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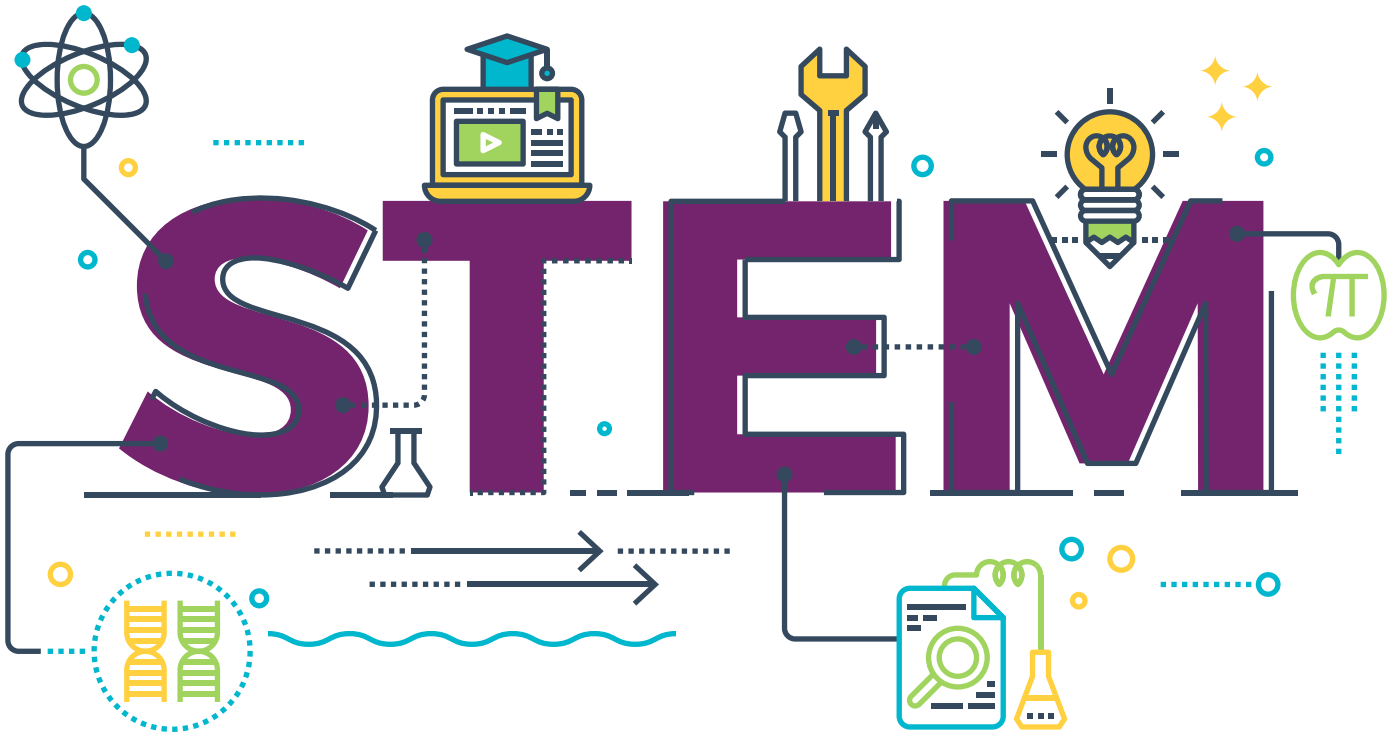

Apex Presentations

2021-22

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About Senior APEX Presentations

Montverde Academy's Science, Technology, Engineering and Mathematics program is an opportunity for students that may be thinking of future careers in STEM beyond Montverde Academy to "specialize" in this field to have advanced preparation for their college majors and ultimately their futures.

Students take courses that are designed to provide a foundation for specific career paths that can be extended once they are in the college environment. During their membership they participate in a variety of field trip opportunities and attend monthly meetings where they can bond with others that have similar academic interests. Across the campus they complete service projects related to their fields and speak with mentors that can advise them regarding their career interests. In their senior year STEM SAC members conduct an Apex project where they choose a subject matter within their field to conduct a scientific investigation or a meta-analysis of existing data about their topic area. They reach out to mentors and design their studies compiling both quantitative and qualitative data and then present their Apex projects to their advisors who then determine if they should go on to a larger presentation experience in our theater for parents, friends, and mentors of the program. This document compiles the best of the Class of 2022's STEM Apex projects and provides them an opportunity that is rare for upper school level students – a chance to be published.


Marco Garcia and Mateo Ortiz
Mr. Parets
Technology
Special Thanks to Dr. Felipe Ortiz
4/3/2022

The Development of Auditory Stimuli on the Development of Circadian Rhythms in Juveniles

Introduction

Circadian rhythms are defined as cycles of physical, mental, or behavioral changes based on a cyclical 24-hour period; hence the name circadian, or 24-hour rhythm. Almost all organisms from humans to microbial bacteria undergo circadian rhythms of some form. The most notable of these circadian rhythms relates to the process of sleep. Specifically, the body's ability to naturally wake up in response to the onset of daylight. In vertebrates, this process is controlled by a cluster of neurons found in an area of the brain known as the hypothalamus. Besides being responsible for a variety of tasks, including management of hormone release and appetite, the hypothalamus also controls the body's reaction to light in order to manage its sleep cycle. In response to the eyes receiving an influx of light during sleep (supposedly in response to the rising sun) a message is sent to the hypothalamus to begin the secretion of a series of hormones and singles to wake up the body. Routinely going through this cycle allows the body to record the sleeping time on its own, leading to the body being able to wake itself up at the usual time without outside stimuli such as light. However, in the modern age most are not accustomed to using the sun to naturally wake up, and instead rely on alarm clocks. The noise emitted by an alarm clock is received by the ear and a signal is sent to the temporal lobe to process the sound. A message is then sent to the amygdala, which sends out a rush of hormones signaling danger in response to the loud noise, which awakes the body. This process has seemingly little to do with the natural process of the body developing circadian rhythms, and yet many individuals have reported waking up at the same time as their alarm clock usually goes off, even if it doesn't. This therefore leads to the question, does auditory stimulus allow the body to develop circadian rhythms in a similar method to visual stimuli? Alternatively, can the body grow to anticipate the onset of an alarm clock? And if so, how long does this process take?

Materials

1. Ten human subjects. All subjects should be in the same relative state of mind, as factors such as stress have been known to affect sleep patterns. The normal sleeping time of all subjects should be constant, but their regular wake up times can be allowed to fluctuate due to limits of experiment (See conclusion for further details). All subjects used in this experiment are juveniles aged 12–18.
2. A space in which each of the subjects routinely sleeps. Said area should be comforting to the subjects and lack any loud noises or possible disturbances during natural sleep.
3. An alarm clock for each of the subjects that effectively wakes them up.

Procedure:

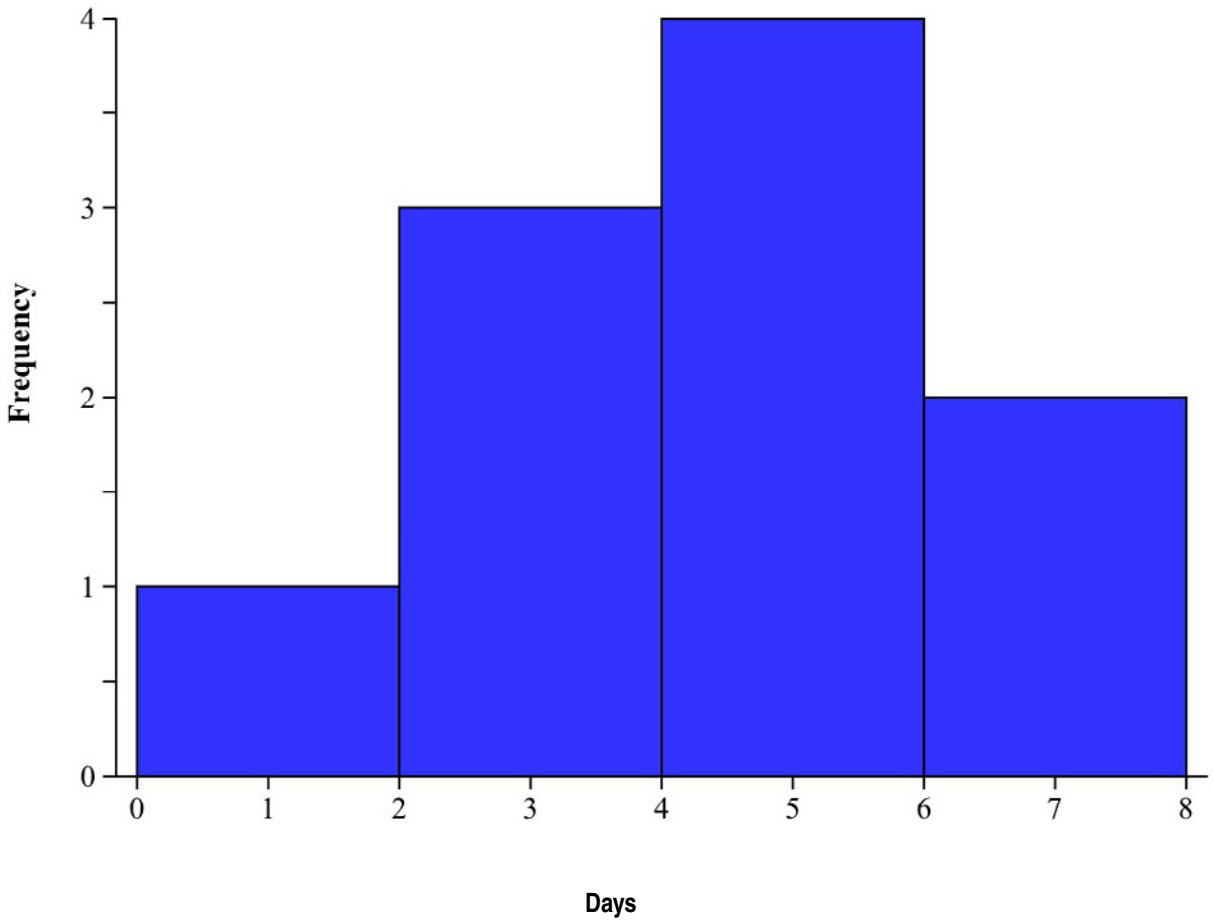
1. Gather necessary materials.
2. Subjects are responsible for managing their own sleeping patterns and observations.
3. Subjects are to report to bed at 9 p.m. (the regular sleeping time of all subjects) and set their alarm for one hour earlier then their usual wake up time.
4. Subjects are to wake up at this time routinely until the subject begins waking up slightly before the alarm sounds. Any reports of major disturbances during sleep due to outside factors will result in the trial having to be redone.
5. Document the number of days it took for the subject to wake up before the alarm. Allow for the subject to continue this process for five days extra days. If the subject starts routinely waking up at this time (i.e., the majority of the five day grace period), then this data point can be recorded as a successfully rewritten circadian rhythm. If results can not be repeated, continue observations.

