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Introduction

We are proud to present the sixth edition of our annual student research publication. The Nikola Tesla STEM Research Journal enables STEM students to share their research with the academic and business communities. The investigations included in this edition demonstrate both the increasing depth and diversity of our studies. In addition, we have included a list of the awards and honors earned by Tesla STEM students this year.

Our thanks to the Tesla STEM staff for ensuring all students are afforded every opportunity to showcase their knowledge and talents and to our students, for their dedication to STEM Literacy. Many thanks to the dedicated student researchers and mentors, your long hours and hard work made this publication possible.

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3D Printed, Body Powered Arm Prosthetic for Children with Adjustable Arm Lengths

Prerna Sheokand

Abstract:

The number of people around the world with limb deficiencies is very large and those in developing countries have few opportunities to get the proper accessories they need due to high costs of prosthetics. Young children who very quickly outgrow limb prosthetics need something that can be used for a longer period of time but keep its functionality. In other words, an arm prosthetic that is low cost, convenient, functional and adjustable needs to be designed. A model of child's arm was created and 3D printed with two forearm pieces. The model was assembled in a way that the two forearm pieces were placed on top of each other with three holes correlating to three different arm lengths the arm can be set to and designed to be completely body powered through the elbow. The functionality of the arm was tested by doing a functional test of picking up four common objects that children use (rubber duck, unicorn stuffed animal, blanket and a water cup) and checking for success or failure at each of the three different settings. The results show that the arm was successful in picking up all the objects at each of the settings except for the blanket, which was unsuccessful at all three settings. The overall arm design was a success as it worked well enough to be effective in countries where money is scarce, proper medical care is rare, and advanced technology is a leisure.

According to the World Health Organization, there are about 650 million people worldwide who have physical disabilities, 80% of which live in developing countries. In those countries only about 1-2% have access to services that can provide them with the proper services they need (World Health Organization 2012). Of those with physical disabilities the population of children with the disabilities present problems of their own that need attention when talking about potential prosthetic designs. Kids outgrow everything from toys to clothes to shoes within months, leaving parents frustrated with having to spend money repetitively for basic needs of their child. Now imagine having a child who doesn't have an arm and having to spend hundreds of dollars on purchasing a quality and functional prosthetic only to have it be too small within a couple months. In developing countries this problem is more serious due to lack of money which many times leaves young children without arm prosthetics and only one functional arm (Krebs et al 1991). With the recent boom in technology use in the medical field to bring to patients' low cost but effective products, these problems seem more solvable. 3D printing has grown in popularity and shown immense potential in helping solve the problem of costs in all fields all around the world due to its low cost but durable and reliable results (O'Neill 2014; Dally et al 2015). Although they might not be as high functioning as motorized prosthetics which can cost upwards of a thousand dollars, a body controlled 3D printed prosthetic seems a much more practical and feasible option for families in developing countries.

Along with high costs, prosthetic arms for children need constant adjustments and alterations to keep up with the speed of the child's growth which is all very time consuming (Resnik 2011). Frequent visits to the doctors to get these adjustments made are not practical for families in developing countries that have children with arm prosthetics. For some families even having a doctor to advise them may not even be an option. All the obstacles result in high demand of a prosthetic that is designed for usability, is user friendly, customizable and durable giving both engineering and medical professionals a task to complete. Body powered mechanisms that are used for some prosthetics, although are less efficient than motor powered, cost less and still do the job and should also be considered when making potential designs (Shaperman et al 1995). So, the next logical step is to try to make a low cost prosthetic that allows you to use one prosthetic for a long period of time, an adjustable design.

Methods:

Designing the model. The intended design in one of a body powered, 3D printed, adjustable length arm prosthetic for young children. A basic arm body powered prosthetic design was taken from Thingiverse and the 3D building software, TinkerCAD and 3D builder were used to make changes and edits to the original design to fulfil the desired design. Average finger lengths of 6 year old were taken and set as the length of the 3D printed fingers (Hohendorff et all 2010). The length of the forearm was also increased before being printed and split into two separate pieces before being printed as the forearm will create the adjustable part of the prosthetic. The final design was printed on a MakerBot 5th generation with PLA material filament.

Assembling the model. The 3D printed forearm and upper arm cuff were molded into a curved shape by placing the prints in boiling water and then molding them into a circular shape by placing them on a circular wood block. All the pieces were attached together using pins and bolts that were also 3D printed. To construct the working arm, nonbraided fishing line was threaded from the fingertips of each finger all the way up to the upper arm cuff in a system that with a bend in the elbow the string would pull causing the fingers to close inwards into a fist. Since the intended design is to create one prosthetic arm with multiple different arm length adjustments so that the life of one prosthetic can be extended. This was done so by placing the two forearm pieces on top of each other to achieve three lengths 6cm, 8cm, and 10cm. At each of the lengths a hole was made through the prosthetic big enough to fit a screw and washer. The purpose of this is so that when a child outgrows the length of the arm, the screw and washer can simply be taken out and the forearm pieces can be separated to meet the next length requirement of the child and reassembles easily.

Testing the model. Four objects (unicorn stuffed animal, water cup, blanket, rubber dick), that children of the intended ages (4 -6) are likely to use, were used to test the workings of the prosthetic. At each of the three length settings of the forearm, the arm was tested by attempting to pick of each of the five objects and success or failure to pick up the item was recorded. To change the length of the forearm the washer and screw were taken out of the hole, the forearm pieces were separated to line up to the new setting and the screw and washer were placed into the corresponding holes and the trials were reconducted.

Fig. 1. The measurements of the final design follow two forearm pieces at lengths 5.5 cm and 5 cm. When placed on top of each other the shortest forearm length is 6 cm, the next hole was placed to create a total forearm length of 8 cm and the next hole to create a length of 10 cm. The fishline was strung from the tip of each finger all the way through the arm to the top of the bicep cuff.

Fig. 2. The measurements of the final design follow the palm size of 2.5 cm and a bicep cuff of 4.5 cm. All pieces were attached with washers and pins at each connection point. The fingers were assembled and at each joint, orthodontic rubber bands were wrapped around to create a tension mechanism.

Fig. 3. A body powered mechanism was used. With the string running from top to bottom of the arm, with a bend in the elbow, the string would tighten causing the fingers to close into a fist. With the release of tension in the strings after the elbow was released the fingers would return to normal because of the rubber bands placed in the finger joints.

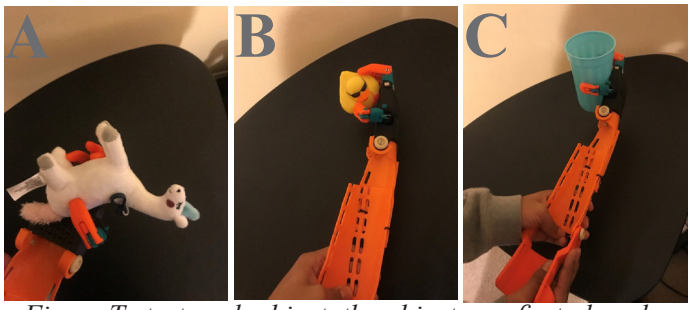

Fig. 4. To test each object, the object was first placed on a table in an upright position. The arm was then placed in a position in relation to the object similar to how a normal arm would be when picking up the object and then the elbow joint was bent accordingly to pick up the presented object. All objects were successfully picked up by the arm except the blanket, which was a failure at each of the three different forearm lengths.
A shows the hand successfully holding the unicorn stuffed animal
B shows the hand successfully holding the rubber duck
C shows the hand successfully holding the water cup

	Object Being Tested			
Length of Forearm	**Unicorn Stuffed Animal**	**Rubber Duck**	**Water Cup**	**Blanket**
6 cm	Success	Success	Success	Failure
8 cm	Success	Success	Success	Failure
10 cm	Success	Success	Success	Failure

Success means that when the arm was manipulated to grab the presented object it was successfully able to pick up the object from the table without dropping it.

Failure means that when the arm was manipulated to grab the presented object it was unsuccessful at being able to pick up the object from the table without dropping it.

Table 1. Test of Success or Failure of the prosthetic arm model to pick up five different objects at each of the three forearm lengths

The model was successfully printed and assembled so that the goals of the model were met, create an arm of low cost and one that was adjustable. The 3D printing of the model and use of body power to make the arm functional successfully meet the first goal and the design feature of having three holes placed on the forearm to create three different lengths so as a child outgrows one length, the family can adjust and change the sizing themselves in the convenience of their homes which meets the second goal. The results show that the arm model was 75% successful with the tests that were conducted on the model. To test usability of the model for children, four objects likely to be heavily used by young children, the arm was used to pick up the objects and recorded as success or failure of the test. Each of the four objects tested for each of the three different lengths. For all three lengths, the unicorn stuffed animal, rubber duck and water cup were successfully picked up. However, for all three lengths the blanket could not be successfully picked up by the model. This shows that although the model was successful in the majority of the situations there were still times where the model was unsuccessful. The results also show the durability and equality of usability of the low cost material used for the model as all three length settings had the same results showing that the functionality of the model was not comprised by the features or material of the model.

Conclusion/Discussion:

This model was designed with two goals, to build a low cost yet functional and reliable prosthetic and to design an arm prosthetic for young children that increases the use period that one single prosthetic can be used for. The results point towards this model being successful. They show that the arm is useful in participating in some common tasks that young children may need to encounter. Since the target audience are young children in developing countries that already find it hard to come across such accessories, the failure in certain tasks of the arm feel insignificant. This is because in environments where even having a prosthetic is a leisure, the ability to have a mostly functional arm is more than some children even imagined. The audience makes a big impact in determining the success or failure of a model and with the given audience this model was a success. This model can help give children opportunities they couldn't have had before, participate in activities they were unable to previously, and of course save the families thousands of dollars, several visits to a doctor, and a happy child. This model is user friendly as it can be adjusted and assembled at home, durable and consistent for all settings and customizable which is what will work most effectively in developing countries given the restraints.

There are still some future work that can be done on this model such as make grips at the end of each of the fingers to increase the success rate of picking up items and preventing slipping of items already in the hand. This would have been helpful for picking up the blanket with the model as the hand was unable to get a grip on the soft material of the blanket. Creating a more curved palm structure will increases the visual appeal of the hand by looking more realistic and increase functionality as the current flat palm limits the tasks that can be completed.

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Building a Durable and Modular Backcountry Splint

Claire I. Whiteside, Sarah Suhy

Author Note
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Abstract
The creation of the splint has provided those in an emergency situation aid upon the discovery of life-threatening injuries, but its design has not changed since it's invention. The most common splint still tends to be a long bracing item and a securing cloth design for the most security. Others have tried to implement splint designs that form to the required shape, but they fail to hold the injury securely in place. Injuries (specifically sprains, fractures, and strains) that are incurred in the wilderness are more serious than ones occurred near civilization because the injury must be secured with a splint before moving to the emergency room. The goal was a 3D-printed splint that easily fits inside backpacker's gear, or similar sized carrying packs, and would not be burdensome on the user. Overall, a compactible design was created that was 3D printed with MakerBot Filament and MakerBot Machines and focused on reducing the size and weight. Upon measuring, each piece of the extendable long brace was 23.2 grams, and 21.0 cm3 in volume. The wrapping pieces were 17.4 grams and 19.0 cm3 in volume. Overall, the design is compact and durable to over 10 kg of impact damage. However, a redesign of the orthotic to keep structural integrity with less infill, and hopefully thinner sections would be ideal. The compact splint is looking promising, but it needs reworking and polishing around the functionality of these thicker, but lighter sections to be truly viable in an unplanned emergency situation.

Keywords: orthotic, splint, 3D printed

The use of 3D printing technology has recently worked its way into prosthetic research, providing prosthetic creators and patients a low cost and quick alternative to traditional, expensive prosthetics. Designers are using 3D printing prosthetics for other work on improving the lives of those needing the replacements, including at John Hopkins where students are adding a sense of touch to prosthetic 3D printed hands (National Institute of Health 2018). Others are infusing drugs with 3D-printed dentures to stop fungal infections in patients, paving the path for others to possible do the same with other medications (Dormehl 2018).

But overall, 3D printing has stuck in the realm of missing limbs and other extreme issues, leaving products from 3D printers away from the hands of healthy citizens. Although more common 3D printed items are coming to hospitals, such as 3D printed tracheal splints from Georgia Institute of Technology, there is still a lack of items that someone could use to prevent the damage before it happens (Jackson 2018).

It was estimated that from 2004-2005, there were 212,718 injuries sustained while doing an outdoor recreational activity that were treated in emergency rooms. Fractures, sprains, and strains accounted for 51.3% of injuries sustained (Flores, Haileyesus, & Greenspan, 2008).

Splints are life-saving upon the fracture of bones in any emergency situation, isolating the bone to one location and not allowing motion for extra tearing. However, there is no easily accessible and sturdy splint that is compact enough to not bear down on the owner. Other options include rolled splints, consisting of hard wire covered in soft foam, which only isolates the bone if no other movement around it is ongoing. And although breaking a bone on a trail is rare, it is better for a backpacker to have something on them that can quickly splint their leg as opposed to having to scavenge around for adequate sticks to make a backcountry splint. Therefore, a necessary invention with 3D printing technology, is a backcountry splint that is light, compact, and unimposing on the carrier.

Methods

The solution created was one that kept both function and adaptability in mind. A modular prosthetic, made up of a backbone and side supports, that would allow the user to determine how long of a splint would be appropriate for the situation, and quickly assemble and administer the treatment. The backbone was designed in TinkerCad, a 3D modeling online program, and then 3D printed on a Makerbot 5th Generation Printer, using PLA plastics. The backbone (Fig 1) has two main attachment methods. The first is storage, with an extrusion on the top of each backbone piece that corresponds to a hole on the bottom. The pieces of the backbone can then slot into each other to form a stack of pieces. The other connection point is for when the splint is in use. Splint pieces will attach lengthwise to create a long and strong piece that will be used to splint the fracture or sprain. The side pieces (Fig 2) in this case can also snap on to similar attachments to form a U shape that will provide support all around the injury and allow for easier securing. The splint was designed to have reuse be as simple as possible. There is no changing in the actual shape, so to reset the splint, you simply have to disassemble and wait for the next usage. Other splints on the market act in a few different ways. The SAM® Splint (Fig 3) markets itself as lightweight and adaptable, but after examination of training and use footage, the product is not that supportive for the injured limb and requires a degree of user knowledge and experience to ensure that it is being folded properly. Our splint only requires assembly, which is an intuitive design for those who might not know as much about first aid administration. Other, less portable splints on the market have a high degree of specialization, and are not good for a generic outdoor usage, because carrying multiple types of splint in case of different types of injury is illogical and ineffective. The last type of other splint is the classic backcountry splint, made of found materials that can provide padding and support for the bone. The most common material for this is wood and sticks. In the case that neither can be found, the suggestion by the International Commission for Mountain Emergency Medicine is to use hiking or ski poles, or even a ski itself (Ellerton, Tomazin, Brugger, & Paal, 2009). Both of these options may be used in a last resort, but the chances of being unable to find an appropriate piece of wood, or being stranded after using a piece of equipment, are high. The splint created during this study is a good backup plan and better alternative, because it lets people have the confidence that they will be able to administer first aid if needed. The design was created from scratch. The backbone was created with a base rectangular prism that had an hourglass shape used to add on the top, and as the slot in the bottom to create the interlocking effect. The prosthetic was tested for its strength and resistance to impact, and those values were compared to wood, along with the weight. A tester to drop weights was created to test the structure (Fig 4), where weights would be placed in a container on the top of the wood ramming piece, and the wood and weights would be dropped from a set height and the effect on the backbone recorded. The splint was also tested for mass and volume, the volume measured with the displacement method, due to the irregularity of the shape. The splint was tested based purely on ease of possession, which included measuring volume with water displacement, measuring mass and stress testing with weighted impact. The displacement of each piece was tested through a 1000 mL graduated cylinder full of 500 mL of water and measuring the change in water level. After drying the pieces, the pieces were massed on a scale.

