th, 9th, and 11th grades at the Berkeley Carroll School racially self-segregate, and whether the degree to which students self-segregate varies as a function of grade. Over 150 participants completed a Google Docs survey during morning meeting after being prompted by their grade dean. The study found that there was a statistically significant difference in the diversity of friend groups among Berkeley Carroll white students and students of color in the 9th and 11th grades, but not in the 7th grade. This suggests a clear relationship between grade and self-segregation (two tailed independent t-tests: p-value for 7th grade 0.436, p-value for 9th grade 0.0044, p-value for 11th grade < 0.0001).

### Introduction

In *Why Are All the Black Kids Sitting Together in the Cafeteria?*, Beverly Daniel Tatum (1997) argues that children initially see people of different races the same way, but as they mature, develop, and begin to define their identities, race significantly impacts how they see those around them. Race becomes so apparent and influential that adolescents consciously choose to self-segregate and form closer relationships with people that identify as the same race they do. Tatum explains self segregation and how it is manifested from adolescence to adulthood. She writes, "walk into any racially mixed high school and you will see black youth seated together in the cafeteria. Of course, it's not just the Black kids sitting together the White, Latino, Asian Pacific, and in some regions, American Indian youth are clustered in their own groups too. The same phenomenon can be observed in college dining halls, faculty lounges, and corporate cafeterias" (p.71).

Tatum's assertions are supported by the literature. Katz & Kofkin (1997) investigated whether or not 200 Black and White children from six-months to six-years old were cognizant of race. The researchers found that by just six-months old, children distinguished between races and genders by gazing at someone of a different race than theirs for a longer period of time. Both researchers believe that infants are cognizant of race even before six months: "initial awareness [of race] probably begins even earlier" (p. 55). Mendelson and Aboud (2012) created and used the McGill Friendship Questionnaire to test how children choose their friends and whether or not race influences their decisions. They found that children keep "an emotional distance from children of other races" (p. 3).

Such findings are supported by a meta-analysis completed by Kun Wang (2011), who analyzed the findings of 74 different studies related to adolescents and race relations to answer three questions: How is racial identity conceptualized and measured for minority adolescents? What are the characteris-

tics of the participants? What are the major research findings on racial identity of minority adolescents? After reducing the 74 studies down to 11 focused on racial identity, 10 of which focused on African Americans and one of which focused on biracial individuals, Wang concluded that older African American adolescents, around age 17-18, felt more "negatively" about being African American due to prejudices and racial biases. Wang also found that both public regard (how one thinks other people feel about African Americans) and private regard (how one feels about African Americans and their group membership) are related to racial discrimination, although she hypothesizes that people with low public regard tend to be more sensitive to microaggressions and other subtle racial cues.

Similarly, a substudy of a mixed-method study aiming to determine "the racial-ethnic centrality, ranging from pride and cultural connection to ambivalence and colorblind attitudes" (Charmaraman and Grossman, 2010) of 1793 adolescents in grades 9 through 12 from three public high schools found that most participants spoke highly about their ethnic background and expressed appreciation for their line-age. Few participants expressed remorse for their heritage, and the researchers believe that some of the remorse could stem from other social identifiers such as gender, and sexual orientation. They also found that female participants emphasized their "racial-ethnic backgrounds" more than male participants, although there were no distinct differences between the sexes.

However, none of the studies described above focused on students attending independent schools, nor did they compare the degree to which students self-segregate as a function of grade. As such, this study aims to test whether or not the students in the 7th, 9th, and 11th grades at the Berkeley Carroll School racially self-segregate, and whether or not the degree to which students self-segregate varies as a function of grade.

## Methods

The sample includes the 7th, 9th, and 11th grades at Berkeley Carroll School, which were studied because they are the most "diverse" grades, as determined by Berkeley Carroll's Director of Community and Inclusion (Melendez, pers. communication, 2016), and the Berkeley Carroll (BC) faculty. The sample size is thus over 200 members, which is fairly large as compared to some of the other studies referenced above.

Participants completed a Google Docs survey during morning meeting after being prompted by their grade dean, who read:

"Berkeley Carroll is doing a study on social interactions in our community to insure that all of our students and faculty feel welcomed and included. The survey is anonymous so please fill it out honestly."

The survey asked participants to identify their race, grade/teacher, gender, and list their top five friends. There were also random filler questions to prevent the subjects from guessing the purpose of the study. For example: "What's your favorite color?;" "Who is your favorite artist?;" "What's your favorite subject?." Then the names of the participants were anonymized and matched with their self-identified race as based on the survey. The data was then analyzed to determine the degree of "racial-overlap" in friend groups, and the degree of racial-overlap was compared across grade levels. Finally, the ratio or proportionality of Caucasian students to students of color in each friend group was then calculated.