Data:

Subject #	# of Days Before New Circadian Rhythm Developed	Other Observations
1	1 day	This is the quickest turn around time.
2	3 days	Subject reported having vivid dreams the last night of the experiment.
3	7 days	Subject struggled to adapt to new sleep schedule.
4	3 days	No special observations to report.
5	5 days	Subject reported being more awake then usual despite getting less sleep.
6	4 days	No special observations to report.
7	5 days	No special observations to report.
8	6 days	Subject reported abnormal feelings of restlessness following sleep.
9	4 days	No special observations to report.
10	3 days	No special observations to report.

Data Analysis:

The Amount of Time it took for Men and Women Aged 13–18 Took to Develop an Auditory Based Circadian Rhythm



Conclusion:

All participants within the study began routinely waking up within seven days of exposure to the new sleep cycle. This suggests that the body can develop circadian rhythms using auditory stimuli in the same manner that it does with visual stimuli. Further experimentation is recommended to further validate these claims. For example, the experiment was limited to using juvenile participants for all trials, and so any conclusions made can only be applied to individuals aged 12–17, which was the age group of the participants. Also, a more uniformed, controlled environment was outside the scope of this experiment, and any follow up should pursue the use of a constant environment for all participants. This entails similar sleeping conditions and alarm clocks. For example, these conditions could be found in a hotel. These findings also suggest communication between various areas of the brain to create these recorded circadian rhythms. Further study of these activities would require equipment and personnel beyond the scope of this experiment, including possible CAT scans or other methods of observing brain activity.

Emmy Hartmann
Mrs. Schlussel
Biomedical STEM
01/11/22

Why do I have allergies that my identical twin sister doesn't have and how does my allergy affect my identical twin sister's chance of obtaining the same allergies later on in life?

Many studies have shown a correlation between the nervous and immune systems. For example anxiety triggers your flight and fight stress response which releases chemicals and hormones like adrenaline. This means that when you are stressed about school or other upcoming events your body will be affected too. Stressors can be something major or minor and usually last for a few minutes. A stressor in my life is school. I have always put immense amount of pressure on myself to do good in school so I could get into good colleges later on in life. Even though, this is a minor stressor it's something my identical twin sister never worries about. Many researchers have found that allergies can be modulated by physiological stressors. This means that Stress can make our allergic response worse. It is thought that this happens because your stress hormones can ramp up the already exaggerated immune system response to allergies. Stress is extremely physical and can have lasting effects on our bodies because it is our body's way of keeping us safe. However there is still more research taking place to learn more about the correlation between stress and allergies.

Physicians have found that people may have the gene for a certain allergy but don't have severe symptoms until later in life. It has been thought that your diet has to do with obtaining severe allergies. My gastroenterologist explained to me that even though these allergies are present, it doesn't mean I will have symptoms when eating these foods. When you get a blood test for allergies the test will detect and measure the allergens-specific antibodies found in your blood. When we come in contact with something we are allergic to our body makes antibodies against it. The antibody tells your body to release chemicals including histamine which is the main hormone released that causes your allergic reaction. I believe that my diet had a lot to do with me obtaining severe allergies later in life. When I was in fourth grade I decided to become a vegetarian which meant that I would be eating more plant based food for the next eight years. What I didn't know is the amount of soy that was in the plant based meats. The more I ate over time the more sensitive I became. My identical twin sister was having no symptoms and the main difference was our diet.

A study was done about the relationship between allergic diseases and OCD as well as several other panic disorders including anxiety. Patients with OCD and or Tourette's syndrome had, more severe allergic diseases than seen in other patients. This suggests that there is a correlation between OCD as well as other panic disorders and developing allergies. Patience with OCD had more allergies compared to the control subjects in this specific study. Although all allergies were higher in patients with OCD and other panic disorders the biggest difference was allergies rhinitis. Allergic rhinitis is essentially the medical term used for allergies usually surrounding your nose and or ear. Many patients experience these allergies due to things like pollen. When I was 16 years old I was diagnosed with OCD. My identical twin sister never experienced any symptoms related to OCD.

Asthma and allergies often co-occur within the same families. The heritability of Allergic Rhinitis has been estimated to be over 0.65. This indicates a strong genetic component part of allergies. When you have an allergic reactions to certain substances or foods it's because our body makes an active form of immunoglobulin 0anti-body that travels to specific cells causing them to release certain chemicals. People who are not allergic on the other hand may still produce the same immunoglobulin causing them to release chemicals as well however, their response may not be strong enough to produce symptoms. This means that my identical twin sister could very likely have the same immunoglobulin that causes my body to release hormones that lead me to be allergic to soy and wheat. Allergy genes have become more researched about since a study that was done in Germany. The study found that the development of eczema which is an allergic skin disease is related to a mutation of a gene or loci in the body.

Monogenetic disorders are caused by variations in a single gene. Monogenetic disorders are usually associated with sickle cell, muscular dystrophy, cystic fibrosis and more. However, there is a correlation between severe allergies and Monogenetic disorder. This shows us that allergies can be caused by a mutation in your gene. Nowadays it is accepted that mutation in gene function does not change your DNA sequence. Meaning that there might be an alliteration in my gene function that isn't present In Lucy's. Histone modification and alterations in miRNA level have been different in gene level in patients with Allergy Rhinitis. Other studies have suggested that changes in DNA methylation might differentiate allergic patients from healthy ones.

Many patients are willing to try different forms of treatment including sublingual immunotherapy. This specific treatment has helped patients with Allergic Rhinitis by decreasing DNA methylation of CpG sites.

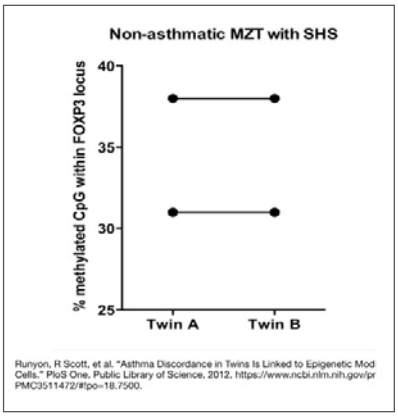
Over the past years physician's have seen an increase in allergic rhinitis. Over 40 percent of populations in both the United States and Europe all suffer from allergies. Through these studies scientists have found that people have less Allergic Rhinitis when on break from work and or school. This is due to them spending more time at home and less time outside. This study helps bring attention to epigenetic's as well as the alteration of DNA methylation. Epigenetic's states that the environment you live in plays a role in your genetic makeup. A study showed that an increase in HDAC activity contributes to the pathogenesis of allergies by increasing pro-inflammatory cytokines and decreasing anti-inflammatory cytokines.

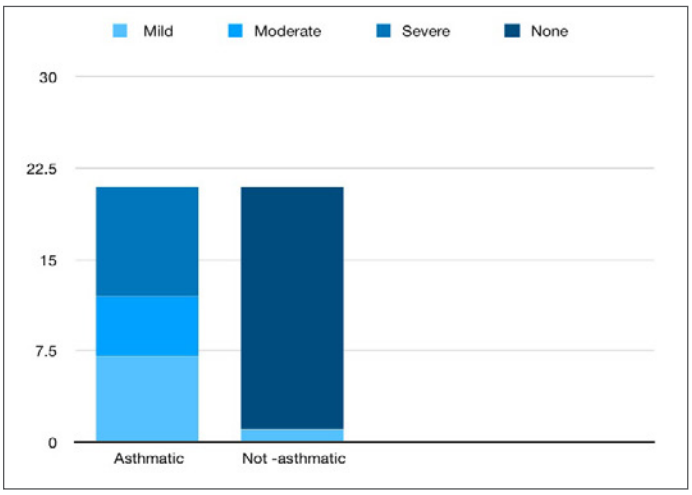
In 2007 an article about asthma was published stating that a gene or loci has been found to be associated with allergies in childhood. Meaning that If some of my genes have a mutation affecting its function it could very well lead to an allergic response. like stated before If I did have a genetic mutation it doesn't mean that Lucy has the same mutation and could be one reason why she isn't experiencing the same symptoms as me. These genes are also often involved in diverse autoimmune disorders. Recently the same scientists who first published the finding of the gene or loci associated with allergies found 41 significant loci of Allergic Rhinitis. This includes 20 novel loci. These novel loci have functioned in innate and adaptive immune processes. Like stated before our immune system and response is strongly correlated with allergies. Most novel loci consist of known immune related characteristics.