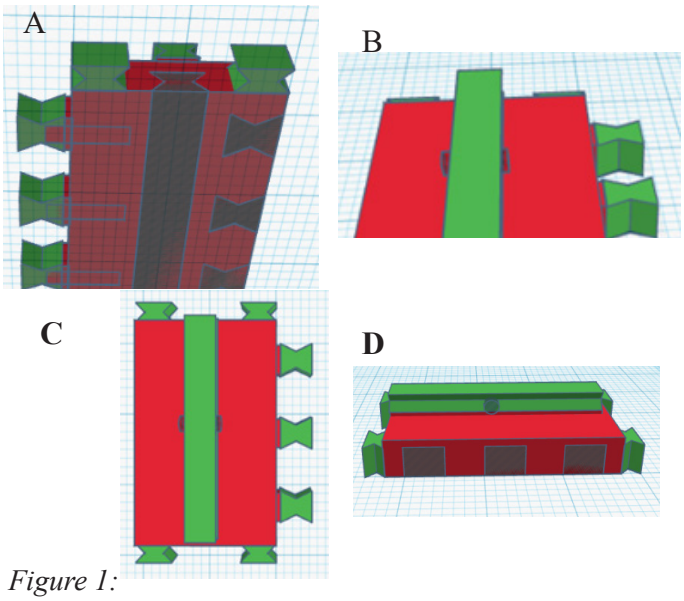

Figure 1:

A - Bottom view,
B -Front view,
C- Side view,
D - Top view.

This is the design for the prosthetic backbone as it was made in the program Tinkercad.

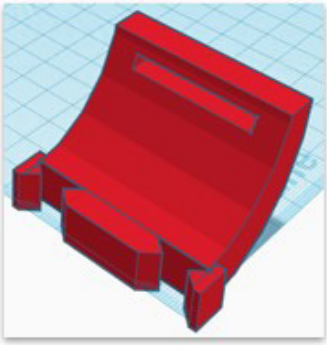

Figure 2: The side piece which attaches to the main backbone.

This design was built from scratch in the program Tinkercad.

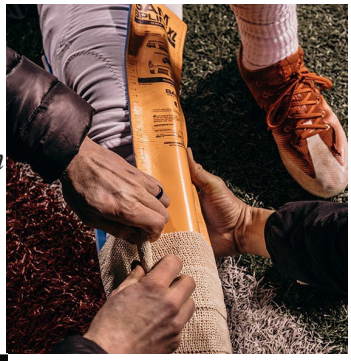

Figure 3: An image of a competitor, the SAM® Splint, in use. It gets the rigidity of the design from the fold of the malleable splint.

Source: sammedical.com

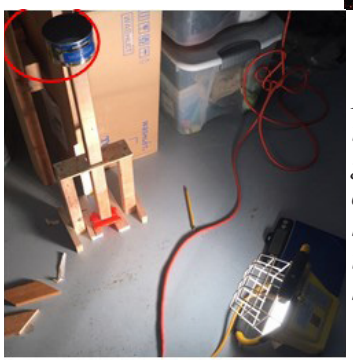

Figure 4: Structure Testing Setup. Weights would go in the circled container and the entire part would be dropped from a certain height onto the splint backbone (orange).

Figure 5: First damage seen in backbone on trial 8. Slight breakage on top attachment but bigger crack on bottom.

Figure 6: Small dent next to top attachment piece, still structurally sound. Trial 10.

Figure 7: Final Damage to the Backbone. Damaged enough that it couldn't be reused, or stacked back together, but still strong enough and structurally sound enough to support weight and maintain shape.

Results

The main results were conclusive after printing over 7 prototypes for each piece. The first stress test that was performed was a simple mass and volume determination. Each side piece that wrapped around the injured body part had a volume of 19 cm3 and mass of 17.4 grams. The long pieces that connect to form longitudinally on the limb were 21 cm3 and 23.2 grams in mass. This can then be compared to other options on the market to see how the splint stacks up. The put together trio of one backbone and 2 side pieces weighed 58 grams, and had a volume of 59 mL, reaching a density of approximately 0.98 g/mL. This is a similar density to wood, for example red oak has a density of .97 g/mL. The key though is the size that it comes in. While the splint that was designed is created to be as efficient of materials as possible, wood pieces will likely be larger than needed and add undue weight onto the injury and cause further pain. When the structure was tested with weight dropped on it, it fared pretty well, not ever losing structural integrity, even when the tester did. The table below shows how there was the first damage done at the 8th trial, with 2.431 kg of weight dropping from a height of .27 m, experiencing a total force on the backbone of 6.6 N. The final test yielded a force of 13.501 N on the structure, and it retained its basic structural integrity. When compared to the N of volume per wood, red oak could withstand 1.4 N per inch^3 of wood before shattering, while our splint withheld 1.833 N per inch^3 before the first shatter and 3.75 N per inch^3 on the last trial without sacrificing structural integrity. It was also observed an unexpected outcome of the pieces floating due to the not solid infill.

Table I: Dimensional Values of Testing Emergency Splint

	Volume (cm^3)	**Mass (grams)**
Side Wrapping Piece	19.0	17.4
Middle Longitudinal Piece	21.0	23.2

Table II: Impact Force Values for Testing Emergency Splint

Trial	Added Weight^ (g)	Added Weight (kg)	Height dropped (m)	Force Dropped (N)	Damage	Notes *
1	431	0.431	0.2794	1.18012972	None	Multiple bounces, first hit at 25s, out of focus video, will up mass by 100g
2	531	0.531	0.2794	1.45394172	None	Hit and deflected to the right, no bounce
3	631	0.631	0.2794	1.72775372	None	No deflection or bounce
4	731	0.731	0.2794	2.00156572	None	No deflection or bounce
5	831	0.831	0.2794	2.27537772	None	Deflected and entire tester fell over, no breakage
6	931	0.931	0.2794	2.54918972	None	Again deflected, going to test in bigger increments
7	1431	1.431	0.2794	3.91824972	None	Too top heavy, need to hold tester to drop
8	2431	2.431	0.2794	6.65636972	Top cracked as well as bottom piece	Hard to get enough weight on tester
9	2931	2.931	0.2794	8.02542972	No further damage	First time didn't hit the structure, second time did
10	3431	3.431	0.2794	9.39448972	Hit on back side of stack, dent and top interlock broken beyond usage, still structurally sound	2 weights taped to side
11	3931	3.931	0.2794	10.76354972	No further damage	Solid hit
12	4431	4.431	0.2794	12.13260972	Slight dent/shatter in the front corner from weight falling off the tester but still structurally sound	Weight getting really difficult to attach to tester
13	4931	4.931	0.2794	13.50166972	No further damage	Tester Broken

* = Notes from during testing, any observations taken immediately and notes for future experimentation if changes in procedure were carried out

^ = Weight of Bearing Can, Nail and Wood that rig was created from is 431 grams.

Conclusion

This splint was a success in furthering the design of a compact splint, however it needs a lot more polishing and work before the splint should be promoted as a viable resource for backpackers/other outdoorsmen. The piece is structurally very strong, but also very heavy compared to the competition, which can be fixed in the future by testing the thickness at which the prosthetic can still have the same level of structural integrity and lower the weight. Designing two different pieces that fit together nicely was a challenge, and it took many different attempts in printing to match the two ends together. But this splint is nicely designed that the pieces do not require much maintenance after printing, which would make them ideal for mass production. Also, the splint, compared to other options on the market, is also a lot more user friendly, and able to be used by the layman instead of someone with extensive training for that specific splint. In the future, since the current prototype is strong and sturdy enough to take damage and still be functional, it would be useful to test how thin the main deck of the pieces could be while still protecting against damage that would leave the piece unusable. This would be done through tinkering around with the design some more and testing more weights, possibly higher than 4391 grams. Overall, the prosthetic was a huge success in the beginning of choices for the consumer in the area of emergency splints that are compact, portable and reliable.

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Creating a 3D Printed Orthotic to Increases Stature

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Advanced Biomedical Engineering

Abstract

Confidence is an important trait for anyone, and there is a positive correlation between confidence and stature. This project set out to make increasing stature affordable without sacrificing durability or comfort. An orthotic sole was created using TinkerCAD and 3D Builder that had a slab on it, that if durable, would increase height. Unlike other forms of stature increasement, this orthotic also allowed for the customization of height with the use of heel plates. In order for the orthotic to be used, it must be durable, comfortable, and be effective at increasing height. The orthotic showed to successfully increase height by about 3.048cm (1.2 in.), never break under any subject's weights, and is decently comfortable and easy to use. Overall, the project was a success because it met all the criterion mentioned earlier, however, we did run into some errors and there are improvements to be made. In general, the problems were related to using the 3D printer. The orthotics didn't always come out as expected. We also had the limitation of inexperience in using the editing programs and there is only so much iteration you can do that will still fit inside the shoe. Some possible improvements could be adding foam and rubber to the orthotic to make it more comfortable and durable. The findings mean that it is possible for anyone with access to a 3D printer to have the ability to increase their stature, and potentially, their confidence.

Key Words: 3D Print, Orthotic, Sole, Height, Stature, Confidence

Height increasing devices exist, however, they can be expensive and inconvenient. This project set out to create a much cheaper and more accessible sole orthotic that increases height. As a result of 3D printings becoming cheaper than purchasing products, there is more access to these medical devices in healthcare than ever before. Sun (2011) examined the relationship between height and confidence. He concluded that the further from the ground you perceive yourself to be, the more confident you are about the accuracy of your answers on a test. Furthermore, you assume that your scores are higher than your peers. With confidence itself being an obvious need for success, our goal was to produce a stature increasing prosthetic.

There are no current 3D printed orthotics that complete this task on the market. They do exist in other forms: high heels, expensive shoes, and hidden heels. These options, however, are not as practical because they do not balance comfort, cost, and discreteness. Gouzien and Vignemont (2017) discovered that amputees tend to not use their prosthetics very often. Subjects predicted they could reach further while using a prosthetic, showing awareness of the prosthetic, however, the healthy limb could actually reach further than the prosthetic. This reveals a misconception between the prosthetics perceived and actual abilities. The implication of this research is that amputees with prosthetics must become more aware of the capabilities of their prosthetic. If they know the abilities and limitations of their prosthetic, then they will better embody it and use it. As well, making an orthotic discrete, and unnoticeable, will allow for better acceptance of the prosthetic.

Current models also follow a "one-size fits all" strategy for mass production. Brandt and Wen (2017) researched the inefficiency of knee prosthesis in differing environments. For example, the prosthetic was hindering when carrying a heavy load or walking up a steep hill. Prosthetics should be more diverse and come with more modes, settings, or adjustments to take differing environments and terrains into account. A sole prosthetic should especially take into account the desired height increases and be adjustable to many sizes. They should also be durable when under the strain of a steep hill or

walking on tough, hard terrains. Unlike hidden heels, you should be able to customize the feature.

Methods

The function of the final 3D printed orthotic was to discretely increase the stature of an individual without sacrificing comfort. The main features of the orthotic are that (1) it can easily be inserted or removed, (2) has a rectangular slab to increase height, (3) a slope, (4) flexible pads at toes and heel, (5) slits for Velcro, and (6) extra heel plates provided. The orthotic is thin, allowing for it to be easily inserted or removed from the shoe. The rectangular slab is positioned in such a way that it dies not dig into your foot or provide massive discomfort. A triangular slope is positioned at the end of the slab to allow for further bending of the toes. The flaky pads located near the toes and heels allows for more side-to-side flexibility within the shoe. Slits are provided for Velcro to be added to remove the movement of the orthotic within the shoe. Finally, extra heels can be printed to customize the desired height increasement.

The use of the prosthetic is pretty straight forward. Simply remove the original sole of the shoe, if possible, and insert the 3D printed sole with the flat side on top, then put original sole on top if applicable. If you want to customize your height increase more than the default, simply add the heel plates to the heel of the orthotic. When ready, put on the shoe like normal, or add Velcro to ensure it doesn't move under your weight.

Based on research, the most similar products are high heels and hidden heeled shoes. High heels are common, but are not unisex. They are also infamous for being uncomfortable and expensive. My model is different in that because it goes inside the shoe, meaning anyone with close-toed shoes can wear it.

My orthotic is also not uncomfortable and effectively just adds another layer to the entire foot, so there is no digging into the heel. Another similar product is hidden heel shoes. These are usually very expensive and give a fixed amount of height increasement. My orthotic is cheap in comparison and allows for heel plates to be added to further customize height increasement.

My orthotic is very different than the original design. Originally, it was just a printable sole. I edited all the features on the surface of the sole and used the original to create the heel plates. TinkerCAD and 3D Builder were the programs that the editing was made in.

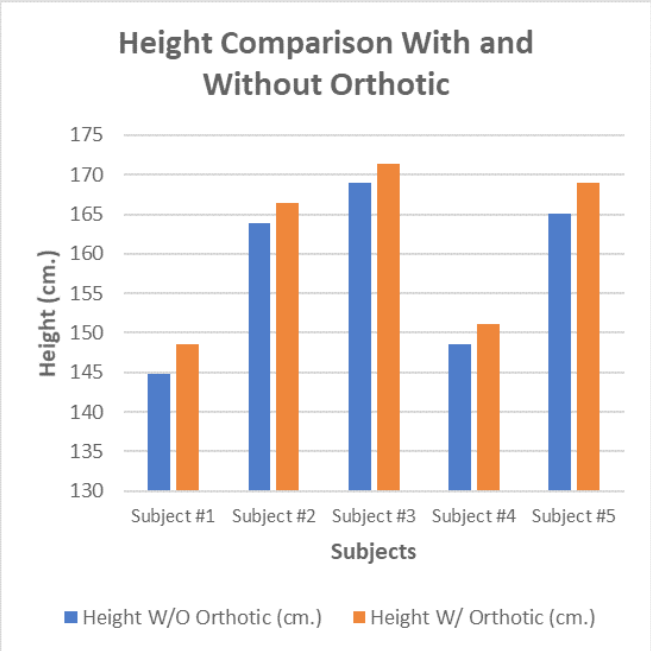
To test the orthotic, we had to make sure it was durable, easy to use, comfortable, and effective at increasing stature. Five subjects were weighed (lbs.) and their original heights (in.) without the orthotic were recorded. They then inserted the printed sole into their shoes and were asked on a scale of 1-10 how easy it was to insert. When they stood up, they were surveyed again on a scale of 1-10 about how comfortable it was. The subjects' heights were re-measured (in.) and then damage to the orthotic was assessed to determine if their weight was too much for its durability capability.