### Data

The data was split into "white" subjects and "POC (people of color)" subjects, and was operationalized by converting all of the Caucasian students into values of "0" and people of color into values of "1".

Then three two tailed independent t-tests were performed to compare mean scores of how "diverse" a friend group is based upon how close the mean value of their friendship circle was to 1 (1 being all people of color and 0 being all Caucasian). The data showed that Berkeley Carroll students do self segregate in the 9th and 11th grade, but not in the 7th grade (p-value for 7th grade 0.436, p-value for 9th grade 0.0044, p-value for 11th grade >0.0001). Figures 1- 3 illustrate the significantly higher means in the students of color 9th and 11th grades compared to the 7th graders.

# Figure 1

7th Grade					
	White Students	Students of Color			
Mean of Diversity	0.3158	0.2033			
Standard Deviation	0.3846	0.2609			
SEM	0.0882	0.087			
Ν	19	9			
P-Value	0.436				

# Figure 2

	9th Grade	
	White Students	Students of Color
Mean of Diversity	0.2522	0.4725
Standard Deviation	0.2876	0.2371
SEM	0.0449	0.053
N	41	20
P-Value	0.0044	

# Figure 3

11th Grade					
	White Students	Students of Color			
Mean of Diversity	0.2603	0.6525			
Standard Deviation	0.2387	0.3222			
SEM	0.0382	0.072			
Ν	39	20			
P-Value	<0.0001				

# Discussion

Based on the data, it seems to be that 7th grade Caucasian students have more diverse friend groups than the 11th grade ones. 9th grade parallels 11th grade; the Caucasian students also tended to have more Caucasian friends (avg= 0.2522) and the students of color also had more friends of color (avg= 0.4725). This means that Berkeley Carroll students are in fact surrounding themselves with people who are racially similar to them as they get older and therefore self segregating which supports my hypothesis. There were also tests done on gender but those results were not statistically significant.

Based on this study, one can conclude that Berkeley Carroll students in 7th, 9th, and 11th grades do racially self-segregate. However there were many limiting factors and sources for error in the data presented. Berkeley Carroll is a predominately Caucasian institution which affects the sample size since it was also predominately Caucasian. The sample size was also quite small – only 157 participants out of about 600 Middle and Upper School students – which also impacts the data and can incorrectly represent the entire Berkeley Carroll community.

Looking forward, the same study can be repeated but with a larger sample size and a more diverse group of students. It could even be tested on grades 1-12, college students, and faculty to distinguish any potential patterns or age/grade that children begin voluntary or involuntary self segregation; or tracking the specific about 1,000 subjects from infancy to adulthood to find a correlation, if any, between age and race relations.

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# Physiological Responses to Art

by Dayna Weissman

## Abstract

his experiment studied the effect of visual art on the brain. The purpose of this experiment was to find out if the heart rate of a subject increases while the subject is looking at artwork that they find aesthetically beautiful. There is already sufficient evidence that beautiful art provokes activity in various regions of the brain, including the caudate nucleus, orbito-frontal cortex, motor cortex, and more. (Ishizu et al., 2011; Vartanian et al., 2004; Kawabata, 2004). In experiments involving emotional stimuli, it was also shown that visual stimuli can deccelerate heart rate (Carretie et al., 2009). However, studies have not yet tested the effect of art on biological systems other than the brain, such as the cardiovascular system, which controls blood flow throughout the body. If it can be proven that art has a significant effect on the body, then this will shed light on what art means to us, and why we we are drawn to it. The hypothesis is that heart rate will increase in the presence of aesthetically beautiful paintings. In the study, 5 subjects were shown 15 paintings, which they rated according to beauty. As they viewed the paintings, their heart rate was recorded with a Polar H7 Bluetooth Smart Chest Transmitter. There was no correlation between heart rate and the painting being viewed, suggesting that beautiful art does not, as a whole, affect heart rate.

# Background

Numerous studies have shown that artwork has an effect on the brain. A 2011 study dealing with the intersection between art and the brain, called *Toward a Brain-based Theory of Beauty*, consisted of showing 21 subjects 60 paintings while giving them a brain scan in an fMRI scanner. The subjects marked each painting as either 'ugly', 'neutral', or 'beautiful' over a 21 second viewing and response period. Researchers found that certain areas of the brain were 'activated' when the subjects viewed art they marked as beautiful. These areas include the medial orbitofrontal cortex, a part of the brain involved in decision making, and caudate nucleus, which is involved in memory storage and processing. Furthermore, the activity of the medial orbitofrontal cortex was proportional to just how beautiful subjects found the artwork (Ishizu et al., 2011). This study provides clear evidence that the brain responds to beautiful art. Activity in the brain implies increased bloodflow to the brain, suggesting that while a subject views beautiful artwork, heart rate should increase in order to provide blood and activate this response.