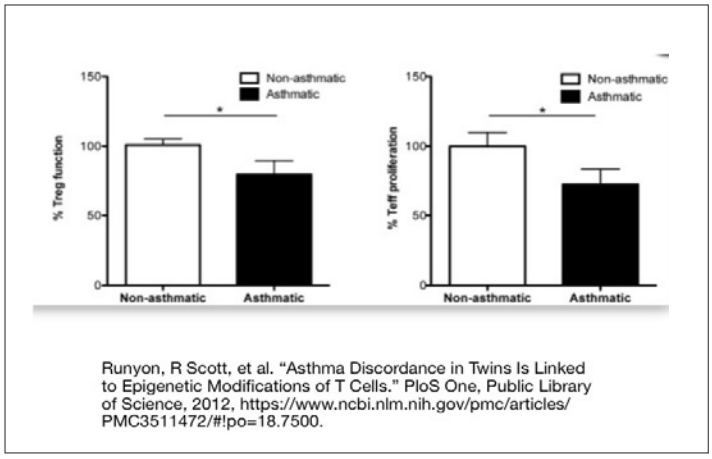
Although there isn't necessarily one specific answer to my question I have found many possible reasons for the differences in my a health and my identical twin sisters. Allergic reactions can happen for different reasons one of them being stress. Although stress can't cause allergies it can definitely cause your allergies to flare up. Other correlations were found including your diet and developing allergies later in life, the heritability of allergies, epigenetic's and your mental health

Subject demographics for twins discordant for asthma

Asthma diagnosis	Asthmatic	Not -asthmatic		
Mild	7	1		
Moderate	5	0		
Severe	9	0		
None	0	20		







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Ethan Kaufman
Mr. Parets
Technology
01/11/22

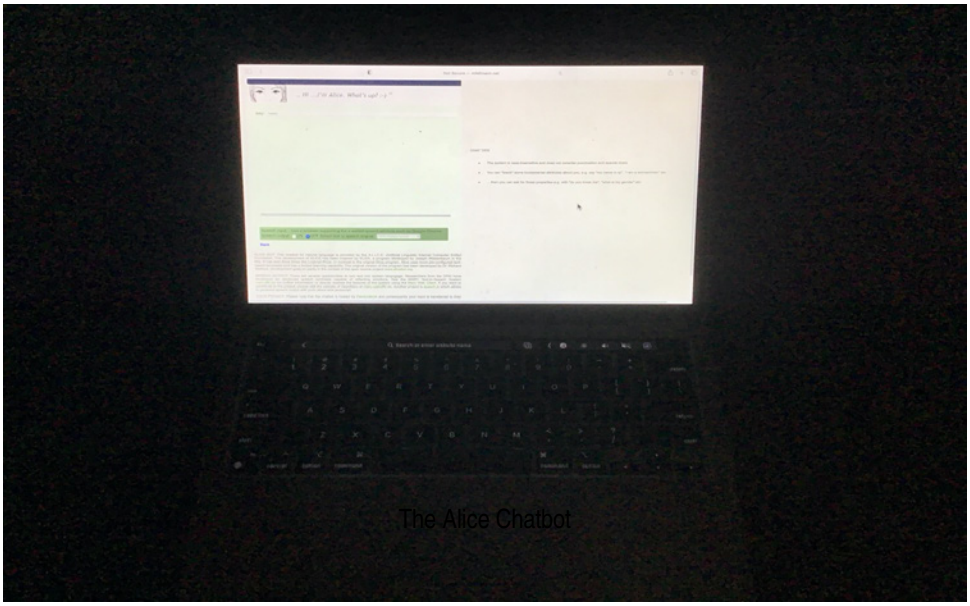
Experimental Framing's Impact on Human Connection with Chatbot Programs

Background:

A chatbot, sometimes also known as a chatterbot, is a computer program designed to imitate online conversation with a human through text entry and reply. Despite their intentions to appear humanlike, chatbots are not truly intelligent, and operate off of pre-programmed responses given based of recognizing key terms in the text input.

While they may initially appear intelligent, they struggle to hold complex conversations and integrate past information into current interactions. However, chatbots are used in many applications, such as customer service and other options where they can provide assistance if a human is not available. In recent years, chatbots have become increasingly common on websites as virtual assistants, designed to answer frequently asked questions of website visitors. One of the first chatbots was known as ELIZA, designed by Joseph Weizenbaum.This program was very limited, however Weizenbaum was surprised by the amount of individuals who seemed to genuinely feel a connection to the program. As chatbots have continued to advance, so have the amount of individuals who associate them with human characteristics. ALICE is a more advanced version of ELIZA, created by Richard Walice. While still unable to pass the turning test,it is far more advanced and will be utilized for the purposes of this experiment. The turning test is an experiment devised by Allan Turning to determine an AI's effectiveness. In order to "pass" the turning test, a computer program must successfully convince an interviewer it is human. Anthropomorphism is the projection of human characteristics onto non-humanentities, such as animals, intimate objects, robots, or computer programs. Anthropomorphism increases the more a subject appears to be humanlike. For example, it is easier to perceive unhappiness in a dog than a rock.

Anthropomorphism has been shown to apply to robots and computer programs as well, with human subjects assigning personalities and character traits to these entities based on physical construction and behavior. I am to see if the mere act of referring to a chatbot with pronouns and the name of a human woman is enough to change how it is perceived, despite the behavior of the program itself staying constant.



The Alice Chatbox

Thesis Statement
Referring a chatbot program with the name and pronouns of a female human will be directly proportional to the reported emotional connection.

Investigation:
Interested individuals were identified and randomly assigned to one of twogroups. Group 1 will be the control group, and will interact with the program in a purely text based form, with the program being referred to as "it". Group 2 will interact with the chatbot with the name present, and it will be referred to with the name "Alice" and with she/her pronouns on the survey and in the experimental introduction. The actual chatbot both groups converse with, will remain exactly the same, with the only thing that changes will be the way it is initially referred to. Each group will encouraged to converse with the bot. Different prompts will be sent to both the control group and the experimental group.

The control groups prompti s as follows:
"This is a computer program, or "chatbot", designed to mimic human interaction. Please ask it some questions for a few minutes and learn about it. The questions can be whatever you like, or you can attempt conversation.Talk to it for about 2-3 minutes, and then afterwards you will take a short survey".

The experimental group's prompt is as follows:
"Attached is a link to Alice, an AI chatbot. Please have a conversation and try to get to know her a little bit. Ask questions, and tell her about yourself if needed. Talk to her for 2-3 minutes, and then take the attached survey."

On the survey, participants were asked to rate the level of connection, trust, fear, and friendship they felt towards the program on a scale of 1 to 10.

Additionally, participants were asked to rate the program's value on a scale of 1 to 10, and their hypothetical level of upset if theprogram was "deleted".

Results
In total, 30 people participated in the experiment, with 19 individuals making up the experimental group and eleven individuals making up the control group.

Factor	Control	Experimental
Avg. Connection reported (1-10)	4.7	5.3
Avg. Trust reported (1-10)	4.31	4.5
Avg. Fear reported (1-10)	3.9	2.6
Avg. Bot's Value reported (1-10)	5.38	5.18
Avg. friendship felt reported (1-10)	3.42	4
Avg. Upsetness if deleted reported (1-10)	3.47	3

The experimental group self-reported larger amounts of connection, trust, and friendship towards the program, and less fear towards the program, when compared to the control group. However, the experimental group reported that the bot had less value and that they would be less upset if it were to be deleted when compared to the control group.

Thesis Restatement
This experimentation has shown a slight positive correlation between referring to a chatbot with human pronouns and a name and the reported emotional connection. However, results are somewhat inconclusive, and further research is necessary.

Suggested Further Research

One flaw with my experiment was the size of the sample group. My control and experimental groups were uneven in size, and the scale itself was relatively small. In addition, I preformed the survey virtually, and was not there to monitor the conversation they had with the chatbot.Ideally each member would converse with the bot for the same amount of time, and be gathered in person for the experiment.

Additionally, it would be ideal to randomly select participants from a population rather than choose participants based on their willingness to participate. Further research is also needed to see how other factors aimed at making the bot seem more human effect reported emotional connection to ALICE, such as the presence of a humanoid avatar or perhaps a text-to-speech program reading the chatbot's responses.

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Forest Long
Mr. Werner
Engineering

Would tracking solar panels be more effective to collect power then solar panels that stay flat on the roof of a home?

Abstract/Thesis Statement

By using a solar panel and following the sun at 5 degrees every single hour I was able to show in my research that tracking the sun could be worth the price of a solar tracker depending on how much it would cost and how much power it would use to have the technology implemented into solar panels today. However, after analyzing my data the results were unpredictable due to a variety of factors including differences in cloud cover and the way I collected my data.