Results

Table 1. Procedural Measurements

Subjects	Durability (kg.)	Height W/O Orthotic (cm.)	Ease of Use (1-10)	Comfort Level (1-10)	Height W/ Orthotic (cm.)
Subject #1	44.54	144.78	4	7	148.59
Subject #2	67.31	163.83	7	4	166.37
Subject #3	101.15	168.91	8	7	171.45
Subject #4	54.43	148.59	5	9	151.13
Subject #5	88.45	165.10	6	6	168.91

Durability is the weight (kg.) of that subject, meaning it was durable for that weight. Weights measured in lbs. then converted to kilograms. Since the prosthetic never broke, it was durable for all the weights. "W/O" is without, and "W/" is with. Heights measured in in. then converted to centimeters. Ease of use was measured on a scale of 1 to 10, where 1 meant impossible to use and 10 meant extremely easy. Comfort was measured on a scale of 1 to 10, where 1 meant unbearable and 10 meant barely fell orthotic.



Subjects	Height W/O Orthotic (cm.)	Height W/ Orthotic (cm.)	Difference (cm.)
Subject #1	144.78	148.59	3.81
Subject #2	163.83	166.37	2.54
Subject #3	168.91	171.45	2.54
Subject #4	148.59	151.13	2.54
Subject #5	165.10	168.91	3.81
Average			3.048

Fig. 1/Table II. All heights measured in inches then converted into centimeters. The height without the prosthetic was subtracted from the height with the prosthetic to determine how much height was caused by the orthotic. The average height boost is 3.048 cm..

Fig. 2 Bottom view of soles. Yellow is left sole. Purple is right sole. 4 slits present where Velcro can go.

Fig. 3 Top view of soles. Yellow is left sole. Purple is right sole. Black and white are heel plates.

I was able to successful 3D print my design. The orthotics increased the average height by about 3.048 centimeters (1.3 inches), was durable under all 5 participating subjects, had an average comfort score of 6.6/10, and average ease of use score of 6/10. Thus, it was easier to use than not and more comfortable than not.

Conclusion/Discussion

The results are a success because our prosthetic increases height by over an inch (1.2 inches), is durable under every tested weight (no damage), and it is generally not super uncomfortable (6.6/10) or hard to use (ease of use: 6/10).

I ran into several problems. First of all, I experienced a couple of printing errors and had to re-print due to poor taping on the 3D printer. Sometimes, one print would come out seeming more durable than others. When the past modifications were not durable, so I had to make edits to make them sturdier while also having to learn how to use the programs. This was a limitation because I had to settle for minor edits because I couldn't always figure out how to do the larger edits. Another limitation was figuring out how to make such a simple orthotic more complex, as there is not much room to work with in the inside of a shoe.

In the future, I would like a mechanism in which the heel plates stick firm with the base of the orthotic sole. I would also like access to more materials,

like memory foam, to make the orthotic even more comfortable. I would also change the "flaky" pads at the toes and heel to a softer rubber-like material. This would give it shock resistance and me more malleable than plastic. No matter how effective the prosthetic is at increasing stature, no one will wear it unless it is durable and comfortable, so these are the two highest priorities.

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Creating and Testing an Orthotic for Patients Suffering from Hand Dystonia

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Abstract

Dystonia is a neurological disorder that causes involuntary muscle contractions resulting in pain and loss of control in limbs and body movements. It can affect any part of the body and can cause the individual to be unable to use fine motor skills to complete tasks, such as writing or typing. The goal was to create an orthotic that allows the individual to write without pain and with ease. In order to test, three patients with Dystonia were given a set of six questions, half of which were short, the other half long. The first time the questions were answered without the orthotic and the second time with the orthotic. The number of times the patient's arm lifted or tried to lift up were recorded and compared to use with the orthotic. The results showed that while the device did not prevent the arm from lifting altogether, it did improve the movement and prevent the arm from turning up, and in turn caused slower hand movement and the user could still feel when their arm was trying to lift. Patient number one went from having fifty or more spasms to having twenty-seven, patient number two went from having sixty spasms to having thirty-two attempted lifts, and patient number three went from having thirty-three spasms to having only twenty-one attempts. The number of spasms were reduced by about half for each of the patients. While it did not fix the problem all together, it did make an improvement in pain and ease of writing all together.

Keywords: Orthotic, brace, lycra, Velcro, Dystonia, spasm

Dystonia is a neurological disorder that causes involuntary muscle contractions resulting in pain and loss of control in limbs and body movements. It can affect any part of the body including the arms, legs, neck, hands, feet, vocal chords, eyelids, face, and torso. Often, Dystonia is accompanied by depression and anxiety because of pain and embarrassment relating to these abnormal body movements. Abnormal body movements can look like twisting or pulling in an abnormal position and shaking or a tremor. This can occur at any time but may be set off when performing certain tasks such as writing or using the part of the body that is affected (Dystonia Medical Research Foundation, 2019). Dystonia can take many forms and may affect a single part of the body or multiple areas. Symptoms may be chronic or occur intermittently, brought on by triggers such as particular movements. Dystonia can be inherited or due to a mutated gene, brain injury, or certain medications, but it is caused by too much dopamine and neurotransmitters that fire too quickly (Bragg and Sharma, 2014). Oftentimes Dystonia is referred to as the "cousin disease" to Parkinson's, an illness caused by too little dopamine.

The problem that needed to be solved was finding a way to allow people with Dystonia that affects their arms to write with a pen or pencil with greater ease. Patients with a tremor in the arm often have a jerking reaction when trying to remain steady and use fine motor skills in order to write, and this can make writing difficult, if not impossible to do, as well as painful and embarrassing. These complications are what can lead to anxiety and depression over being able to function normally, especially in public and the inability can add depression to the combination.

Modern treatments for this disorder include oral medications, botulinum toxin injections, and deep brain stimulation. Along with these and less commonly used are physical therapies, which have the goal of improving the function of the affected limb (Bragg and Sharma, 2014). Braces have been used to try and stabilize the limbs, but few have been successful. The ones that have been useful

were for inversions of the leg and included straps, a metal bar, and lots of padding (Hurvitz et al, 1988). For the hand a lycra brace was invented for children to gain better control of their hands, and it did make improvements in writing for children with mild symptoms (Mohopatra et al, 2015).

Methods:

The final hand-writing orthotic has been designed in such a way that it forces the hand to stay flat and removes the possibility of the arm being able to jerk upwards, causing sloppy and painful writing. The orthotic works by having the person place their hand into the curved space underneath the cross-strap, and then they would tie the Velcro strap across their arm, so it is tight enough that the arm doesn't slip or have too much room to move. The wrist would need to be hanging far enough towards the front edge of the orthotic in a comfortable position for the person to write.

The main feature to highlight is the extended base. This base mechanically prevents the arm from being able to extend, or bend, outwards. It is just long enough to prevent the orthotic and in turn the arm, from spasming, but isn't so long that it is unfunctional or becomes a burden of its own. The width of the base is also thin enough that it doesn't impair the ability to write with ease on a piece of paper. The other feature is the Velcro cross-strap because of its ability to stabilize the arm and keep it in a comfortable position, whereas a Dystonia patient who would try to write without it would have a difficult time doing so.

This model is different from other orthotics or braces because of its unique shape, size, and structure. There are not that many products like these available for patients in general, but the ones that are designed to keep the finger and arm straight and are not much different from a standard brace (Mohapatra et al, 2015). Orthotics for the legs have also involved using metal as a way to keep the leg straight and was successful in doing so, which contributed to the idea of using a solid material that can't bend with force (Hurvitz et al, 1988).

Instead of keeping the standard fabric design that covers the entire arm and is worn throughout the day, this brace is made entirely of 3D printed plastic filament. The single strap allows for ease with placing the arm for use and removing the arm when finished. The interior padding adds extra comfort for the user, but by not making the entire device out of a fabric like lycra, it makes it easier to clean and more durable.

To test the effectiveness of the device, three patients suffering from Dystonia in the arms were asked to write a set of six sentences without the brace on. The sentences ranged in length with three short phrases asking their name, age, and favorite thing to do, and three longer questions that inquired about family, favorite world location, and favorite food, all with an explanation. The number of times that the person's arm lifted or spasmed and caused a jerking sensation was recorded. The process was then repeated with the patient using the orthotic and results were then collected and compared.

Results:

All three of the Dystonia patients were given a list of six sentences ranging in length to write without the orthotic and to count the number of times the arm spasmed and either tried or succeeded in lifting up causing a pause in writing. Patient number one had fifty or more spasms, patient number two had sixty spasms or attempted spasms, and patient number three had this occur thirty-three times (Table I). The process was then repeated using the orthotic writing device and results were collected. Patient number one had 27 attempted lifts, patient two had thirty-two attempts, and patient three had twenty-one attempts (Fig. I). Printing of the writing device was successful after many attempts and design flaws and changes. There is still room for improvement but overall this has been a successful experience.

Table I

Patient	Trial Without Orthotic- # of Spasms	Trial with Orthotic- # of Spasms
Patient #1	50+	27
Patient #2	60	32
Patient #3	33	21

Number accounts for complete and attempted tremors

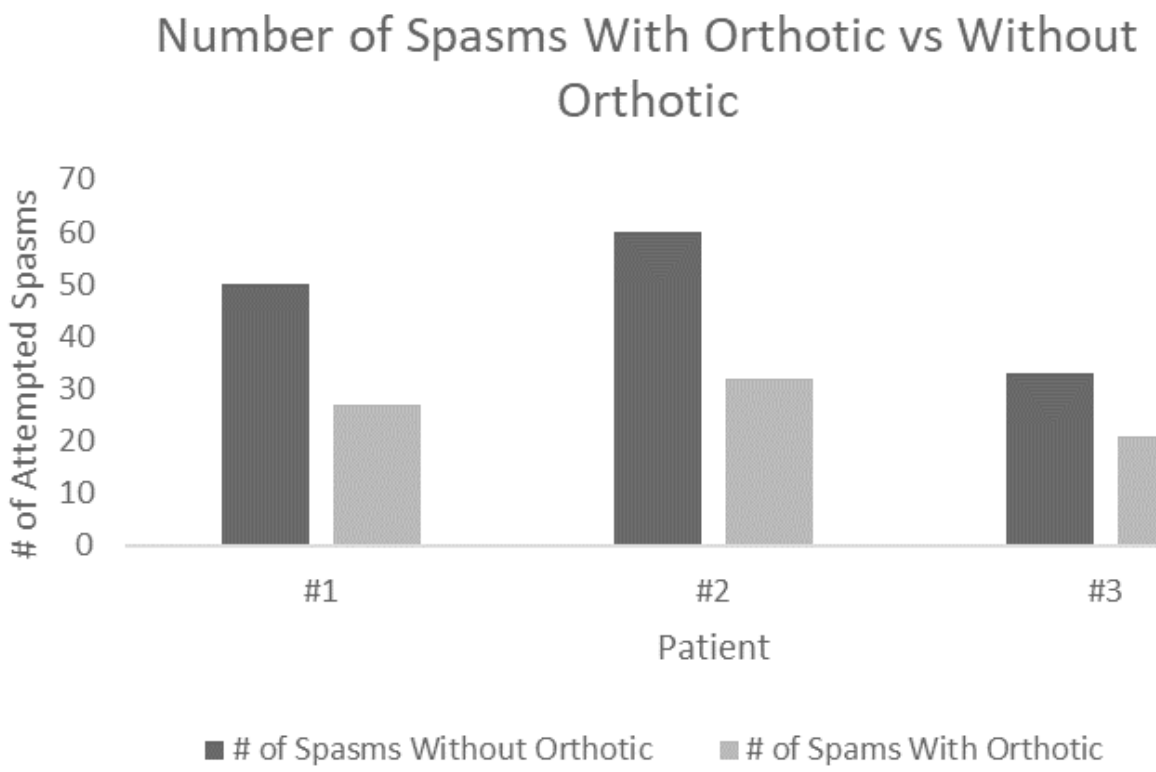

Figure 1. Numbers account for attempted spasms

Conclusion:

The results have shown that the orthotic does indeed assist with writing in patients suffering from Dystonia in the arms. The success is thanks to the solid structure and base that is just long enough to prevent the arm from lifting up when writing, along with the Velcro strap, which helped reinforce the straightness of the wrist and hand. Three patients suffering from arm Dystonia were observed while attempting to write a series of sentences, each varying in length. The goal and prediction were that the arm would lift or try to lift approximately forty-five times without the brace in one sitting of the sample sentences and that with the orthotic the arm would attempt fifteen to twenty times but would not be successful in doing so. The features mentioned above provide the insight as to why this happened.

Not many limitations were faced, but each individual does have a different sized wrist and arm, and the prosthetic was only sized for one patient, so it would be important to measure the hand of each potential client who might want to purchase an orthotic. The base was also thin enough to allow the user to write but making it even a drop slimmer could make a difference.

In the future different colors could be used to personalize the orthotic since it is designed to be used to reduce embarrassment, especially in public. The base would also be about a quarter of an inch slimmer. These are all for aesthetic and functional purposes for the user.

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Detachable Prosthetic Device for Writing

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Author Note
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Abstract
When those responsible for designing upper arm prosthetics are able-bodied individuals, there can often be a disconnect between the needs of an amputee and the goals of an engineer. Many people who wear prosthetics care more about functionality and comfort over visual similarity to a biological hand, with 49% of children who abstain from prosthetic use doing so from discomfort and 53% from lack of functionality (Wagner 2007). Too often, the amount of time and training dedicated to working with a prosthetic can make limited functionality and discomfort not worth the effort. Thus, the purpose of this prosthetic is to serve a deliberate function, in our case writing, comfortably without training. To do so, the base is an aerated slide on socket that can be easily put on or taken off, and a writing device modeled after mechanical writing mechanisms instead biological mechanisms so usage can be easily mastered. With this prosthetic, when asked to copy a prompt, 80% of individuals were able to legibly write within 10 seconds of their time with their biological hand on their first try. Those individuals' writing mimicked the same characteristics of their natural handwriting with similar curvature of the letters and balance between capital letters and lowercase. This indicates that those individuals were able to capture the motion of their biological hand with the prosthetic on their first attempt, demonstrating that prosthetics modeled from machinery may be more practical that those modeled after biological limbs with current technology. This prompt continued research on the applications of machinery towards prosthetic design and the development of more potential devices that can work with the base socket.

Keywords: Traumatic Amputation, Hand Prosthetic, Writing Aid

When a hand prosthetic is made, often times the goal is to make it as similar to the function of a human hand as possible. However, the truth is, many amputees wear a prosthetic only when necessary, with 38% of unilateral amputees and 30% of bilateral amputees wearing a prosthetic for less than 10 hours a day (Kestner 2006). Unless the task at hand requires the use of a prosthetic, the natural state is preferred to one artificially constructed to look like the natural state of an able-bodied individual. Especially for unilateral amputees who can complete most unilateral tasks without the help of a prosthetic, they primarily only using the prosthetic for bilateral tasks (Kestner 2006).

In fact, the reason many people prefer to not wear a prosthetic can be usually be accounted to discomfort and unhelpfulness. 49% of children with unilateral congenital transverse forearm deficiency reported that they choose not to wear a prosthetic because of discomfort, with 53% reporting it did not help with function (Wagner 2007). Much like a cast, when a prosthetic is meant to be worn for an extended period of time it can feel constricting and tight.

On the other hand, since hospital meditated amputations are carefully done to suit future prosthetic use, many traumatic amputees find prosthetics to be even more uncomfortable than congenital amputees. Traumatic amputees reported that they were less satisfied with their prosthetics, and only wore their prosthetic for 31% less time per day that those who were not. (Gaine 1997)

Even when a person who has either a unilateral or bilateral amputation decided to wear a prosthetic, a large amount of training is needed in order for full use of the prosthetic. Even with an experienced prosthetic user, switching to a new prosthetic immediately worsened function and took dedicated

time and practice in order to return to the baseline function. (Dromerick 2008). Likewise, most people who wear a prosthetic required of training by a physical or occupational therapist with 65% of unilateral and 71% of bilateral amputees receiving professional training.