The findings discussed in *Towards a Brain-Based Theory of Beauty* have been supported by multiple other experiments in neuroaesthetics. A 2003 study titled *Neuroanatomical Correlates of Aesthetic*  *Preference for Paintings* focused on reactions taking place in the occipital lobe, the area of the brain that processes vision. In this experiment, subjects were shown three versions of each painting: an original, unaltered image; an altered image in which one object was moved to a different location within the work; and a filtered image, an image digitally made to be blurry and less detailed through the application of a noise filter. Subjects then rated each version of 40 paintings on a 1-4 scale. Paintings with a high score produced maximum activity in the bilateral occipital gyri and left cingulate sulcus, parts of the vision-processing occipital lobe. It was found that paintings with a low score produced the least amount of activity in the caudate nucleus, involved in memory storage. These results are in line with what we already know about these areas of the brain. The caudate nucleus has been observed to exhibit low activity in patients with depression, so it clearly plays a role in processing pleasure. But most relevant to the topic of cardiovascular responses to art was the finding that "viewing pleasant . . . pictures results in increased regional cerebral blood flow (rCBF) in right primary visual cortex" (Vartanian et al., 2004). This suggests that viewing beautiful paintings has an effect on blood flow, supporting the hypothesis that heart rate in the presence of beautiful artwork will be higher than resting heart rate.

In *Neural Correlates of Beauty*, a similar study done in 2004, ten subjects rated 300 paintings each on a scale of 1-10, then underwent brain scans while viewing the paintings for a second time. Researchers found that both the orbito-frontal cortex, a portion of the brain involved in decision making, and the motor cortex, which controls voluntary movement, were activated while subjects viewed the paintings. More specifically, the orbito-frontal cortex exhibited the highest level of activity in the presence of beautiful paintings, and the motor cortex exhibited its highest level of activity in the presence of ugly paintings. This was an important finding- both regions reacted to art, but the intensity of the reaction depended on the subject's judgement of the art. The motor cortex has previously been found to react in the presence of "fear-inducing visual stimuli" (Kawabata, 2004) and other emotionally charged situations, so the idea that it would react strongly in the face of ugly paintings is not entirely unsupported. Researchers were, however, confused as to why beautiful paintings would not produce a similarly intense reaction if the motor cortex reacts to all emotional content.

Another experiment dealing with neuroaesthetics that relates to my experiment was *The Striatum Beyond Reward: Caudate Responds Intensely to Unpleasant Pictures.* This experiment, unlike the others that have been reviewed in this paper, aimed to test the effects of emotionally charged artwork on the brain, rather than artwork that is simply aesthetically pleasing. Eighteen pictures, categorized as either 'emotionally positive', 'emotionally neutral', or 'emotionally negative', were shown to eighteen subjects as they underwent fMRI scans. The subjects rated their emotional arousal to each image on a five point scale. The striatum, an area of the brain located in the basal ganglia that receives information about the environment, activated more strongly in response to emotionally 'negative' images than it did to positive ones. Researchers noted that "A majority of dopaminergic neurons project to the striatum, dopamine levels being a key factor modulating emotional processes," (Carretie et al., 2009). The caudate nucleus was also sensitive to emotionally negative imagery. This was interesting in comparison to the findings of *Neuroanatomical Correlates of Aesthetic Preference for Paintings;* in this study, the movement-controlling caudate nucleus reacted the least strongly to aesthetically negative paintings. The caudate nucleus would seem, then, to play a bigger role in processing emotion than in imagery.

This experiment also utilized a unique way of controlling outside variables. Each image viewed was marked either by a red or green cross; as the subjects were being scanned, they pressed a button on a device in their left hand if the cross was red, and a button on a device on their right hand if it was

green. This extra aspect of the experiment seems pointless, but it is actually a strategy used to ensure that the brain activity picked up by the fMRI scanner was actually in response to the emotional content of the paintings rather than "outside cognitive factors," or factors that can distract subjects, like noises from outside the room. Indirect tasks such as the one used here have been confirmed to "diminish the risk of cognitive, task related, interferences" (Carretie et al., 2009) in experiments concerning emotion. This is relevant to the current study; if it does not yield significant results, variables that might have interfered with the results will need to be considered.

One variable that could interfere with the results, 'decoupling' of arousal measures, is discussed in the 2005 study *Emotional Responses to Art: From Collation and Arousal to Cognition and Emotion.* This paper claims that biological responses to emotional arousal do not go together in the way one might think. For example, it might be expected that if blood pressure rises in reaction to emotional arousal, the electrical conductivity of the skin might too. However, these two reactions could be decoupled, meaning one may not happen in conjunction with the other even if it seems like emotional arousal was accomplished. This decoupling can happen between two responses in different systems, or even within the same system. So the cardiovascular system might respond to emotional arousal, but only express this through, say, blood pressure, and not heart rate. If in this study, heart rate does not change in response to artwork, it does not necessarily mean that the cardiovascular system as a whole is not changing in response to the artwork in order to increase bloodflow to the brain.