Research

I discovered some different facts from other experiments that were performed like mine. When tracking the sun, it would increase the power intake by 10-100 percent more power. The power it would take to move the solar panel would be 2-3 percent of the power that is collected. (Mousazadeh et al., 2009) The amount of energy that was collected by a solar panel also depends on the location of the panel on the home. Without the proper location, the panels would be inefficient. This would also apply to how well the sun is tracked on its location on a roof. To maximize the collection of solar energy, the panels are installed at the highest point on the roof facing perpendicular to the sun rise. Edward, et. al. states that using a solar tracking system is most optimal between the hours of 10 a.m. and 2 p.m. because times either before or after produce less radiant energy to convert to electrical. It was determined that the output of solar energy using the solar tracker was not as efficient and houses located near the equator should not use one at all. (Edward, et.al., 2019) On the opposite side, solar tracking efficiency can increase the amount of energy collected by 40 percent. (Mollahasanoglu and Okumus, 2021) In a study where the solar panels were fixed, connected by one axis and then two axes, the energy collection between 9 a.m. and 6 p.m. by the tracking panels was improved by over a 50 percent in efficiency over the static panel. (Mollahasanoglu and Okumus, 2021). The single access tracking system was more feasible than the dual access tracking system.

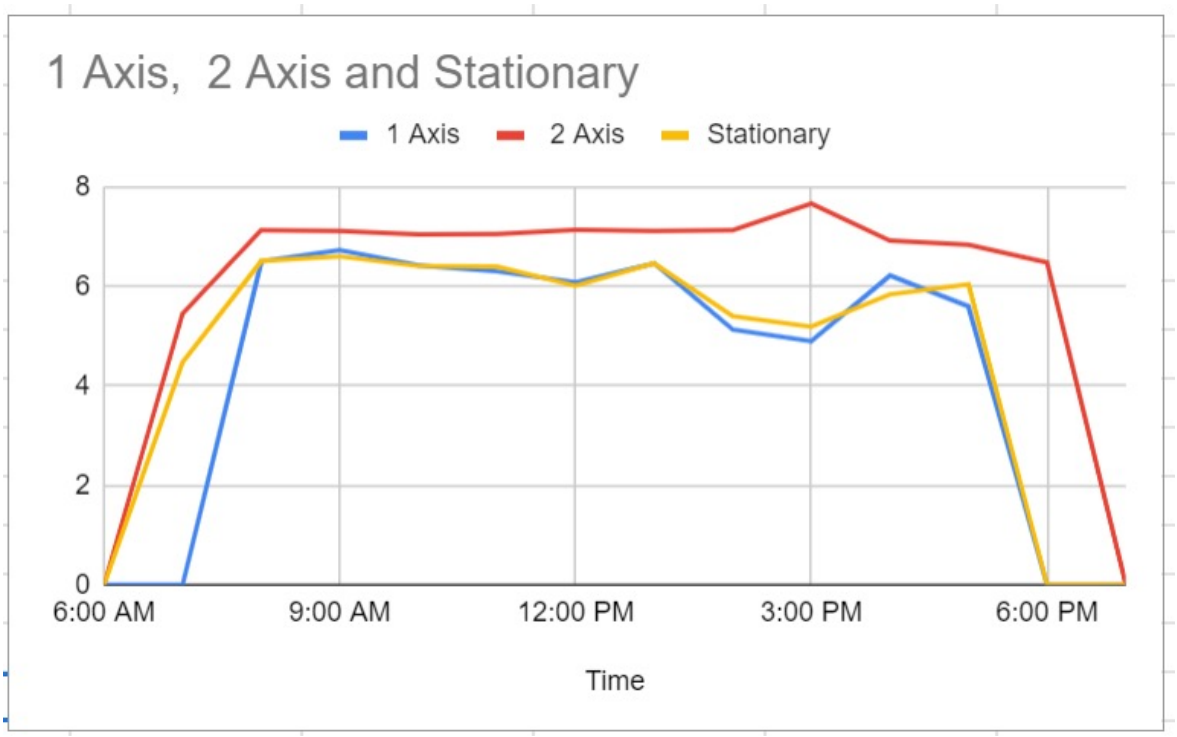
Experimental Process and Analysis of Data

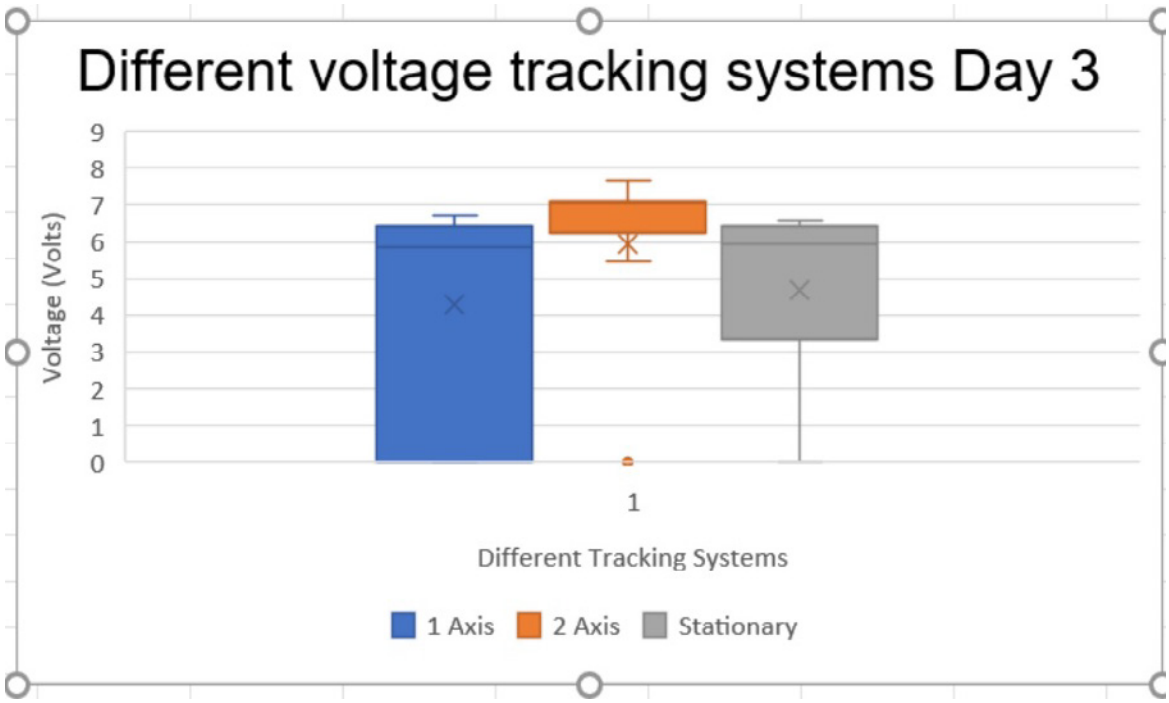
- Materials list:
- 1 Solar science station kit (Browndoggadgets.com
- Laptop to record data
- Independent Variable

Procedures:

1. Determine the intermediate point of sunrise and sunset at my location (Verde Ridge housing development).
2. At the top of each hour between 6 a.m. and 6 p.m., record the voltage produced from the solar panel kit at each of the degree points in 5 degree increments. (0-180 degrees) This will be my independent variable. The dependent variable is the amount of voltage that is measured with each movement of the solar panel.
3. Repeat step two during two other days. This allows for the data to show different results for each day.

Data: Raw and compiled data can be found at the following link: Solar Panel Data





Analysis:

With the day one data the 2-axis line is larger than both the stationary and the 1 axis data which both look similar. The box and whisker graph does show that the averages are pretty like each other. On day two the data is a bit closer than day one, but 2 axis is still over top. Both 1 axis and stationary are close and together. The box and whisker graph is closer then on day one as well with their averages. On day 3 it is more averaged between the two with the 1 axis and the stationary staying close together. The box and whisker graph has the second axis stay more together but the averages are still close together.

Conclusion:

The data does not support my hypothesis. According to my data the amount of energy produced moving the solar panel does not produce enough energy to support the extra expense of changing it from a static collector to a movable one. For a 20 percent average increase it truly isn't worth the mechanics and upkeep for the extra voltage. It would be more economical to buy one more stationary panel instead.

Discussion:

Some of the key issues I encountered while performing my experiment were trying to find a more accurate way to collect data. The voltage readings changed so quickly that I first tried to take pictures with my phone on the burst setting, but the refresh rate of the digital display and my phone worked against me. The best I could do was to read them off one by one and have someone write them down for me when I could or write them down myself when I was working on this alone. One of the biggest issues I had was trying to read off the voltmeter because when installing I placed it upside down, so it was hard to read the numbers that were coming up, but I was able to overcome that issue. A way to improve this experiment and do better next time is by not only finding a more accurate way to collect the data but also having more time to collect even more data to show more accurate results. Due to the cloudy weather during the days that I was recording data there is no consistent answer on what the most prominent degree of measurement was. By picking up the device and pointing it directly at the sun I also made the data collection for that portion inconsistent. If I did this again, I would choose days to measure with a more consistent type of cloud cover to control that variable more.

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Salome Ramirez
Krishna Patel
Mr. Parets
Technology

As time progresses, there are collectively more achievements with technology. With innovative means of communication, transportation and entertainment, simulations have become the core of this new technology. Different simulations help us understand how newly developed technologies will function and what we should expect from them.