Furthermore, the purpose of this study is to build a prosthetic that is mean to only be worn when necessary and is comfortable. We hypothesized that a prosthetic made to serve specific purposes required in every day life such as writing could be easily worn when needed and subsequently taken off. Current prosthetics serve as a more generalized function of a hand and are meant to be worn for most of the day like those researched above. We also hypothesized that since the prosthetic would be worn for significantly less time, function and ease of use should be valued over aesthetic. We found that by looking to machines and mechanical devices that serve the purpose of writing instead of the human hand, would lead to a more accurate prosthetic that required less training in usage. The implications of this prosthetic point to the importance of building prosthetics that serve the needed of amputees rather than mimicking the functions of a biological hand.

Methods (Functionality and Testing)

Our prosthetic is compatible with those people who have either a bilateral or unilateral metacarpal amputation, wrist disarticulation, or below elbow amputation (transradial). It has a base which would go over the residual limb and then a location to attach different devices. For quantitative research, we focused on a writing device. Once the prosthetic is put on, the user would just write as if there was a writing utensil attached to their body. One important feature of our prosthetic to insure comfort, is the aeration of the base through both small hexagonal holes and large 2 large holes centered on each side. This insures breathability of the residual limb when attached. Another feature of our prosthetic is the face that the devices are detachable so the prosthetic can have multiple purposes and be transported easily. The easy attachment of to the limb and different parts is so a person could travel without the prosthetic on, but bring it with them to quickly attach when necessary. Additionally, the detachable device allows for it to be attached at different angles or orientations, making the prosthetic compatible with both the left hand or rights hand.

Most prosthetics for a hand focus on making it as similar as possible to a biological human hand. However, for this prosthetic our goal was to make a prosthetic which serves same purpose such as a spoon or pen would to a able-bodied person, in the sense that it is just a device put on to complete a task, otherwise being put away. This makes the prosthetic much cheaper than those currently on the market because the simple design has only parts necessary to function. Furthermore, our detachable parts mimic the functionality of a piece of machinery for the best possible function. The writing device has an adjustable clamp at the top to be compatible with different types of utensils and can be secured tightly, unlike many of the grasping mechanisms in current prosthetics, which have a more uncontrolled, weaker holding capability.

While the attachable devices were designed on our own, the socket for the residual arm is originally from Thingiverse. We changed the design of the holes in the socket to improve breathability and attachment. By making them larger, the residual arm has more contact with the air, but now there is enough room to reach within the socket and potentially itch the limb or remove any dust. They were also made bigger to allow for better attachment to the wrist, where if the size of the limb potentially changes through weight loss or the plastic is not reacting with the skin well, Velcro straps can be weaved through or a layer of fabric can be added easily. Additionally, the top of the socket was edited in order to be compatible with our hexagonal or octagonal attachable parts. It was made to be attachable with both, so the attachments could be easily divided by the use by the shape of the attachment, either hexagonal or octagonal, as well as for a better fit with the attachment. Previously, one would have had to screw in an attachment, but through our design the attachment can just be pushed in, making it easy for a unilateral amputee to attach.

For the writing attachment we referenced pen holding items such as those on a desk and created our own clamp that could be secured into attachment device. Instead of making it a grasp mechanism but a slide in mechanism via a clam, we made it autonomous and easy for a person with a unilateral amputation to use on their own.

Figure 1
Writing device that will hold a pen/ pencil with the clamp

Base socket where the residual limb will go inside

Writing device attached to base for a right-handed individual with pen placed in clamp

We tested this prosthetic by asking able-bodied individuals to place the socket over their balled hand and control the socket by their wrist and arm. By having able-bodied individuals to test our prosthetic, we were able to compare their writing utilizing the prosthetic with their typical writing. Our subjects were male and insure female, as well as both left and right handed, to reduce potential lurking variable as well as that results were uniform across all prosthetic users.

Our method of testing was based of forensic handwriting analysis procedure, where we had subjects each write the statement “The quick brown fox jumps over the lazy dog,” a sentence which features every letter of the English alphabet. We asked each subject to do so with their biological hand and with the prosthetic and timed each trial. We analyzed the difference in time to see how much functionality dropped from using their own hand to the prosthetic, and then analyzed the writing. We analyzed the writing through both initial legibility and neatness compared to the original writing, as well as analysis on the distance between letters and the uniformity between letters. By looking at legibility with the prosthetic we were able to understand how well the functionality was, and by comparing that to their writing without we were able to see how similar it could be to their typical writing.

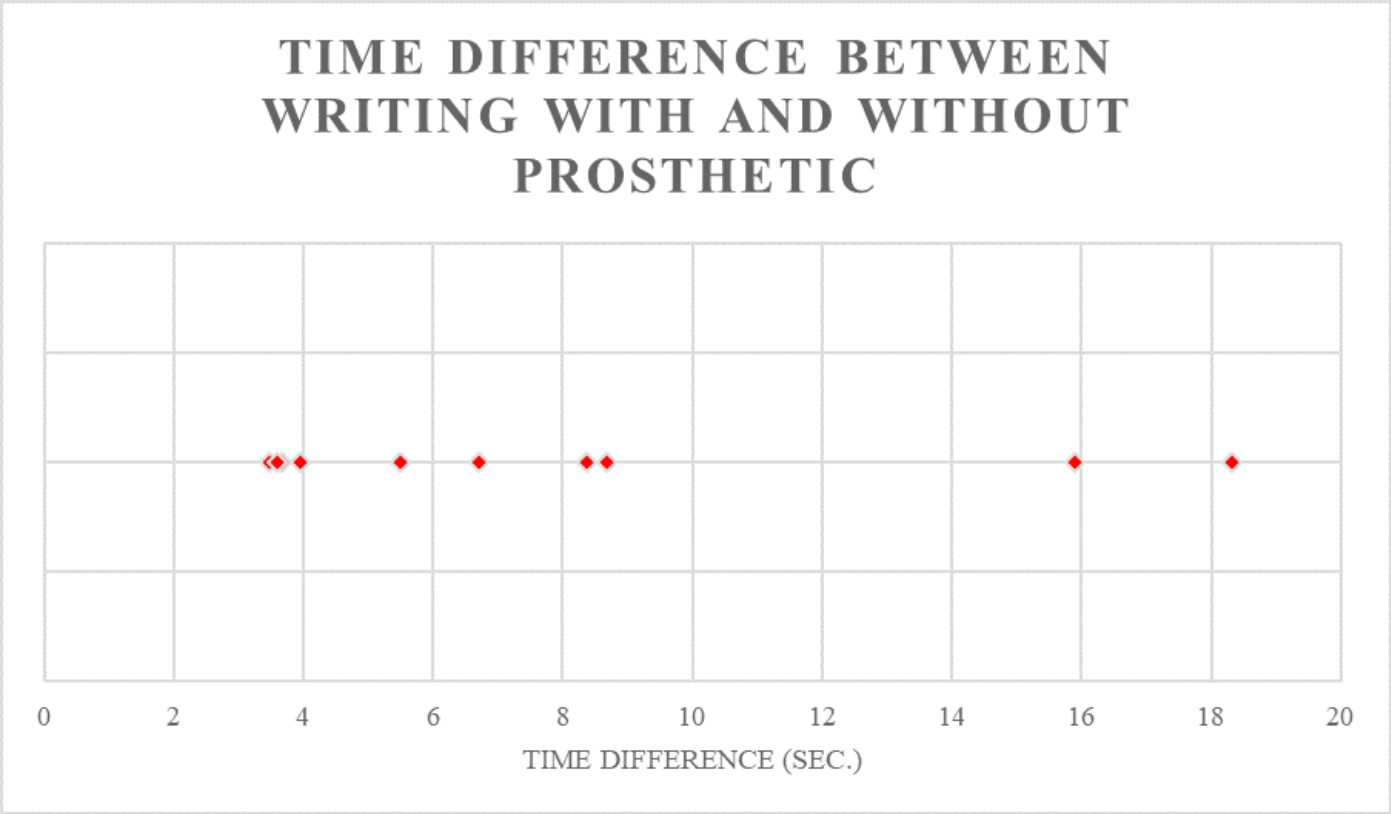
Results

Table 1
Timed Writing

Test Subject	Time without Prosthetic (sec.)	Time with Prosthetic (sec.)	Time Difference (sec.)
A	19.20	35.10	15.9
B	14.05	19.55	5.5
C	17.82	21.76	3.94
D	23.17	26.65	3.48
E	18.53	36.86	18.33
F	22.58	26.25	3.67
G	19.53	28.20	8.67
H	21.63	25.22	3.59
I	18.79	27.15	8.36
J	20.45	27.16	6.71

This table features the timed writing for both the subject's standard writing with a biological hand and with the prosthetic placed over their balled hand, with their difference in time mapped to see how similar the prosthetic functions to a biological hand.

Figure 2



This graph maps the range of time difference between writing with and without the prosthetic. Subject typically were within a 10 second difference excluding 2 outliers.

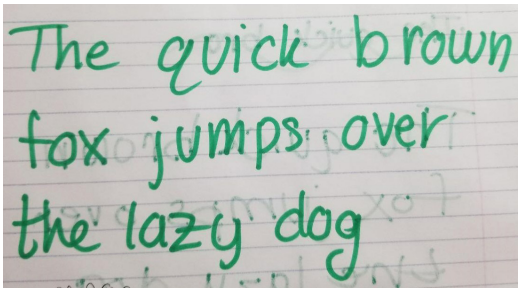


Figure 3 Writing w/o Prosthetic - Subject G

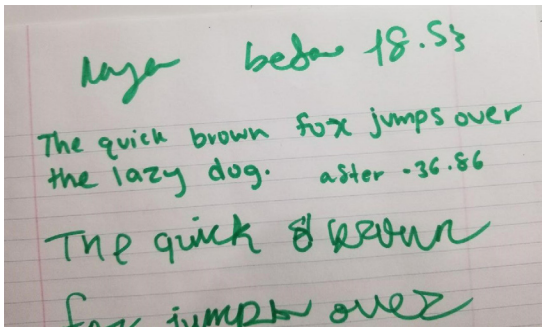


Figure 5 Writing w/o Prosthetic - Subject E

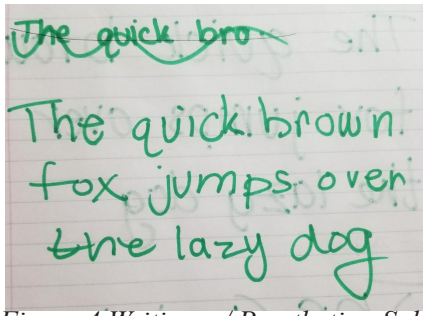


Figure 4 Writing w/ Prosthetic - Subject G

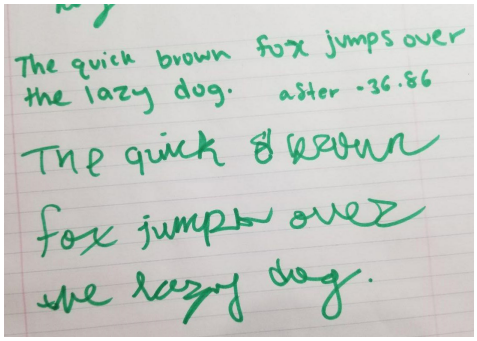


Figure 6 Writing w/Prosthetic - Subject E

Note: Subject E is left-handed and male. The writing with the prosthetic increased in overall size of the letters and led to more interconnected letters like those of cursive. This test subject's style of writing is significantly different and spent an extended period of time writing compared to their natural writing.

The difference between those who fell within 10 seconds in their writing times and the 2 outliers is what is astonishing about our data. The individuals tested within the cluster of data around 3 to 9 seconds were able to mimic their natural handwriting when writing with the prosthetic. Their writing had the same curvature of the letters and ratio between upper case and lowercase, with the only distinct different being an increased spread of letters. However, the two outliers clocked at around 16 to 18 seconds difference had handwriting unrecognizable to the original with separate structure of the letters entirely. This is likely the different between those who recognized the prosthetic between an attachment of their body, versus an entirely separate entity they are trying to control.

Conclusion/Discussion

The time difference in function was below 10 seconds for all but 2 subjects, indicating that while more difficult then their biological arm, writing with the prosthetic is practical. The test subjects with time differences below 10 seconds had similar handwriting both with and without the prosthetic, while those above had significant changes in handwriting. We hypothesize that this is due to whether the brain recognizes the prosthetic as a continuation to the body, versus a foreign object that they are trying to control. The subjects who reacted to the prosthetic better typically wrote faster with more legible handwriting.

Our subjects were all tested on their first try with the prosthetic, and every subject was able to complete the sentence legibly with the prosthetic, indicating that this prosthetic would not require training with use. However, every subject did have a decrease in the neatness of their handwriting with wider and more extended lettering and less differentiation between spaces between letters and spaces between words. Many of the subjects also had more connection letters using the prosthetic, likely pointing to the subtle controls of raising and lowering the prosthetic slightly when writing being hard to master.

We consider these results to be a success, because all subjects were able to write the indicated sentence with the prosthetic legibly on the first try. The prosthetic was put over the arm on the spot and used for the first time in the trial, accomplishing our goals of making it quick and easy to use without any training required. The legibility of the writing of each alphabetical letter also shows that the prosthetic can be used for standard writing.

While this prosthetic we consider our success, this was our second print because our first prosthetic could not be comfortably used by our subjects. Our first prosthetic base was printed with an upright orientation which caused significant rafts to be placed on the inside of the base, and when removed left jagged edges which causes discomfort against the skin. Thus, we reprinted the prosthetic on its side in order to reduce the number of rafts that would be inside of the socket, resulting in a much smoother interior that our subjects could comfortably use. Additionally, when testing the prosthetic, subjects with considerably larger hands struggle to secure the prosthetic, however this was likely due to the hand being balled up, increasing the amount of space taken up, and we hypothesize that this would not be an issue with those that have only a residual limb.

In order to test whether our issues with socket sizing was due to the balling of the hand, in the future we plan to test our prosthetic with subjects that have upper extremely amputations and their functionality compared to their current prosthetic. Moreover, our testing is currently confined to the writing device, but in the future, we would like to print different devices to accompany the prosthetic such as those for painting or cooking and test the function of those compared to a biological hand. We are also considering a “swiss army” attachment which would have multiple specific functionalities in one device.

While untested, we also plan to improve upon the portable aspect of the prosthetic. Currently the separation of the device from the base allows for easier travel with the prosthetic, but in the future, we wish to modify the base so it can fold upon itself, making it easier to slide within a bag or briefcase.

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Development of 3D-printable Prosthetic Foot for Syme's Amputees

Ishika Mukherjee

Abstract

Prosthetic feet for Syme's amputation patients are often incredibly expensive with little-to-no functionality other than being a placeholder for the missing foot. Three prototypes of differing flexibilities were printed from a 3D printer. They were tested by measuring their motion through the angles of four set reference points changing during different parts of a stepping motion. The prototype with a medium amount of flexibility was found to be the closest in motion to an actual human foot. At less than $10 per foot, this prosthetic is an incredibly low-cost, accessible alternative to the prosthetics that exist today.