### Procedure

To test the hypothesis that beautiful art increases heart rate, a Polar H7 Bluetooth Smart Chest Transmitter was attached to the subject, and then connected to the Polar Beat iPad application. The subject sat in a chair for 60 seconds so that a reading of their average resting heart rate could be obtained. Only subjects who had resting heart rates between 70 and 79 BPM were able to be tested. If the subject's resting heart rate was outside of these limits, I dismissed them from the experiment. If they had and acceptable heart rate, the slideshow of artwork then began. For the first three subjects, this slideshow was shown on a Smartboard; however, the other two viewed it on the smaller screen of a computer due to technical complications. The slideshow included 15 paintings by various artists, many of them famous, and all of which have been generally agreed upon as being aesthetically beautiful by art historians. The slides were shown in a random order, and were changed after 15 seconds. This gave the subject a 15 second viewing period for each slide, a time frame agreed upon to be optimal for the subject's full comprehension by *Toward a Brain Based Theory of Beauty*, a similar study done in 2011. The heart rate monitor was collecting data for a total of four minutes and 45 seconds. After all 15 images had been viewed, the heart rate monitor was shut off, and the subject was given a survey. Each image was played back for them, and they indicated on a scale of 1-5 how aesthetically beautiful they found it, with one being the lowest score and five being the highest.

For analysis, the data was put into five sets. In the first were included the heart rates of all subjects who had rated any painting with a score of 1 out of 5 while they were viewing said painting. In the second set were the heart rates of all subjects who had rated any painting with a score of 2 out of 5 while they were viewing said painting, and so on with each rating up to five. Each heart rate value in a set was compared with the average resting heart rate of that subject, to check for consistent correlations. I performed 5 two tailed correlated t-tests, one for each set of data. For the paintings rated 1/5, my p-value was 0.865904; for the paintings rated 2/5, my p-value was 0.211461, for the paintings rated 3/5, my p-value was 0.440646, for the paintings rated 4/5, my p-value was 0.530704; and for the

paintings rated 5/5, my p-value was 0.881922. None of these p-values were significant, meaning that there were no trends in the data. My p-values were all above .05, meaning they were too large for there to be a statistical difference between resting heart rate and heart rate while looking at any given painting. The hypothesis, which is that heart rate will increase in the presence of aesthetically beautiful paintings, was not supported by either the p-values or the graphs shown here.

# Data

# Figure 1

# Paintings Rated 1/5



# Figure 2

Paintings Rated 2/5



# Figure 3

Paintings Rated 3/5



### Figure 4

Paintings Rated 4/5

### Figure 5

**Paintings Rated 5/5** 



# Conclusion

I did not find a correlation between heart rate and viewing aesthetically beautiful art. In each graph – regardless of the level of beauty of the paintings – there were no trends of changed heart rates in comparison to resting heart rate. Furthermore, none of the p-values were significant, meaning there was no difference in any of my subjects, between resting heart rate and heart rate while looking at any of the 15 paintings. Art, therefore, does not seem to affect heart rate in any consistent way. However, there are some interesting and significant spikes in heart rate that act as outliers in the data. In particular, one subject's heart rate spiked significantly compared to their average resting heart rate while they viewed a painting that they rated as 4/5, and another spiked significantly while viewing a painting they rated as 5/5. But upon closer analysis, these spikes both came from the same subject and took place in the same few seconds, meaning that an outside factor, and not the art, was most likely responsible.

There are multiple factors that could have led to error in this experiment, mostly stemming from technical issues. It was very difficult to accurately determine a subject's heart rate at a single moment in time because of the setup of the heart-rate recording app that was used. In many cases, heart rate had to be estimated. It was also difficult to ensure that subjects would not be distracted or affected by factors other than the paintings inside the testing center, which was Berkeley Carroll. It also was not possible to take into account subjects' preexisting level of comfort, or lack thereof, with art. For example, a subject who was interested in art may have had stronger reactions to viewing it than one who was not. Further, only a very small amount of data was available to work with, since the heart rate monitors frequently stopped working or were unable to detect any heartbeat at all on certain subjects.

I remain interested in the ways we respond to art, even though my results did not support my hypothesis. I am led to believe that the presence of a reaction may be very dependent on the subject. One of my subject's heart rates consistently rose in the presence of any painting, regardless of the rating they gave them, while another subject's heart rate almost always dropped in the presence of any painting. These reactions were particular to each subject. In the future, I would be interested in study-ing different kinds of physiological responses to art.

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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