In this experiment, we decided to test the accuracy of a simulation compared to the real world. Ultimately asking the major question of, how accurate are simulations when it comes to balancing on one foot with your eyes opened and closed?

Our goal with this study was to predict how accurate simulations may/may not be, in order to assess whether they can be used to study new medicine, test new technologies, and more.

Hypothesis:
While strategizing an APEX Project idea, our group looked back on our UF Dual Enrollment Statistics Class. In the course, we were assigned three projects all using the same data but analyzed differently. This data was gathered from a website named The Islands. In this website, there are islands that have smaller cities inside them. Every city has a household and in the households reside islanders. These individuals can be asked to perform different tasks and we are able to measure the variables. This virtual human simulation has been created tospecifically support learning and teaching in experimental design.

Since the simulation provided so many different tasks and information, it got us wondering,how accurate is all of this data? Can we prove if it is accurate?

In order to test this, we decided to replicatethe experiment. Before performing the experiment, we hypothesized that this simulation would have a negative correlation to the real world data. Our hypothesis stemmed from the fact that there are different variables and external factors in the real world compared to the simulation. Thus, we concluded that the simulation will, on a significant level, be inaccurate.

Materials:
- Timer (on iPad)
- Volunteers (from MVA)
- Graphing Calculator

Procedures:

Collect data from The Islands simulation. Use random selection to pick the residents to study. For each Islander, collect the time balanced on one leg with eyes open versus eyes closed.

Collect data from volunteers at school. Using a timer and specific instructions, collect the time they are able to balance on one leg with eyes open versus eyes closed.

Make graphs and analyze the data.

Data:

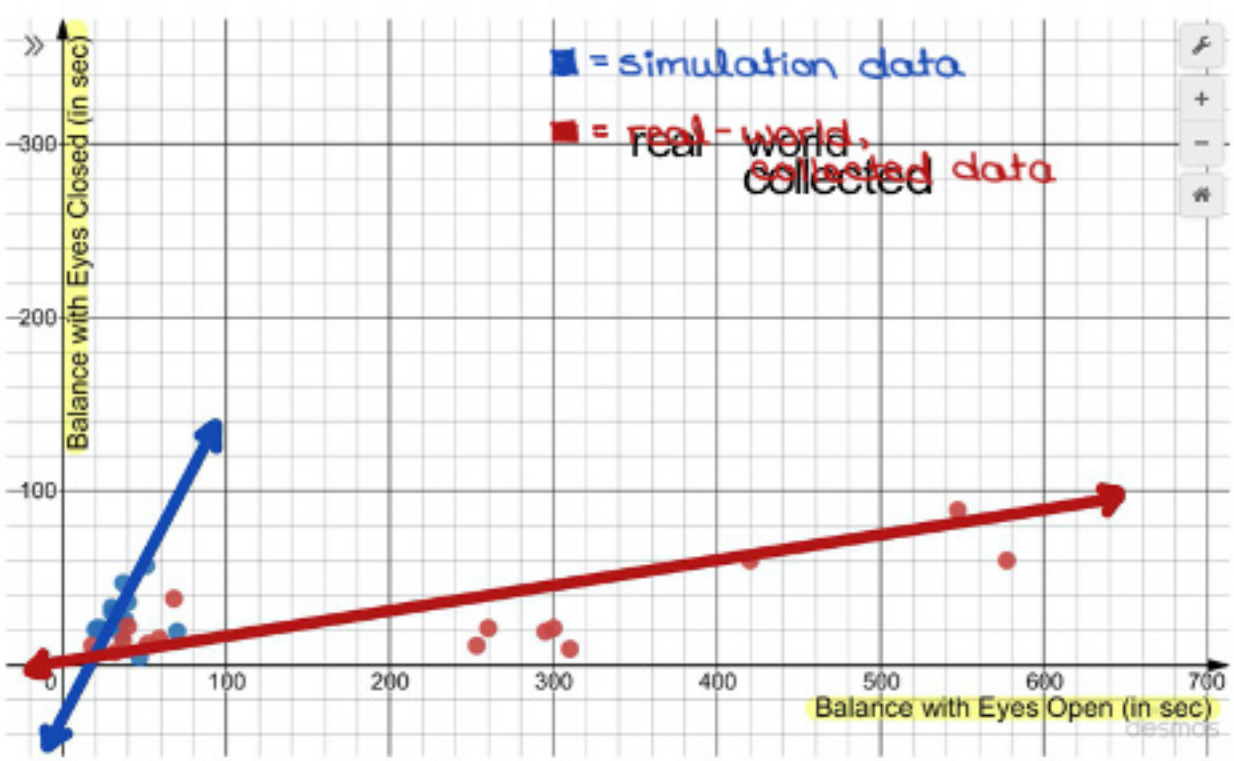
Data from Island Simulation:

Name	Gender	Balance Eyes Open (in seconds)	Balance Eyes Closed (in seconds)
Axel Solberg	Male	47	4
Nabhi Pillai	Male	21	21
Daniel Eklund	Male	22	7
Kari Solberg	Female	37	47
Aimee Hardy	Female	36	17
Bruno Hauser	Male	51	57
Seymour Simon	Male	40	36
Malena Thorn	Female	35	24
Peter Sato	Male	33	30
Henry Delacroix	Male	20	20
Laranya Dhirwan	Female	70	19
Ian Collins	Male	30	33
Chahna Tamboli	Female	38	26
Luke Sato	Male	23	21
Nadia Mardua	Female	30	30

Data We Collected:

Name	Gender	Balance Eyes Open (in seconds)	Balance Eyes Closed (in seconds)
Annabelle Pasiecki	Female	68	38
Emmy Hartman	Female	40	22
Lucy Hartman	Female	37	14
Shivani Patel	Female	260	21
Marco Garcia	Male	253	11
Josue Torres	Male	59	15
Hanan Geda	Female	295	19
Scarlett Gunasekera	Female	32	7
Maelee Johnson	Male	52	12
Laila Shirley	Female	18	11
Karina Resto	Female	310	9
Juan Ramirez	Male	577	60
Marissa Desir	Female	547	89
Ismael Ramirez	Male	420	60
Rafael Ramirez	Male	300	21

Graph:



Data from the Simulation:
Mean for Eyes Open: 35.5 seconds
Mean for Eyes Closed: 26.1 seconds

Data We Collected:
Mean for Eyes Open: 217.9 seconds
Mean for Eyes Closed: 27.3 seconds

Analysis:
Ultimately, our hypothesis was proved mostly accurate. The data from the simulation, specifically for the time balanced with eyes open, differed vastly from the data we collected. The difference was huge – the Islanders were only able to balance with their eyes open for 35.5 seconds while MVA students were able to do so for 217.9 seconds. This gap can be attributed to several factors. Wide scale simulations, at least thus far, are not smart enough to take into account external effects like athletic ability, atmosphere (sunny versus shade can impact balancing ability), and more.

However, at the same time, the difference for time balanced with eyes closed was minimal – 26.1 seconds for Islanders versus 27.3 for MVA students. This counter acts our hypothesis, suggesting that perhaps simulations are indeed getting better at predicting real-world happenings.

These conclusions can also be seen in the graph, where the blue (simulation) and red (real-world days) are different. The x-axis is more widely spreadout, representing the vast difference in balanced time with eyes open. The y-axis is less spread out, showing the closeness in balanced time with eyes closed.

Conclusion:
Our study used a simulation that was open to the public and widely available to use. Our goal was to determine if such simulations (small, free) are accurate enough. New technologies in the market, like Tesla, do have accuratere presentations. This, our study aims to prove that smaller, cheaper simulations still need more work to be perfected and used in actual research.

Overall, we proved that simulations have progressed (that is, the time balanced for eyes closed was close to the real-world data collected), but still need work (that is, the time balanced for eyes open was vastly different from the real-world data collected).

However, there are some confounding variables and errors that could have messed with our results. Firstly, we did not consider age into our calculations. The Islanders were mostly in their mid-30s while MVA students are mostly 17 or 18. Additionally, MVA volunteers used different legs, different poses, etc. to balance on one leg. Such variables can produce faulty results as we cannot fully determine cause and effect. Thus, if we were to repeat the experiment, we would likely create one specific definition by which to test volunteers and look for residents in the Island that are of simila age.We will also try other simulations to see whether our study can be applied to simulations in general, or if they are specific to only The Islands.

James Tanis
Mrs. Schlussel
Biomedical STEM
March 10, 2022

Solid State Organ Transplants

When I think of surgery the first thing that comes to my mind is organ transplants. These procedures not only are very fascinating, but save many lives daily throughout the entirety of this world. For years we have seen the success of these transplants but as cases worsen and some organs come in rare supply, we have to look at the success of the transplant as well as the transportation of the organ. Since the major usage of transplants from the 1950s to the present, scientists and doctors have discovered ways to have higher success rates, better immune system outcomes, and better transportation methods when it comes to solid-organ transplants.

One organ that is the main focus of my project is the heart. This organ is the most important in the body and by far the most difficult to be able to keep alive for an extended period of time outside of a human body. The first recorded successful heart transplant was performed in the year 1967 by a doctor by the name of Christian Barnard in a small hospital in South Africa. From that day to the present more than 100,000 lives have been saved due to the procedure, and that number still grows more and more every year. As more procedures are made and put into practice the need for transplants are being cut back, but there will always be a need for transplants, so there is a timeline a recipient must go through to see if they really do need a transplant.