Over 1.6 million people are living with limb loss in America alone (Ziegler-Graham et al., 2008). Lower limb amputees must navigate many challenges on their path back to normalcy, including re-learning simple tasks such as walking, running, or biking with their new prosthesis. Prosthetic devices are incredibly expensive and often not covered by insurance. Prosthetics for adults are only designed to last 3-5 years and must be replaced after they wear out; additionally, children must be refitted with a new prosthesis as often as every 18 months due to growth, wear and tear, and as part of the natural healing process. A new prosthetic limb can cost anywhere from $5,000 to $50,000. This means that, on top of the numerous hardships endured in the recovery process, many amputees and their families must take on a major financial burden as well.

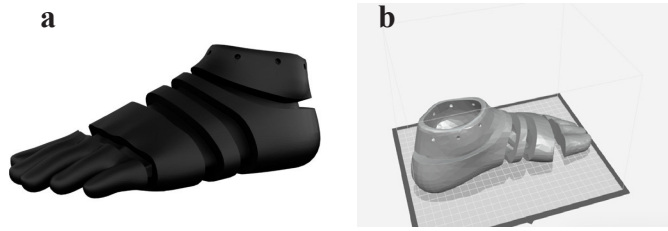
A Syme amputation is a type of ankle disarticulation. It is the most conservative below-the-knee amputation and provides the best weight-bearing stump (Diveley, R. L., & Kiene, R. H, 2008). The most basic prosthesis used with these amputations is the Kingsley Syme Foot, which starts at just over $500 for the most basic plastic foot; adding any flexibility, cushioning, ankle control, or energy storage takes the price up to well over $2,000 just for a basic foot. However, newer research shows that a lack of flexibility in a foot prosthesis can lead to overcompensation by surrounding muscles and joints, which can be detrimental to the patient's comfort and health (Fey et al., 2011).

The purpose of this project was to develop a low-cost, easily replaceable, accessible alternative for Syme's amputees.

Methods and Materials

The original design for the foot was retrieved from https://www.thingiverse.com/thing:1574336 and modified with TinkerCAD software to separate the foot into 4 separate sections, as shown in Figure 1. The idea was to create an affordable prosthesis that behaved as much like the human foot as possible.

Comparison of Original vs. Modified 3D Model



Original foot retrieved from Thingiverse (a) compared to edited 3D model (b). Modified foot is split into sections to allow for flexibility to be added in later.

For each prototype, the modified model was 3D printed on a MakerBot Replicator+ printer with PLA filament. The ring-shaped segment to the right of the large ankle segment was not used. SwordFish brand springs of varying sizes (for varying levels of flexibility) were attached between the segments using hot glue. Also, hot glue was applied across the bottom of each foot to provide traction when walking.

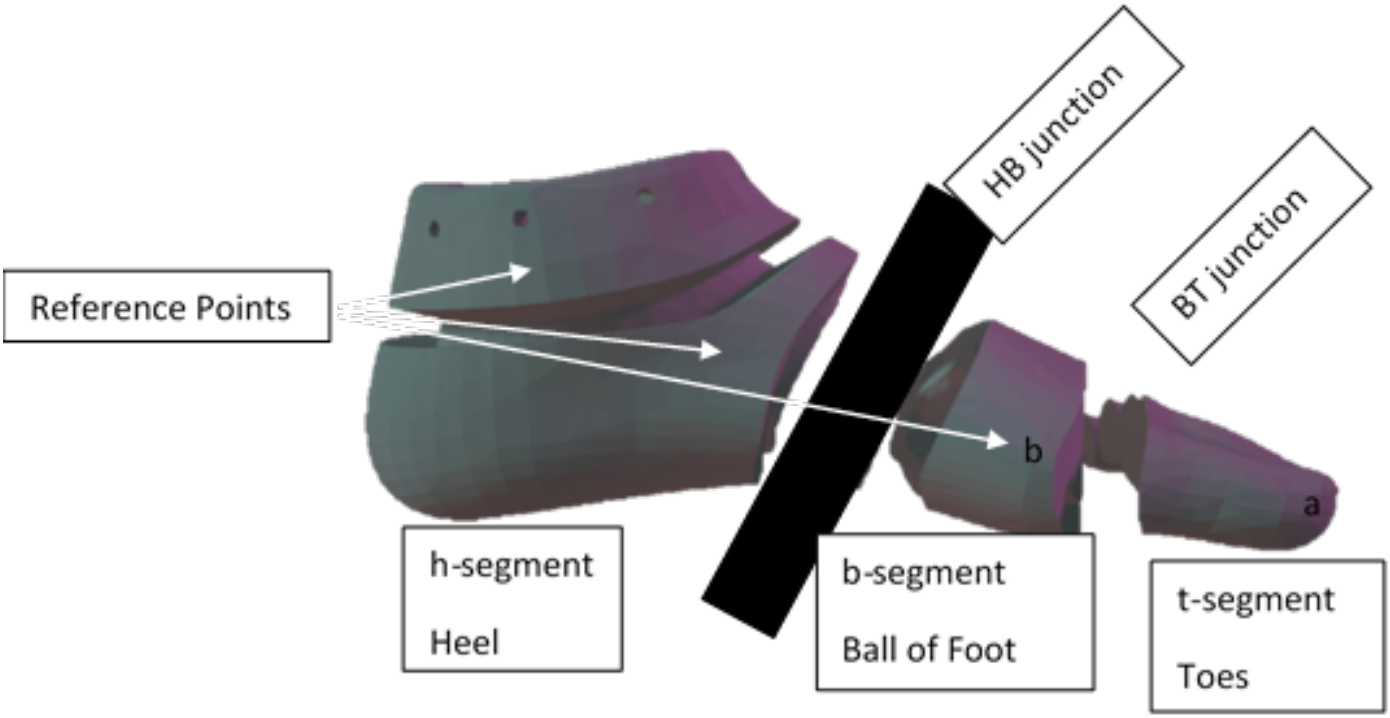


Figure 2. Reference for Labels Shows labels for terms unded throughout paper

Three prototypes were created with varying degrees of flexibility, as shown in Table 1. The springs allow for flexibility similar to the way joints work in the human foot. The hard plastic is rigid, just like the bones and tissue that do not bend in the natural foot. Although humans have a joint where the BT junction is located on the prosthesis, humans do NOT have a joint in the corresponding anatomical position of the HB junction. This was designed to mitigate the lack of an ankle joint in Syme amputees.

These prototype prosthetics are different from existing prosthetics because of the flexibility and the low cost. A similar non-moving foot cost upwards of $500 from Kingsley Prosthetics, while these prototypes have more features (namely flexibility) and they cost less than $7 each.

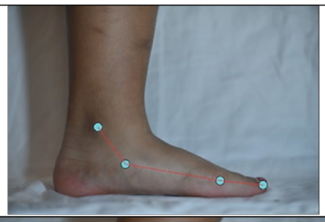
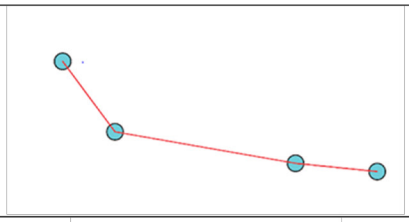
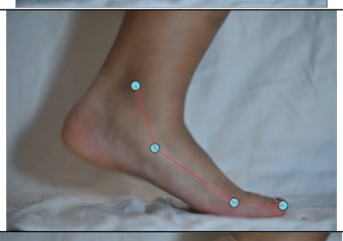
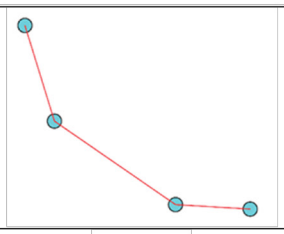
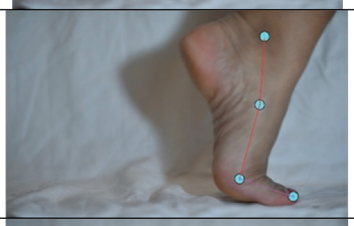
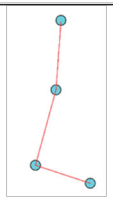
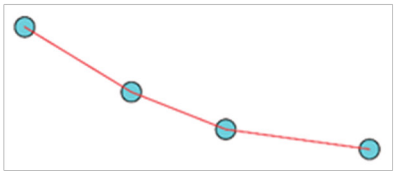
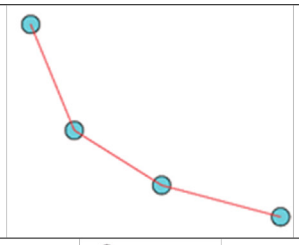
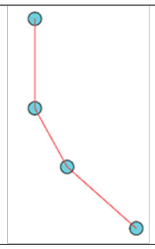
The prosthetics were tested by measuring the angles between 4 reference points (shown in Figure 2) at three different stages of walking- flat on the ground, mid-lift, and at tiptoe, the moment directly prior to the foot lifting off of the ground and completing the step. These angles were then compared to the angles made by a human foot.

Name of Prototype	HB Junction Springs	BT Junction Springs	Photo
FLEXLite Limits mobility	short thick spring	no spring; hot glued together	
FLEX Medium amount of mobility	short thick spring	short medium thickness spring	
HyperFLEX More mobility	short medium thickness spring	long thick spring	

Table 1. Summary of Prototypes
Technical specifications of each of the three prototypes

RESULTS:

Table 2. Data from Motion Test of Prosthetics

Prototype	Position	Angles	Photo w/ Ref. Points	Skeleton
Human Foot	flat	a→b = 174.24° b→c = 170.107° c→d = 126.62°		
	Mid-lift	a→b = 176.59° b→c = 145.483° c→d = 107.173°		
	tiptoe	a→b = 161.81° b→c = 74.789° c→d = 85.821°		
FLEX-Lite	flat	a→b = 172.141° b→c = 158.468° c→d = 148.706°		
	Mid-lift	a→b = 169.179° b→c = 147.947° c→d = 112.447°		
	tiptoe	a→b = 138.363° b→c = 118.875° c→d = 90.17°		

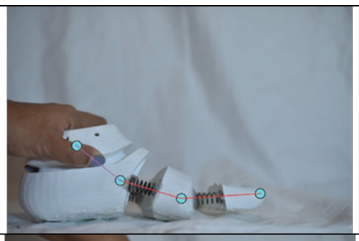
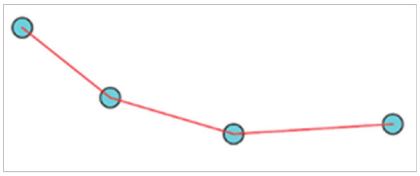
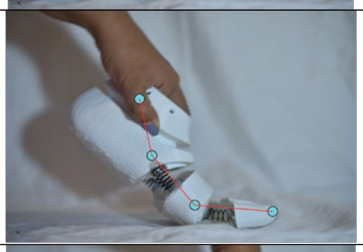
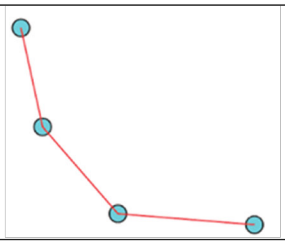
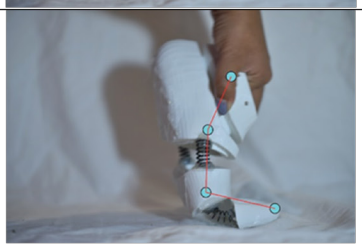
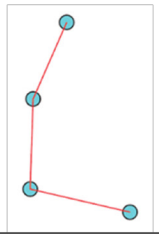
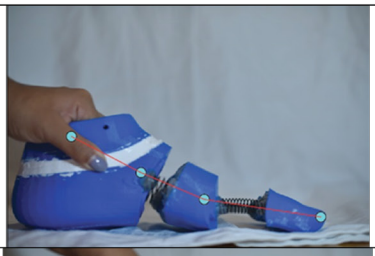
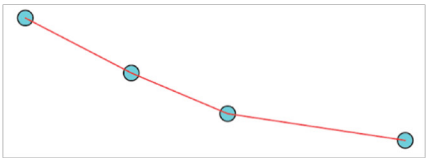
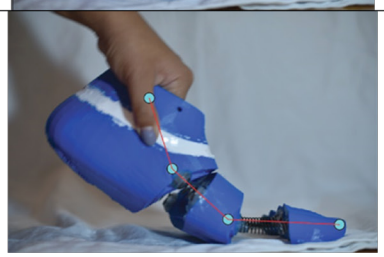
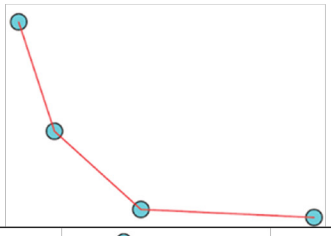
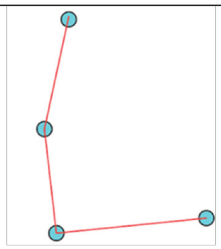
FLEX	flat	a→b = 183.568° b→c = 163.566° c→d = 141.464°		
	Mid-lift	a→b = 175.401° b→c = 130.96° c→d = 102.332°		
	tiptoe	a→b = 166.949° b→c = 88.143° c→d = 66.384°		
UltraFLEX	flat	a→b = 171.436° b→c = 157.109° c→d = 152.601°		
	Mid-lift	a→b = 177.328° b→c = 137.779° c→d = 107.779°		
	tiptoe	a→b = 185.744° b→c = 96.531° c→d = 77.865°		

Table 2. skeletons and angles allow for comparison between human foot and prototypes.

The FLEX prototype was the closest to the human foot, in both the angles between the reference points as well as the shapes of the skeletons themselves.

Conclusion/Discussion

The prototypes were a success. The FLEX very closely mimicked the motion of the human foot. The HyperFLEX was similar to the human foot but was not as accurate as the FLEX. The FLEXLite did not have much in common with the human foot. The flat and mid-lift skeletons were somewhat similar, but the tiptoe skeleton had a completely different shape. Also, there was a significant difference between the angles of the two feet.

The biggest limitation throughout this project was the fact that there were no human amputees to test the prosthetics. The prototypes were designed to act as similarly to the human foot as possible, but without a real amputee testing its stability, comfort, and other variables, the real-world feasibility cannot be accurately determined.

These specific prosthetics did not have a specific socket or way to connect to the amputee's leg; this was merely proof-of-concept testing. In the future, a socket should be designed, and the comfort and overall practicality should be tested.

One thing to keep in mind is that the goal of this project was to create a prosthetic foot that was similar to the human foot, and it was found that the FLEX prototype was the closest. However, this does not mean that the other two prototypes were failures; there may be certain advantages to the increased/decreased flexibility that simply cannot be extrapolated without further testing.

All in all, this project was a huge success. I was able to create a prosthetic that, in theory, functions as well as the human foot, but for a fraction of the price. At less than $10 a foot, this prosthetic is affordable for everyone.

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Engineering a New Carpal Tunnel Brace by Innovating Existing Designs

Claire Maurer

Abstract

Carpal tunnel syndrome is a common condition that causes numbness and tingling in the hand caused by compression of the median nerve, often during repetitive activities or sleep. Night splints or braces exist to keep the wrist straight, but these braces are often too constrictive to be worn during the day or during other activities. A redesigned brace that combined the concepts of two already designed braces was constricted online and 3D printed. The redesigned brace was tested by two users with mild carpal tunnel syndrome and was assessed on its comfortability and its effect on typing speed. The redesigned brace was slightly more comfortable than its store-bought counterpart and had less of an effect on typing speed, but still slowed typing speed by around 10 words per minute. While the comfortability and effect on typing speed were not as promising as hoped, slight adjustments in the material and the design could be taken to improve these limitations. Further steps could include an increased testing period and number of testers to fully test the redesigned orthotic in the future.