Heart Transplant Timeline

Because of the rarity of healthy hearts in the world a patient must go through extended evaluation of the heart to see if they are a good candidate for the transplant. There are many signs that are clear giveaways that a patient's heart needs to be replaced. One evaluation technique that takes place is to see the oxygen consumption of the heart. If the heart has an oxygen consumption of about 14 mL/kg per minute or less, they are usually shown to be a good recipient of a transplant. If this is the case then the patient would move to see if the transplant would benefit them or if there is another solution to the problem. Then patients would then be evaluated on irregular systolic blood pressure, hemoglobin levels, creatinine levels, and complications to beta-blockers or renin-angiotensin. Once these factors are evaluated, the patient is finally evaluated to see if they are at end-stage heart failure and no other treatment is suitable besides heart transplant. Once this is the outcome of the evaluation, the patient's other non cardiac organs are inspected to find any faults that would suspect doctors to believe they will affect the transplant. To test this it usually consists of imaging and other lab tests. Another factor that must be looked at is the size of the recipient. As obesity becomes more common in the United States transplants are difficult to have a success on those who are obese. Once all of this is evaluated and a person is found to be a good candidate for a transplant. The patient is then put into a waiting list with other recipients like themselves to get a transplant.

The Matching

To find a good heart for transplant the donor usually is deceased from a brain dead related injury, this can be a stroke or a traumatic injury. The reason that these donors are the best for harvesting the organ is because the heart is not affected by a stroke or other traumatic injuries to the head, so the heart stays intact and is a good organ to save a life. Once a donor is pronounced dead they are evaluated and run through the OPO system. The OPO is a non profit organization that evaluates the donors and keeps the organs and prepares them for transplants. The donors are put through many tests to find issues with the rest of the body such as infectious diseases (HIV or syphilis). The donor is then put through cardiac tests (echocardiography and pulmonary artery catheterization). Even if there is a small problem with the donor they may fail the ability to be a donor, only about 30% of all the deceased have an acceptable organ for transplant. Now that they have a heart ready for transplant there must be another set of requirements that a patient must have before receiving the heart. The paint must match similarities to that of the donor. Sex, size, body weightblood type, and age all go into the matching process of the transplant. Once the patient has a match with the organ they are once again put into another list with other potential recipients.

The Transplant

The transplant itself regions two surgeons. One surgeon to remove the heart from the donor who is deceased and one surgeon to take the heart and transplant it into another living human. The first surgeon will one again check the heart for any problems that they see and then remove the heart and

place it into a cold storage to move to the hospital, where the patient has already been prepared. When the organ is in the OR and ready to be transplanted the second surgeon begins the recipient for a cardiectomy. The surgeon then performs a sternotomy and the aorta is clamped and the heart is removed. The donor's heart is then transplanted into the recipient chest cavity and the clamp on the aorta is taken off. The heart then starts to beat vigorously and the pairneets body begins to reach a stable level. Once the body reaches homeostasis the surgeon checks the heart and makes sure there is nothing that concerns them, and then the chest cavity is coles and the patient is moved to the ICU. After the transplant the patient goes through many immune procedures to make sure the heart adapts to the new body and the patient is healthy.

The Transportation

One part of this timeline got me thinking about transportation from one place to another. Most transplants are done in close range scenarios where the organ is placed on ice and moved from one part of the hospital to another, but I wondered what needed to take place when the donor and the recipient were on the other side of the world. When placed on ice the heart can only stay alive before the cellular functions die for about 6 or less hours. When transplanting around the world this is not enough time to successfully transplant the heart and have better than perfect results. One solution that is becoming more and more popular amongst the transplant community is Ex Vivo perfusion. And in simple terms it means keeping the heart alive for a long extended period of time through an artificial body. Ex Vivo perfusion takes all the functions of the human body and does it in a cart like machine that is developed by a medical company called TransMedics. TransMedics is a fairly new medical corporation that has recently been testing new ways to transport organs in ways that are safe and healthy for the patient and the organ. The new device is a fully functional automated artificial human body that keeps the organ warm, circulated, and full of nutrients. Having this new technology has saved many lives and makes worrying about organ transplant a thing of the past. All of the same evaluation period is still conducted up until the transplantation time. The heart will be removed from the patient and placed into the machine and the Ex Vivo perfusion starts. This allows for the heart to stay alive longer and transport anywhere around the world. The pulmonary artery and aorta are attached to the machine and have the blood pump in the opposite direction of a normal heart flow. This is because when you pump in the opposite direction it allows for the coronary arteries to fill with blood. This is called Extracorporeal membrane oxygenation, this is how the heart gets oxygen when on Ex Vivo perfusion. The heart will then receive the vital nutrients that it needs to survive such as keeping hemoglobin levels and glucose levels at an ideal place while the heart is moved around. The box also allows for the heart to keep a good temperature as if it is in the body, basically the opposite as if it was on ice. When put on ice the rate that the tissue starts to break down is slowed dramatically so the heart has the ability to be preserved and kept alive for the recipient to revive it. While in ECMO and EVP the heart is kept at a temperature it would be in the heart so the cellular functions are kept going and never stop or slow like on ice. This allows for the heart to stay healthier than if on ice. Now that the heart is placed in the artificial circulator it can be moved all around the world without having to worry of the damage that a lone heart can have if not inside a human body. Although this is not a solution that can allow the heart to live forever, it is a great alternative for the heart to stay healthy and make it from point A to point B safer, and alive. Having it in this machine also allows for the surgeon to put the heart in the new recipient easier and quicker and not having to worry about damage to the heart through transportation or the cellular damage due to the ice.

The Model

Through much research and design I have constructed a working model of the relatively new technologies that have been put into place when keeping alive and transporting organ tissues. The main parts of this model include a pump that allows for a pumping action for the heart, it is attached to a timer that controls the BPM of the heart. Doing this allows for the heart to pump like the body does. When attached to the heart saline pumps through and allows the muscle to expand and contract and pumps the saline through the ventricles and into the cavities. Since this is just saline, it does not oxygenate the heart so it is not really keeping it alive but it is the closest thing to what the real artificial machine does. The first part in the model is the reverse circulation that is achieved by pumping the saline through the aortic root. And letting it flow naturally through the heart. When the saline is first pumped it starts in a reservoir and has a pump push it through an oxygenator. For the case of the project the oxygenator is not a functioning oxygenator, but represents one. From the oxygenator it is pumped in the opposite direction of the heart, then pumped back through to the reservoir completing the cycle and running as if it was keeping it alive. In the real EVP and ECMO machine oxygenated blood is pumped through new plasma for the blood and allows for the heart to be rich in plasma for the recipient. Since there is no way to show this in the model without actually doing this it is not included. Although it gives the heart an even better chance, having plasma be run throughout the system is not needed for the success of the heart transplant. The heart that is used in my model is a sheep's heart. Originally I was on the lookout for a pugs heart, but was unable to find one. Through further research and tests I found that a sheep's heart is very similar to a pig's heart and a human heart. The heart has the same structures and is about the same size as both the human and pig heart. I started with two sheeps hearts and dissected one of them. I did this so I could get a better understanding of how the heart pumped as well as the structures of the heart. Knowing this helped when attaching it to the mock EVP and ECMO device. Once I found the structures and understood the flow of blood I began to attach it to the device. I started with sewing up the arteries and small veins that when in the heart pump to other parts of the body, because it is not attached to an actual body they are not needed. After sewing up these I attached the pulmonary artery and the aorta and attached them with a machsift stent. Once the heart was mainly attached to the machine I started to pump the saline through the heart and

found any leaks that were taking away from the natural flow of the heart. I sewed them up and continued to watch the flow of the heart. Once the heart was attached to the machine I pressurized it so there was little to no air in the tubes so the heart had constant pressure and flow. This is important in EVP and ECMO because this, in simple terms, controls the blood pressure of the heart while in the device. Once the device was pressurized I allowed there to be a one second pump and a one second stop. This means the saline is pumped once every one second, very similar to that of a human heart at a very resting rate. Since the heart is not really being kept alive there is no way for the heart to pump on its own and needs the pump. That being said this only happens when electricity runs through the heart and allows for muscle to expand and contract. There is no need for this because as long as nutrients are being pumped through the heart and the heart has a flow, the need for the heart to actually pump is unnecessary. The heart may pump a little bit because of the natural structure of the heart but not because the muscle is moving electronically. Finally I changed the pressure of the system to see how the heart would react. In this model not much happened and this shows the model is working because in the real device changing things like pressure or temperature does not do much for the heart.

The Future for Heart Transplants

As the medical field grows and more and more procedures are developed the ideal way to transport organs will very soon be underway and present in the medical society. Looking towards the future this machine will be reduced in size, cost less money to make, and be able to keep an organ aline for much longer then it currently does. As this device grows and becomes more feasible to use, the need for heart transplants and other organ transplants will start to become less and less, this is because of the new medical products to treat the person without the need for a transplant. Since this is a relatively new procedure there are some limitations that only the future will be able to help and fix. Some of these things include complications after the initial transplant, problems with the new organ adapting the new human, and problems with pressure in the aortic root. Not only is the function a problem of this but the very high cost to do EVHP alone. It costs about 25,300 USD to do an EVP, this is a very costly procedure compared to one without EVP through TransMedics. In the future the idea of transporting outside of the body and keeping it alive must be tested more using medications to see the effects of the organ, and other cellular level tests to make having this done ideal for the patient. There are even studies to see a way to bring a heart or organ back to life after it has started to deteriorate at the cellular level. Pairing that as well as this new way to keep the heart alive would allow for a shortened waiting list, and a better outcome for patients who need the procedure.

Conclusion

In conclusion, I have discovered and researched how transplantation works, how it is performed, and how there are new methods to transport the organ. I have built a working model of how ECMO and EVP is done and how to transport organs from point A to point B in a better way and for a longer time. I have found that this is a very underlooked field of medicine and in my opinion a very important one. The way that scientists and doctors have come up with a way to keep an organ alive outside of the human body is extremely interesting, and mind blowing. This gives me hope that the future of not only transplants but the medical field entirely will change the world and bring health to people all over the world.

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Xavier Williams
Mr. Werner
Engineering

Magnetic Battery Train

Abstract

I did this lab because of my interest in high-speed transportation systems such as maglev “bullet trains.” I think research into the subject of electromagnetism and how it can be used to improve infrastructure will prove to be extremely useful in the future just as it is now for areas that rely on public transportation. The problem in this lab is how do the number of magnets used affect the time at which a battery can travel through a bare copper wire coil? I used copper wire coils, batteries, and neodymium magnet to setup a simple tunnel for the battery to travel through. I predicted that increasing the number of magnets would increase the strength of the magnetic field thus decreasing the time as the force increases; however, the field would only increase up to a certain extent. The results were just as predicted and an observable diminishing marginal magnetic field was shown in the sub experiment. The marginal magnetic field decreased due to each additional magnet being farther from the battery (skullsinthestars, 2004).

Introduction

This lab explores the fundamentals of electromagnetism and how it can be used in transportation. The main purpose of this lab is to research and understand the modern ideas behind magnetic fields. Through this, we could see its application expand in transportation besides using bullet trains.

Problem

The problem in this lab is discovering the relationship ship between the quantity of magnets and the strength of the magnetic field. Through this, we can discover the most optimal amount of magnets to be used in the coil wire in this experiment so that both strength and efficiency are maximized.

Hypothesis

Adding additional magnets to the battery should produce a stronger magnetic field which will result in a higher speed leading to less travel time but only to a certain extent.

Materials

- AAA Battery (Recommended)
- 2x15mm Neodymium Magnets (must be larger in diameter then battery)
- Non-insulated Copper Wire (100ft+ and 14-20 Gauge Recommended)
- Recording device or stopwatch (High framerate camera recommended)
- Tesla® Meter

Method

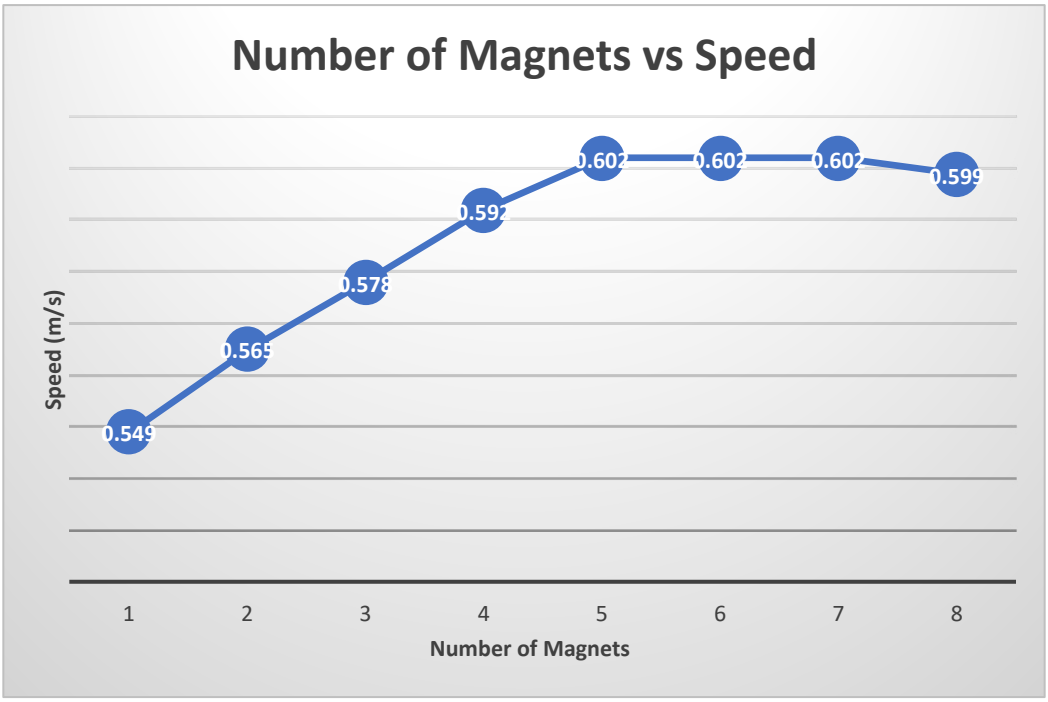
- Use rotatory machinery or a round object to wrap the wire in a coil. The coil must be wrapped tight and uniformly to prevent the magnetic fields from being out of uniform as well. This will make sure the battery train will travel normally.
- Neodymium magnets **must** be larger in diameter then chosen battery but smaller than the coiled wire diameter. This is so the magnets can make physical contact with the wire rather than the battery which in turn will create the closed circuit essential for this experiment.
- Battery **must** not be dead because the circuit will not work without a voltage source.
- Magnets are to be placed near the battery with same attraction in opposite directions, this is further highlighted and explained in depth in the conclusion.

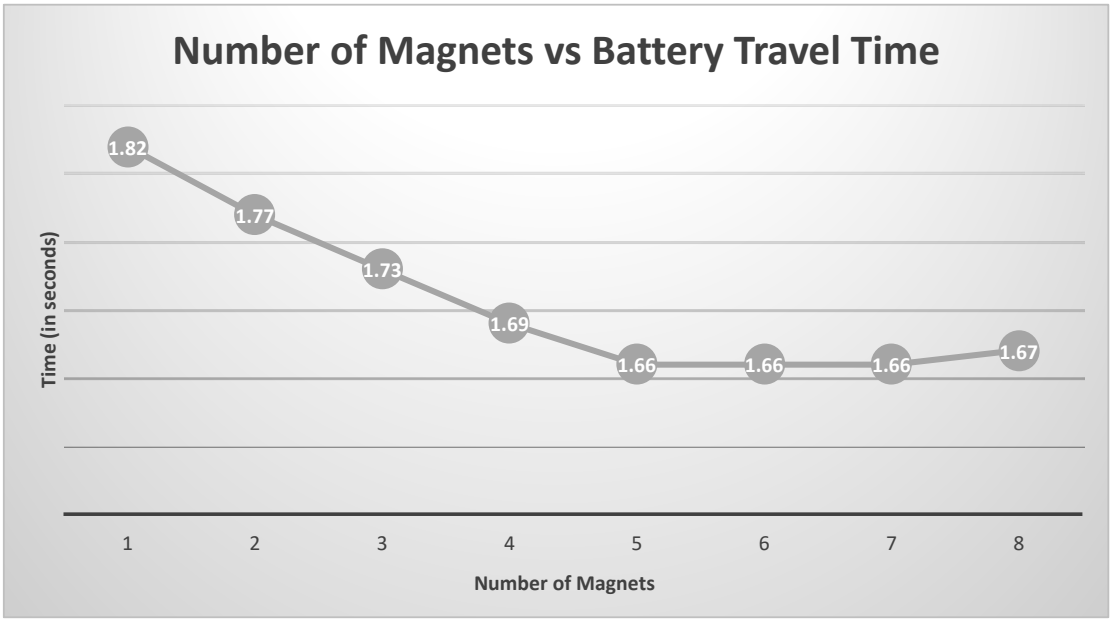
- Background Experiment: Use a Tesla meter to record the magnetic field strength between magnets.
- Add additional magnets while recording the magnetic field each time until the difference in magnetic field strength is insignificant and thus unrecordable.