Carpal tunnel syndrome is the most common peripheral neuropathy. This condition, which most often causes numbness and tingling in the hand, is caused by compression of the median nerve as it passes through the carpal tunnel. Common associates with carpal tunnel syndrome include age, gender, weight, pregnancy, diabetes, and occupation (Barcenilla et al., 2011). Carpal tunnel presents itself with different degrees of numbness and other symptoms ranging from mild to severe. Treatments vary with these degrees and with other needs of the patient, but common treatments include overnight wrist splinting, steroid injections, surgery, and others (Padua et al., 2016). Night-splinting is often seen as a first line of defense for carpal tunnel syndrome and seeks to keep the wrist straight while users are asleep, as people tend to bend their wrists while asleep. These splints or braces are often constrictive, adjustable braces made of fabric and do not allow much movement. Braces can be worn during the day as well, but the constrictive nature of the brace means that it can impact daily activities. The effectivity of night splinting has not yet been proven using a placebo-controlled trial, and the benefits of it are generally seen as minimal (Atroshi, 2018). These braces or splints are not cost-prohibitive, but advancements could be made in their cost-effectiveness.

Methods

The goal of the model I created was to keep a user's wrist straight during sleep or during activities that would cause strain on the median nerve. Because people often bend their wrists during sleep or during these activities, my model's design intent was to keep the user's wrist straight. It does this by encompassing not only your wrist, but part of your hand and your arm in firm plastic that has been molded to your wrist specifically and held firm by adjustable Velcro bands. Additionally, you can change the measurements of the brace to fit the user's hand using 3D printing software if measurements of their hand are taken. If the user wishes, they can place a fingerless glove on top or underneath the brace to keep their wrist warm (which can be helpful in the alleviation of carpal tunnel syndrome) and to alleviate any scratching from the plastic brace. The most important features of my brace are its moldability to the user's wrist, its ability to be worn with a fingerless glove, and its sleek and nonobstructive design. Many wrist braces are often too unwieldly or uncomfortable to be worn during the daytime, and users may feel embarrassed wearing a brace to their job, especially if they have a job that requires many repetitive movements. Additionally, these wrist braces can often be expensive and may even be over-the-counter, which makes them difficult to acquire for those without consistent

access to a doctor or lacking funds to see a doctor regarding their carpal tunnel syndrome. Cheap wrist braces for around or under $10 are available online, but fit is not guaranteed with these and they would take time to ship if a user is in need of immediate relief. Furthermore, my model is sleeker and less obstructive than the typical wrist brace if one were to wear it to sleep in.

In order to create my model, I first downloaded a design off of the website Thingiverse: "3D Wrist brace/arm cast" by user "rider12." The design was a small wrist brace with a hexagonal pattern that wrapped around most of the hand and reached from mid-palm to the upper-arm, lower-wrist area. I also took inspiration from another user's design: "Wrist brace" created by user "piuLAB." This brace was similarly designed but featured a more complicated hexagonal pattern, covered less of the hand, did not reach as far down the arm, and had reinforced sections of material on it. I like the first design because of its longer and wider shape. The second design appealed to me because of the solid reinforcement material and its more complex patterning, which meant it could hold the wrist in place better. I combined the ideas that appealed to me in these two designs to create my model. I took the design I downloaded, created by "rider12," and added similar-looking reinforcement pieces from the second design to my new model using TinkerCAD. The overall design of the first brace had almost everything I desired in it besides those reinforcements and the ability to use Velcro with it. I additionally replaced the small holes in the brace with larger ones to hold Velcro straps in place.

I tested my model by having my testers compare a store-bought design and my design. My testers had mild carpal tunnel syndrome, which is typically the level of carpal tunnel syndrome a wrist brace is recommended with. The store-bought design I used to compare my model to was bought the local drug store and cost about $41. When wearing a wrist splint overnight or all the time improvement in function and sensation is only typically reported after wearing the brace for several weeks. Therefore, I did not have the testers see how much their numbness decreased after only a few days of use. I had the testers wear each brace for one night and give a number on a scale of 1 to 10 on how comfortable it was to sleep with. I additionally had them take a typing test while wearing the brace, not to judge improvement in typing, but to see how much each brace restricted their movement.

Results

Listed below are the results of the tests.

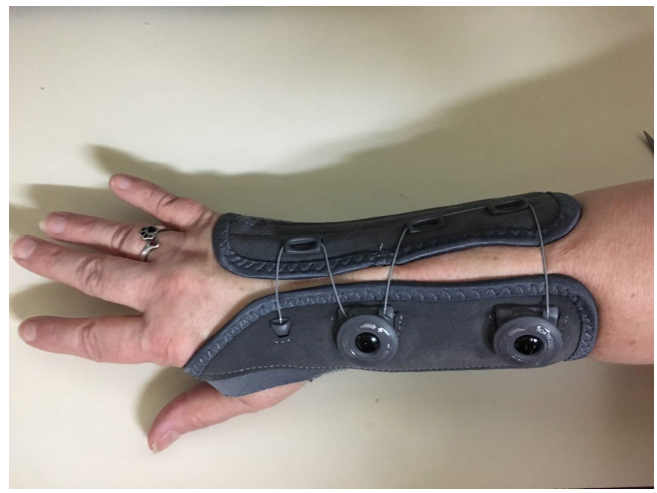

Figure 1. Store-bought brace being worn by Tester A. Note the fit of the brace.

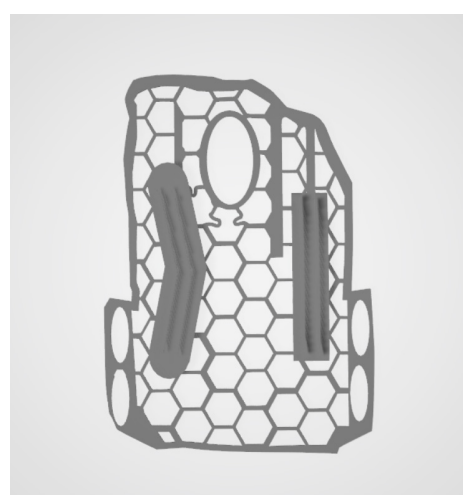

Figure 2. Online view of my redesigned prosthetic, featuring reinforcement panels and larger holes.

Figure 3. Front and Back view of the redesigned prosthetic being worn by Tester A.

Table 1. General information for the two testers of the different braces.

Tester	Gender	Age	Degree of Carpal Tunnel Syndrome
A	Female	50	Mild
B	Male	52	Mild

Table 2. Comfortability rating of different braces on a scale of 1 – 10.

Tester	No Brace	Store Bought Brace	Redesigned Model
A	10	4	6
B	10	7	8

I was able to successfully 3D print my design, although the thin material did cause some breakage.

Conclusion

While the quantitative results for the model were not as promising as I had hoped, I still consider the product a success. With a few tweaks on fit and sturdiness of the brace it could be a cheap and viable option for those suffering from mild to moderate carpal tunnel syndrome. The product was not a success because it met or exceeded the goals I set for it, but because it challenged me to find a new solution to a common problem and think outside the box in finding this solution. Furthermore, it helped me develop the new skill of using 3D printing software and designing and redesigning new and already existent models. My original plan for this project was in a completely different direction, and this project challenged me to think creatively and use what I already had to make a new project with an entirely different agenda.

The problems with the brace, which include sturdiness and comfortability, could be changed easily and tested again. My redesigned brace itself is more comfortable than the store-bought brace in terms of strain on the wrist and arm, but the 3D printing material of the redesigned brace can scratch and irritate the user's skin. One of the greatest limitations I had with this project was learning and using the correct 3D software. Oftentimes the software I was using was either too simple or too difficult for the edits I was making, and it made it difficult to achieve the design I wanted. Another limitation I faced was the material. Not only is it irritating on the skin, but the thin plastic can easily snap with pressure, which creates a problem if the user were to sleep on the brace. Printing the model thin also made it hard to separate from the substrate and caused breaks. Having the brace too lose or non-conforming to the skin can also cause not only irritation but can limit a user's movement. This could be solved by increasing the thickness of the material of the brace, or by changing the material the brace was made with. Overall, the limitations I faced were generally could be easily overcome with some innovation and a change of materials.

Steps I would take in the future are a change in materials, a greater consideration for the anatomy of the user, and a slight redesign. Since my product

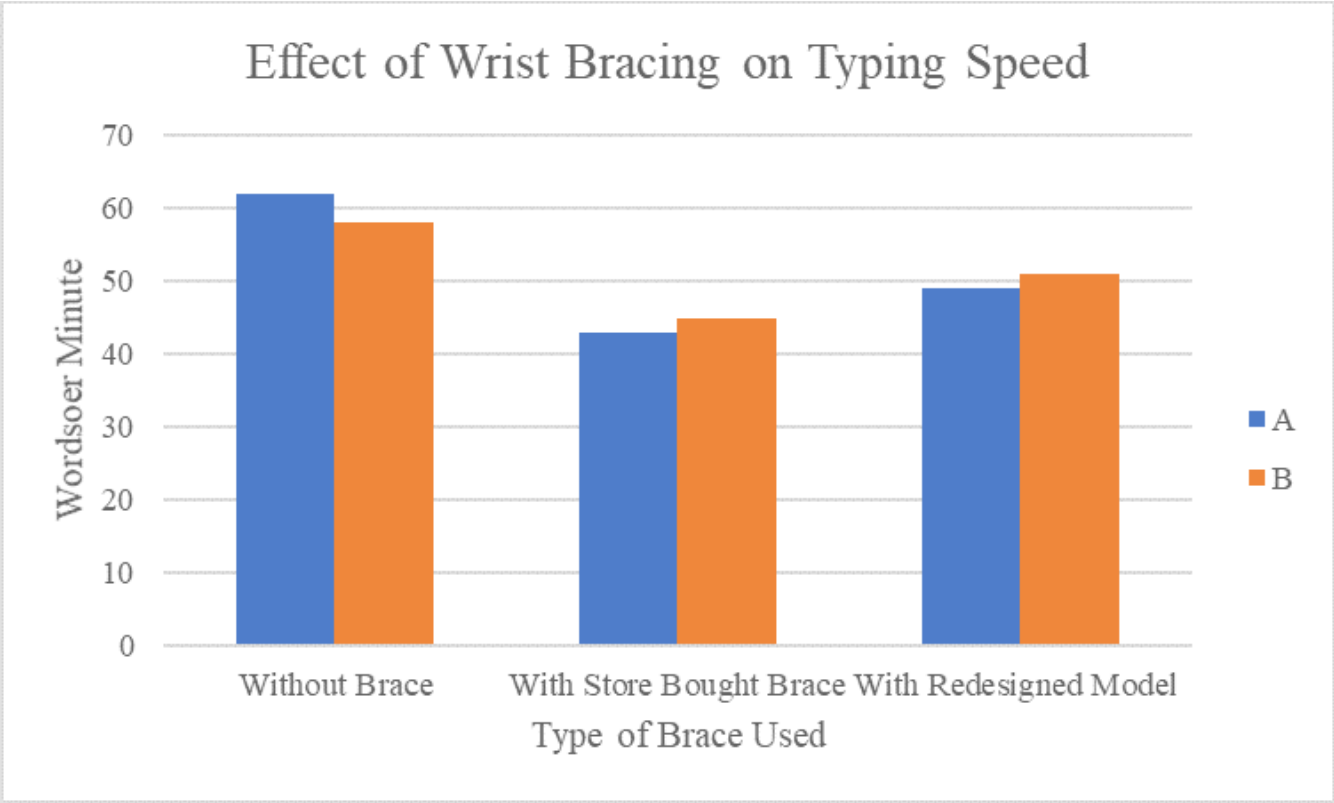

Figure 4. Type of Wrist Bracing vs. Typing Speed

did not perform as well as I had hoped, I will need to redesign to make it more effective at keeping a user's wrist straight and make it more comfortable. Additionally, I need to keep in mind that the median nerve needs to remain unrestricted to avoid the very numbness and tingling my product intends to keep at bay. Steps I could take in the redesign are making the material thicker and making the hexagonal pattern of the brace smaller and more complex so that it allows less wrist movement and is more all-encompassing, like a typical carpal tunnel brace. I do need to keep in mind that the brace needs to allow as much digital movement as possible, for those who rely on typing or other similar, repetitive movements for their job. The brace could also reach even further around the user's arm so that there's less room for the user's wrist to move. Another thing I would change is getting more testers and having more time to test. Because of my limited access to users with carpal tunnel syndrome, I was only able to get two users to test my product. Ideally in the future I would have as many users with carpal tunnel as possible test my product so I can more accurately assess its effectivity. Another way I could more accurately test effectivity would be having the testing take place over several weeks, not several days. Having the testing only take place over several days means I was unable to effectively assess any improvement in function.

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Enhancing the Shock-Absorption of Socket Prostheses in Trans-Femoral Amputees

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Biomedical Engineering

Abstract:
Falling can be a substantial risk for upper-leg amputees, especially during transfer or household-use where a full-leg prosthetic is either not accessible or not affordable. For this reason, a protective prosthetic that absorbs the shock on the residual limb during a fall or other traumatic impact can reduce the risk of further amputation or injury. To accomplish this, a shock-absorbing dome was appendaged to an existing socket model, with slits down each side of the socket to reduce weight and increase breathability of the dense, 3D-printed socket. The model was printed and reviewed by upper-leg amputees, asking them to evaluate their benefit from such a prosthetic and the values of cost, comfort, and function in buying a prosthetic. Respondents valued comfort over price, and found that they would use the prosthetic frequently enough to warrant its purchase and further development.

Keywords: Trans-femoral, amputation, shock-absorption

Every year, 2/3's of upper-leg amputees experience a serious fall. (Crenshaw et al, 2010). This can cost a community already heavily economically strained even more in emergency room visits, and result in further medical problems like concussion and wound re-opening. These injuries often occur during simple day-to-day tasks, like transfer to the toilet or shower and getting dressed (Hunter et al, 2016). Typically, upper-leg amputees use a simple nylon blend stump sheath, which does little to protect from impact or other trauma to the residual limb. There has been little exploration of a stiffer protective sheath, and especially not one that addresses potential fall trauma risks. Landing on an amputated stump during a fall can cause horrific pain and be dangerous for both the residual limb and the rest of the body, especially the head as the ability to brace yourself from a fall, trip, or slide is inhibited. Preventing these falls in the first place is of the utmost importance, but to be prepared and safer in the event of a fall is what can make the difference between a bandaid and an emergency room visit. This project seeks to investigate ways to reduce the impact forces exerted upon the residual limb during a fall and increase the shock-absorptive capabilities of a upper-leg stump sheath. Furthermore, this project seeks to make such prosthetics less expensive and more accessible to those who can't afford the thousands of dollars for a full prosthetic leg, for those with growing bodies and unconventionally sized ones.