Data

Number of magnets (both sides)	Time to travel meter (seconds, 5 trials)	Speed (meters a second)
1	1.83 1.83 1.81 1.80 1.83	0.549
2	1.77 1.75 1.79 1.78 1.77	0.565
3	1.76 1.72 1.70 1.71 1.74	0.578
4	1.71 1.69 1.70 1.68 1.68	0.592
5	1.68 1.67 1.65 1.67 1.63	0.602
6	1.66 1.66 1.66 1.66 1.67	0.602
7	1.67 1.66 1.66 1.68 1.66	0.602
8	1.67 1.68 1.66 1.67 1.67	0.599
9	--	
10	--	

Pearson Coefficient: 0.892167



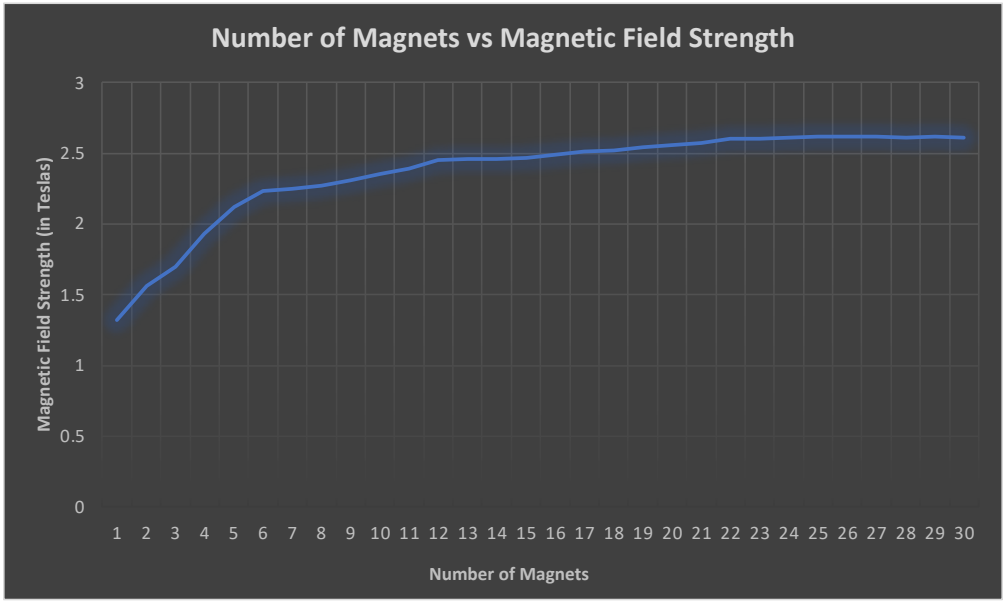


Pearson Coefficient: -0.8436

Number of magnets	Magnetic Field Strength (Teslas)
1	1.32
2	1.56
3	1.7
4	1.93
5	2.12
6	2.23
7	2.25
8	2.27
9	2.31
10	2.35
11	2.39
12	2.45
13	2.46
14	2.46
15	2.47
16	2.49
17	2.51
18	2.52
19	2.54

20	2.56
21	2.57
22	2.6
23	2.6
24	2.61
25	2.62
26	2.62
27	2.62
28	2.61
29	2.62
30	2.61

Pearson Coefficient: 0.835417



Analysis

Increasing the number of magnets results in a decrease in time as hypothesized but only up to a certain extent. After five magnets there is no significant change in time. Nine and 10 magnets seemingly do not allow the battery to travel through the coiled wire. Despite switching the battery and making sure the magnet is contacting the coiled wire, having nine and 10 magnets on both sides produced no results. The findings of the sub experiment helped to explain the lack of change in time and why the train didn't work.

Conclusion

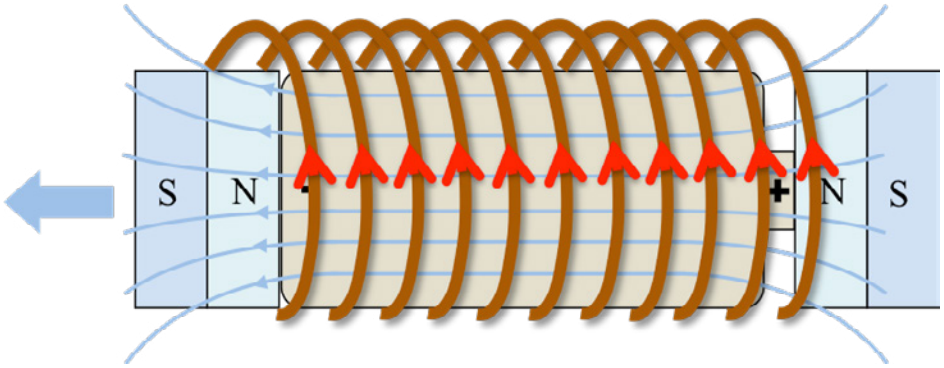


Figure 1

The battery train functions from the magnets on both sides of the battery contacting the copper wire. This contact with the copper wire produces a closed circuit which allows for the flow of current as the battery provides an arbitrary voltage that is stored on it. This is modeled in the equation,

$$V = IR$$

V standing for potential difference, I standing for current, and R standing for resistance. In an ideal scenario a battery will not have internal resistance; however, when experimentally tested virtually every single common use battery will have some internal resistance that can affect the strength of the current that will flow through the copper wire. Resistance is inversely proportional to that of current. If the resistance is to increase at a significant value, then current will decrease. This will in turn decrease the magnitude of magnetic field that is created around the copper wire as magnetic field is proportional to current due to the battery train being a solenoid. This means ampere's law applies and,

$$\mathbf{B = u_o nI}$$

n being the number of loops of wire per unit length, u not being permeability, and I being current.

The battery progresses throughout the coil due to the continuous flow of the current through the closed circuit leading to the interaction between the copper wire magnetic field and neodymium magnetic field until either the battery is drained or there is no copper wire left. This fundamental discovery is why Maglev (Magnetic levitation) trains are very attractive for the economy and even boast the capability of travelling at speeds up to 400 km/hr or 250 mph and higher. The materials needed to power and make these Maglev trains are extremely environmentally friendly.

Anyways, battery trains find its basis in electromagnetism. As aforementioned, the contact between the magnet and the copper wire produces a closed circuit which is best represented in *Figure 2*.

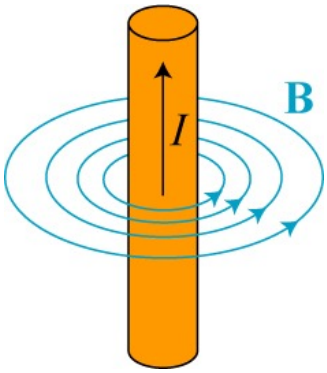


Figure 2 (skullsinthestars, 2014)

The resulting magnetic field which is shown by B in Figure 2 circulates in relation to the direction of the current which is determined by using the right-hand rule as modeled in *Figure 3* (skullsinthestars, 2014).

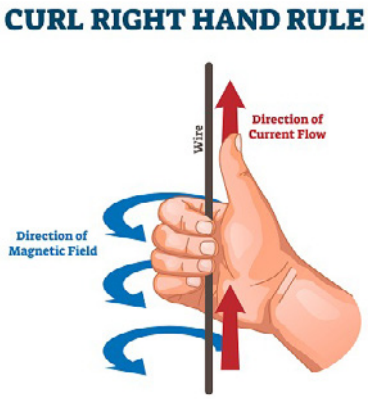


Figure 3

Simply put, the right-hand rule says the direction of your right thumb follows the current and the direction of the magnetic field follows the curls of your fingers.

With the fundamentals out of the way, let's get into the physics about why the battery moves through the coil. Each neodymium magnet has a North and a South pole. These poles are of opposite charges with the North being negative and South being positive in general situations. Now for the important part, the magnets North poles must be pointing away from each other on each side. The front magnet must be getting pushed away while the back magnet is getting pulled. This is best illustrated in *Figure 4* (skullsinthestars, 2014).

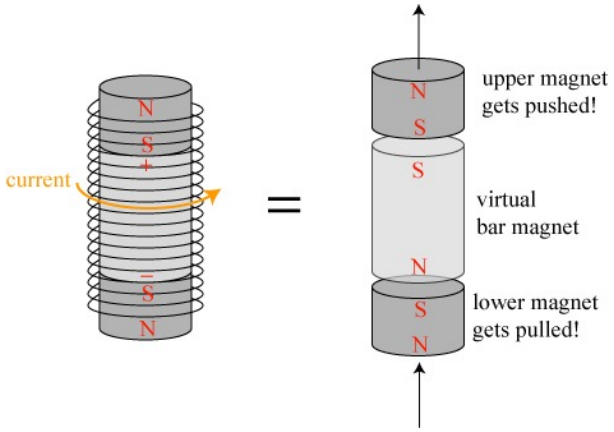


Figure 4 (skullsinthestars, 2014)

One thing you probably noticed is the "virtual bar magnet." This magnet does not physically exist and is a result of the closed circuit that is formed (skullsinthestars, 2014). To reiterate, this circuit means that a current is produced which creates a magnetic field from the copper wire. This magnetic field is why the front magnet is being pushed away while the bottom magnet is being pulled. Don't let the magnetic attraction to the battery itself fool you when designing this experiment! It will not work if you don't design it as shown in *Figure 4* so make sure they're positioned in a way in which they are **repelling** each other before placing them on the battery.

Deduction (before sub experiment)

Using more magnets will produce a stronger magnetic field which will result in the "battery train" traveling faster as analyzed. However, the reason why the time stops making significant changes after five magnets on both side is because the magnetic force will only increase until the length is about equal to or greater than the diameter of the magnet itself. The reason why nine and 10 magnets didn't work may be left up to the force of gravity being too strong or the Inertia being too high. Inertia being resistance to change in motion

However, the force of gravity is solely independent from movement along the x-axis in this system. The resulting data for nine and 10 magnets could be left up to human error in making sure the batteries and magnets are placed uniformly in each trial I ran.

Deduction (after sub experiment)

To help scientifically prove the reason why the battery stopped travelling I created a sub experiment in this lab. This sub experiment ratified that each additional magnet comes with diminishing marginal field strength. This means the magnetic field will increase at a decreasing rate; however, the rate won't be negative, and the field strength will be at its maximum and constant when the rate is zero (human error in data collection led to magnetic field strength falling below max). After roughly nine magnets the rate at which the field strength increases for each additional magnet is low and eventually near zero. This means that in the main experiment I was essentially just increasing the mass on the battery; nonetheless, it becomes difficult to work with many magnets in the train. The magnets on the far end provide very little magnetic force on the battery itself due to its distance and become prone to colliding with the sides of the coil which makes the train nonuniform.

Sources

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Apex Presentations

2021-22