Methods:

The prosthetic model I designed is a protective socket for trans-femoral (upper-leg) amputees, made to be worn around the house and used daily. Much like one covers and braces a broken bone with a hard cast, the socket cover is meant to protect the stump from daily trauma and abrasions that a simple liner couldn't prevent. The model can be made from any preferred 3d printing filament, in our case PLA, known for its durability and less brittle consistency. It is shaped much like a standard socket, with the exception of a dome-shaped appendage on the distal end and two slits on each side. I used an educational socket model off of thingiverse for my base, found at this link: https://www.thingiverse.com/thing:3233555

The dome-shaped end is designed to promote shock-absorption in event of fall or other trauma to the amputated limb. By increasing the distance between the impact force (say, the ground) and the stump by extending the length of the prosthetic with

a hollow dome at the end, the force imposed on the stump is lessened and damage is reduced. The same logic is applied to old cars, where I drew my inspiration – the longer front-end that houses the engine is designed to crumple at impact, lowering impact forces and saving lives in the event of motor accident or crash. From my research, very little has been done to apply this logic into protective prosthetics, many opting instead for a thin bottom lining that does very little to reduce force applied.

Besides the integrity of the lower-end of this design, it still maintains its comfort and use while in a wheelchair or lying down with thin side casing that maintains structure and protection while still being thin enough to wear daily and discreetly. The sides feature two rectangular slits running down each side of the thigh when worn, This is meant to allow more breathability through the prosthetic and inner lining and keep the limb from getting too warm, sweaty, or constrained throughout the day. The liner protects from any hard ridges that would be felt from the sides of each slit, making it still comfortable for the user while also providing a hold in which to pull on or pull off the prosthetic from the lined stump.

Perhaps the most important design feature of this prosthetic is its material – PLA filament. In contrast to more expensive competitors, this prosthetic can be printed by anyone with a 3d printer and enough filament, and custom-fitted. This can reduce cost to below $150 in estimates, compared to an impractically expensive model that can cost thousands of dollars and still provide very little functional use.

The 3d model is very easy to adjust in size and thickness, making it easy to adjust and print for growing children and bodies of all shapes and sizes. The filament can also be customized with various exciting colors, making what could be a scary new prosthetic on a child something much cooler and decorated with stickers and designs. All of this can be accomplished without impeding on functionality or drastically increasing the price to the user, making the prosthetic both affordable and adaptable. Because of limitations in model size and the lack of access to a Tensile machine, I tested the prosthetic with a survey of amputees and members of the disabled community. I created a survey with 8 questions on the site SurveyMonkey that asked about both their experience with fall trauma and how appealing the prosthetic was to them in terms of cost, design, and functionality. This allowed me to determine what they valued in a prosthetic and how often they might actually use the protective socket in order to improve future iterations of this model and create a more palatable design to be printed to scale. The survey was distributed to a men's disabled basketball team by my uncle, a trans-femoral amputee himself, and responses were collected over the course of three days and are shown below.

Results:

Prosthetic Model Design & Prototype

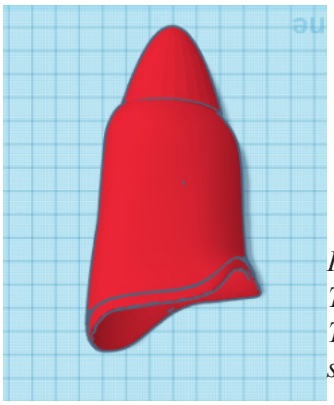


Figure 1: The first model made using TinkerCad without the side-slits from a top view.

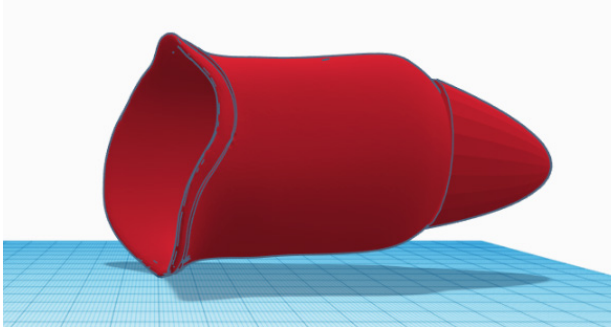


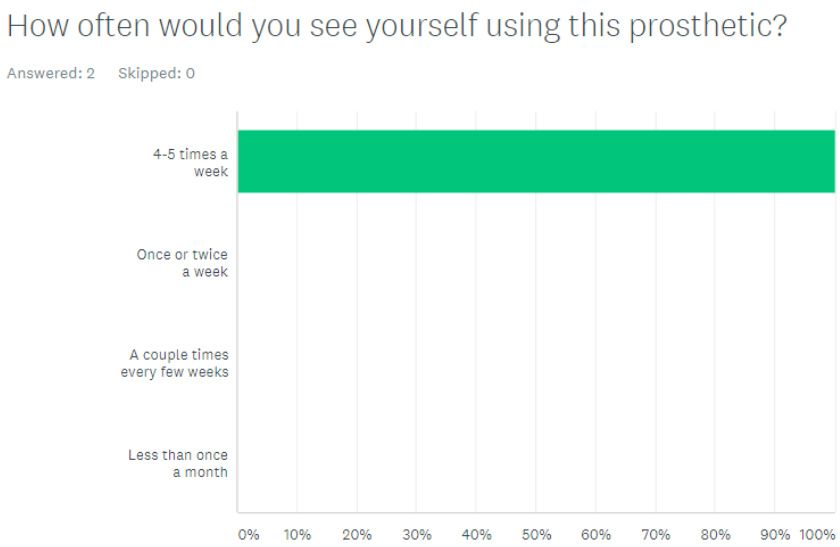
Figure 2:The first model made using the Tinkercad software, without the side-slits. From a side view.

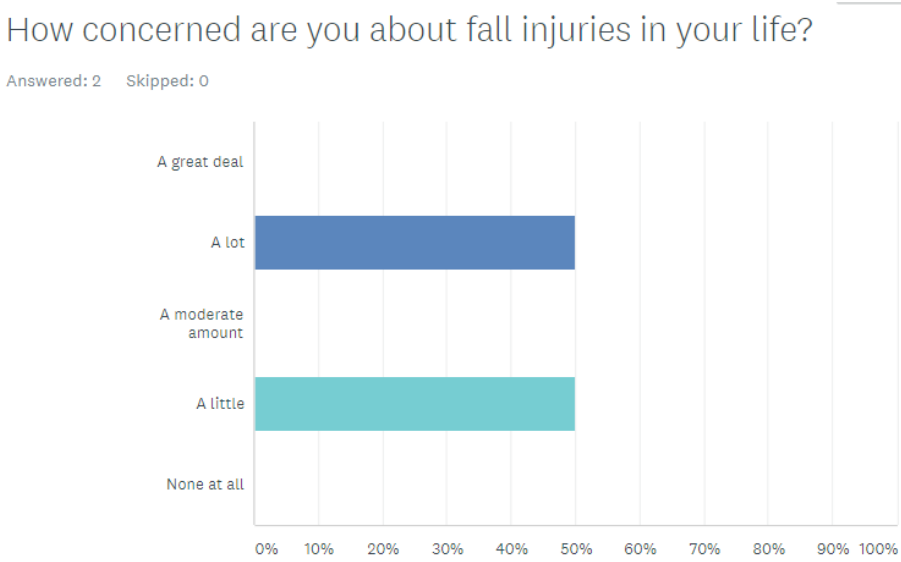
Figure 3: The side view of the first prototyped 3D-printed socket prosthetic, showing off the longitudinal slits on each side.

Figure 4: The top view of the first prototyped 3D-printed socket prosthetic.

Figure 5:
The 3D-printed prosthetic model with a socket liner for reference

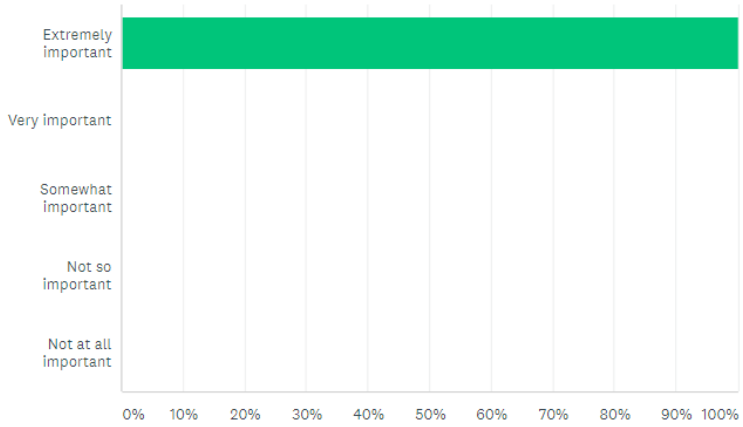
Survey Questions & Responses





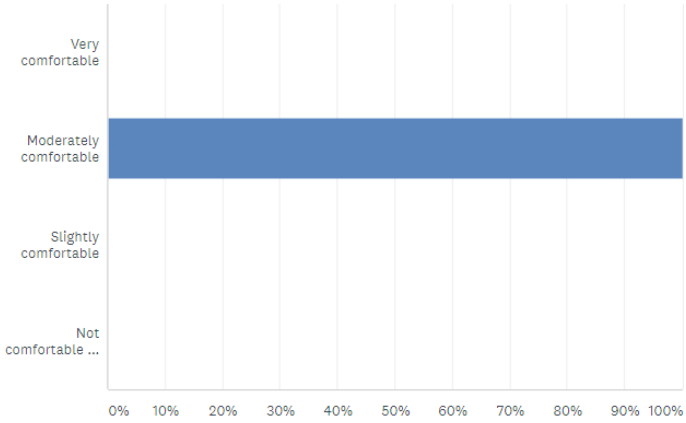
How important is comfort to you in a prosthetic?

Answered: 2 Skipped: 0



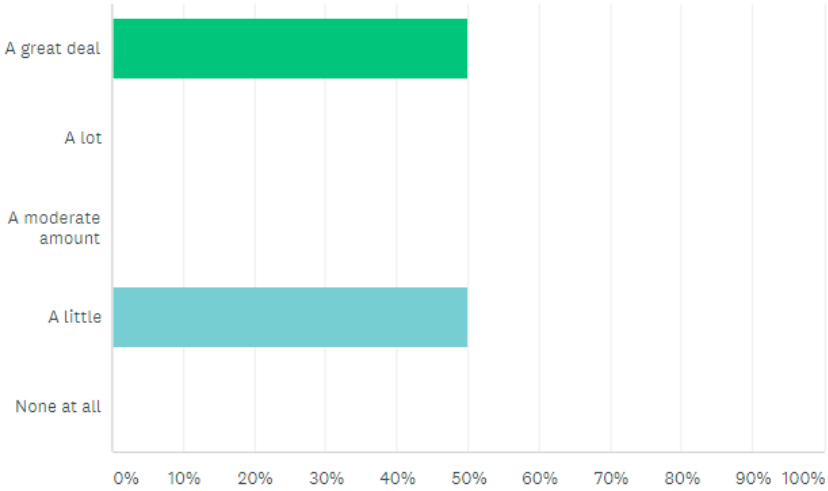
How comfortable would you anticipate this design to be? (With proper liner, of course)

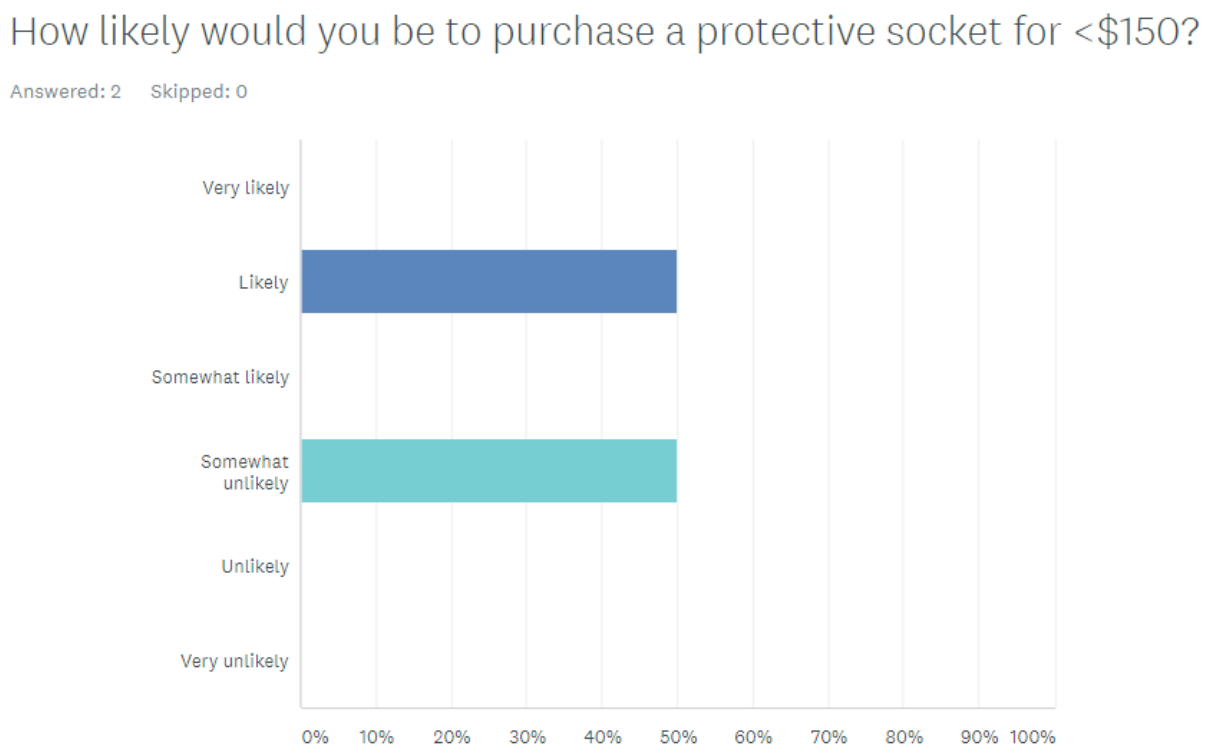
Answered: 2 Skipped: 0



How much influence does cost have on your purchase of a prosthetic?

Answered: 2 Skipped: 0





Question 7: (Comments/Criticism Box)
How will the socket be suspended or stay on? What will prevent socket fromrotating? How will I donn the socket? Can it easily be removed for tolieting - when I am at risk for falling during transferring? Can I use it for weight bearing? Is it tight? Will it cause blood constriction? Is it adjustable?

Discussion

As the first upper-leg prosthetic of its type designed for protective and shock-absorption purposes, the current model is serves its purpose and accomplished the mission of the project. Of course, it requires further development- after taking in the feedback from real amputees and their needs, the model can be modified to better meet their needs. After this stage, printing a scale model and testing it would take the project closer to realization. However, for the scope of this project, I'd consider it successful. Limitations were a factor in project depth, as finding a sufficient sample size for the survey (out of 12 amputees solicited, only 2 responded.) I also was limited because of the lack of access to a tensile machine to assess impact and shock absorption on the model, which left no option but to test it with qualitative data from amputee respondent's reviewing the prosthetic. The amputee feedback was very valuable and posed a lot of good questions for further investigation, which is something I wish had been conducted earlier to incorporate more of their suggestions and address their concerns. For example, one respondent expressed concerns about how the prosthetic will stay attached, wishing for it to be tight enough to stay on without rotating but loose enough to be easily removed. This could've been better incorporated into the design with input collected earlier. However, the most promising feedback comes from the first survey question, in which all participants responded that they would use this prosthetic, and frequently. There is no point in improving a design that there is no use or demand for, so carrying this demand in mind, it is possible to improve the prosthetic's design to make it more comfortable and accessible to the user according to the feedback.

Conclusion

This study gave insight into how amputees' gait compares to those without amputation. The scientists determined that amputees walked with a 29% slower velocity than those unaffected. They observed an asymmetrical gait pattern and that the amputees compensated for their slower steps with longer strides rather than more steps, perhaps indicative of the pain and exertion of producing another step. The amputees also walked with a larger stride width than their

unimpacted counterparts, thought to be a result of the hip flexation and rotation with each step. Hip stabilizing muscles had atrophied in 5 of the 13 subjects, resulting in a large swing of the trunk of the leg and a bending during the stance phase of their ambulation, as well as an asymmetrical, eccentric gait. The walking speed of each leg was unequal for all participants, most staying longer on their intact leg and having a slower response time and shorter duration on the amputated limb. The intact knee remained in the flexed stage during all times of ambulation, differing from non-impacted subjects in the study, perhaps to compensate for the weaker other side.

Powell, C., & Wheeldon, R. K. (1998). Mechanical efficiency during gait of adults with transtibial amputation: a pilot study comparing the SACH, Seattle, and Golden-Ankle prosthetic feet. Development, 35(2), 177-185.

This article distinguishes between the spring-efficiency (amount of energy retained and dissipated by the prosthetic in motion) of three leg prostheses: Golden-ankle, SACH, and Seattle. The study was intended to determine the difference between prosthetics with a stiff ankle and rigid foot and those with a flexible one, as in previous studies they'd been analyzed in the same way. They found that the soft, cushioned heel of the SACH actually decreased the time required to achieve foot-flat (each full step), and inhibited the user by causing eccentric movements to compensate for the lack of a plantar flex in the prothesis. This suggests that the compression of the heel cushion serves no beneficial purpose, in it doesn't store much energy during the stance phase of ambulation, and rather detracts from the amputee's ability to walk. The cosmetic viscoelastic material around the Seattle prosthetic also inhibits ambulation, making the energy potential similar to the SACH. However, the Golden-ankle prosthesis had higher energy recovery than either in its forefoot especially, suggesting that the compression heel design isn't very useful.

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Orthotic Sole Implant to Increase Stature

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Abstract

The average adult female height in the United States is 63.7 inches and the average adult male height 69.3 inches. Girls stop growing between the ages of 14 and 15, and boys stop growing between the ages of 17 and 20. The importance for height can come for everyday activities such as reaching for something at a store or workplace. With the age of new technology there are new ways to achieve a greater height, such as through orthotics. With this technology, the goal was to create a 3D printed sole orthotic, that could fit under the fabric sole of a shoe, which was also contained the ability to increase a person's height, be comfortable, have a good amount of strength, and be easy to use. To determine if the orthotic met these requirements, we applied all of them to five subjects. The orthotic was able to increase the height of our subjects by between 1 and 1.5 inches compared to their original height, comfort levels were between 4 and 9 (in a scale of 1 to 10) , the strength of the orthotic was tested through each of the subject's weight, and how easy the orthotic was to use was between 4 and 8, with the use of the same scale as the comfortability.

One of the most popular inventions that also intertwined with the world of fashion are high heels. However, because they are also a piece of fashion they are more obvious to the eye how the height is reached, and high heels elevate the heel of a person's feet, which makes it uncomfortable to wear for long periods of time and bruising can also occur in those areas. Currently there is also the product of shoes lifts, which are meant to place at the heel of the shoe and a person's own heel is supposed to be placed in top of that. However, because all the pressure is being place toward the heel there is also more strain in that area, which can also cause uncomfortableness and eventual pain. Shoe lifts even have the ability to affect posture in a negative way. The purpose of the orthotic was to make a comfortable and subtle way for people to increase their height.

Methods

The function of the sole implant orthotic is to allow the person who has the sole inside of their shoe to become taller, the goal was to make it create more height, be comfortable, to be strong, and for people to use it easily. Our orthotic works by taking out the original cloth sole in the shoe and placing both parts of out orthotic into the shoe, then the cloth sole taken out earlier fits back on top of our orthotic. The important features that allow for height is a large rectangular block on the back side of our orthotic that goes across in a straight line. The block in the middle allows for the person that is wearing the sole with the orthotic to feel like that the only change in their shoe is that they fell a little taller and no pressure is put into directly one area of the foot, so that there is a maximum amount of comfort. This orthotic is different than anything else already created because it is very discrete to the point that the orthotic cannot be seen even when looking directly into the shoe, and that the reason for the like focuses to be across the foot rather than just on the heel.

The parts that we specifically edited on the model to make it different from any online designs, was that we had the sole outline piece from Thingiverse, that wee fitted to the dimensions of the shoe, but the rectangle block was made in TinkerCAD along with the slope on one side of the rectangle so that it wouldn't be to hard on the feet, and the soft flaky parts on the top and bottom of the rectangle was also created in TinkerCAD so that the sole had a softer landing every time someone would walk in the shoes. Testing included 5 subjects, who would all measure their height in the shoes without wearing the orthotics before measuring their height again with the orthotics, we also sought to see how strong our orthotic was by having all the subject weigh

themselves and walking with the orthotics, then we would take out the orthotic see how much damage came to it. To see if the orthotic was comfortable we asked the subjects to rate them between 1 to 10, in which 1 would be that it was so uncomfortable that it was unbearable, and 10 would that it was very comfortable and didn't feel as different as just wearing the shoe without the orthotic. We did a similar scale when asking people if it was easy to use, we asked each subject to put the orthotics complete in the shoe and we asked them to take the orthotics completely out of the shoe. This time our scale of 1 to 10 was that 1 represented that it wasn't easy at all and 10 being that it was very easy to use the orthotic.

Figure 1. Bottom view of final orthotics

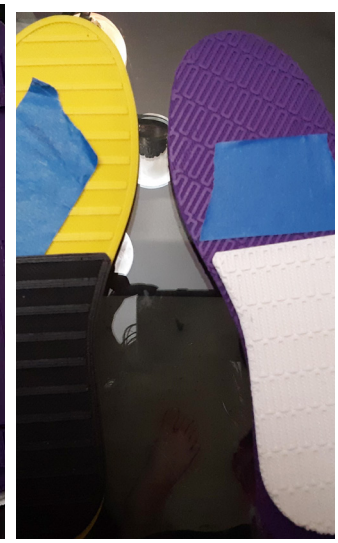

Figure 2. Top view of final orthotics

Results

SUBJECTS	HEIGHT W/O ORTHOTIC (IN)	HEIGHT W/ ORTHOTIC (IN)	DURABILITY (LBS.)	COMFORT (1-10)	EASE OF USE (1-10)
SUBJECT #1	57	58.5	98.2	7	4
SUBJECT #2	64.5	65.5	148.4	4	7
SUBJECT #3	66.5	67.5	223	7	8
SUBJECT #4	58.5	59.5	120	9	5
SUBJECT #5	65	66.5	195	6	6

Table 1. The original height for each subject (the height without the orthotic) and the heights of each of the subjects that were using the orthotic (the height with the orthotic) in inches, the weight of each subject in pounds, the comfort rating for each subject between 1 to 10, and how east the orthotic was to use in a scale of 1 to 10.

	SUBJECT #1	SUBJECT #2	SUBJECT #3	SUBJECT #4	SUBJECT #5	AVERAGE
COMFORT (1-10)	7	4	7	9	6	6.6
EASE OF USE (1-10)	4	7	8	5	6	6

Table 2. The comfort and ease of use rate for each subject and the overall average rate between 1 and 10 for the level of comfort and how easily it is to use the orthotic.

Conclusion/Discussion

Our results were a success in that the orthotic increases the height of people up between 1 to 1.5 inches and was able to stay intact through all of the weights of the subjects, however in terms of comfort, the orthotic had an average rating on 6.6 (between a scale of 1 to 10) and the ease of use had an average rating of 6 (between a scale of 1 to 10). One of the limitations and problems was to make our original design more complex (the sole bottom with only the rectangular block on it), but our additions to make it more complex, were troublesome due to the 3D printer. One if our initial final ideas was to add Velcro for a better fit on the shoe but the holes fused shut, and some of the flaky parts of the orthotic (at the top and bottom) were not in place and did not fit correctly causing them to fall apart we had to reprint to try to get stronger one. And sometimes depending if we pushed to hard or pulled to hard when taking the orthotic out the parts would break. On a few of our prints the rectangular block was thicker and wider on one end but was not on the other end. In the future we would try to layer the top and bottom more so that it is not easily broken apart before testing or to the touch, we would also try to make a way to add different blocks for different variations of increased height, we want to be able to change the sizes of the orthotic sole that it could fit in any shoe, and we would want to add a cushion to our orthotic so that it it would feel more comfortable to walk in.

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Pinky Orthotic to Allows Minimally Impaired Typing and Improved Airflow

Aayushi Nalinaranjan

Abstract

A broken finger can because by many things and may stay stiff and cause pain if left untreated. There are a few options for splints if you have a broken pinky, more specifically. Some problems my orthotics tries to solve are a lack of airflow that would cause unpleasant smells after prolonged use, bulkiness, customizable fit, and to a limitation of range of motion to unrestricted fingers. A number of these problems are present in current options for pinky braces. I tested the range of motion of other fingers in my brace by seeing how many words per minute can be typed with and without the brace. While the brace did hinder typing ability, it was not significant. In the future I would something to make it more comfortable to wear and permanently secure the Velcro strips.

Without treatment, a broken finger may stay stiff and cause pain (AAOS). Your finer can be fractured by occurrences that are not uncommon such as accidently slamming your fingers in a door, when you put out your hand to break a fall, or when your finger jams while trying to catch a ball (AAOS). There are a few options for splints if you have a broken pinky, more specifically. You may get a piece of plastic molded to the shape and size to your hand (figure 1). This restricts your fingers the way the doctors want but it is often poorly ventilated and is bulky. Another option is more similar to a glove with part cut off. It has mesh material and to metal strips embedded to be able to position the fingers to the appropriate position (figure 2). This one allows better breathability than the previous and adjustable finger positions. This maybe be changed however so it maybe be misshapen by accident and costs anywhere from 25-75 dollars off Amazon. Some problems my orthotics tries to solve are a lack of airflow that would cause unpleasant smells after prolonged use, bulkiness, customizable fit, and to a limitation of range of motion to unrestricted fingers.

Figure 1 – This shows the first options for splint that was discussed in the background

Figure 2 – This shows the second options for splints in the background

Methods

The function of this product is to allow better airflow then a traditional model while providing enough support to restrict the movement of the pinky enough to heal and not overly restrict the hand so that other movements such as typing are easier. The important features are that it can be molded in hot water and it can be printed smaller to fit children's and adult's anatomy. It also has lots of gaps in it for easier molding and more airflow. Right now, custom pinky braces are either far less breathable or more restrictive than they need to.

The design that was on the web for pinky braces had a set angle, so they are not able to be customized easily so if a doctor suggests a different angle for someone's fingers or providing extra support by binding two fingers together, it would not be possible. There was another design that was intended as a wrist brace so it had a hole in the design for a thumb to go through but I filled in the holes with hexagons, so the user would not put their finger through there and am re- molding it to be used as a pinky brace.

I tested my prosthetic my putting it different subjects and going to typingtest.com and did the Aesop fables for one minute. I recorded how many words I could type in one minute using the adjusted speed. I then used no prosthetic and typed the Aesop fables for one minute and recorded the adjusted words per minute. I repeated these two tests with different people three times each and compared the words per minute it could type for my prosthetic and no prosthetic to see how much a prosthetic would hinder typing ability. When putting on the edited prosthetic the pinky and ring finger were put together. When assembling the orthotic I printed it and then molded it by putting it into hot water and wrapping it around my hand the way it is supposed to be positioned. I then added 2 pieces of Velcro to the prosthetic.

Results

I was successfully able to 3d print my design, secure it with Velcro and molded it.

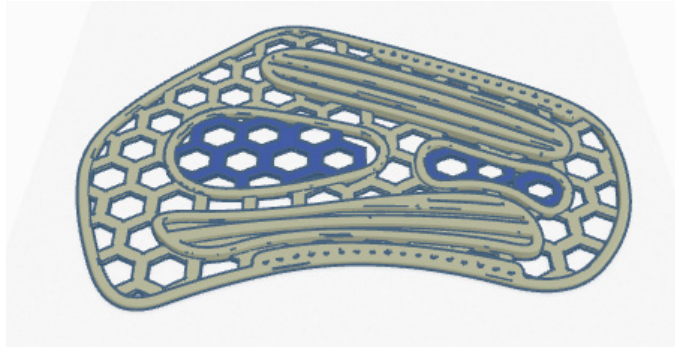

Figure 3 – This shows what the brace looks like in the 3d printing software MakerBot. The blue part is what I modified it in the Tinkercad program. The base design was from thingiverse.com. It was supposed to be used as a wrist splint which is why there is a hole for your thumb. I covered that to provide more support in my implementation of this orthotic but still allows aeration.

Figure 4 – This shows what the brace looks like when it has been molded and has the Velcro holding it in place.

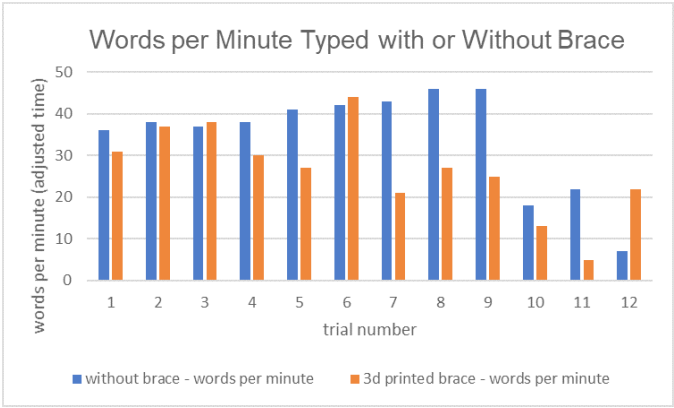

Figure 5 – This shows all trials of the experiment run where people typed with and without the brace. The difference in using the brace and not using the brace may also be because people are used to typing without any thing on their hands, especially restricting two of their fingers mobility. For example, the first three trials was done by someone who in both conditions typed in the

non traditional way which didn't use the left pinky and ring finger anyway. The 7th, 8th, and 9th trial were done by someone who types the traditional way with pointer fingers on the F and J keys. This kind of typist would use their left and ring fingers as much as any other finger, which was observed during testing which would cause a greater difference. This is one of the reasons why in the future I would test with other orthotics on the market to see how mine compares to others.

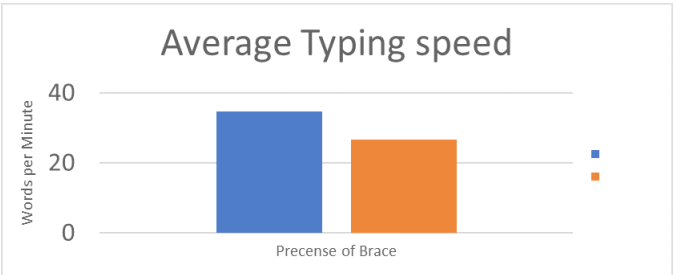

Figure 6 – This is the average speed that all subjects type with and without the brace. The difference between these is 8 words per minute which is as large as the range of the speed for most subjects when typing without the brace. This shows that the number of words per minute typed changes about as much as it does between having the brace on or off and just different trials of typing without the brace.

Words per minute typed	
Without brace	With 3d printed brace
36	31
38	37
37	38
38	30
41	27
42	44
43	21
46	27
46	25
18	13
22	5
7	22

Figure 7 – Every three of the trials are from the same person so we can see the range of words per minute for each person. The average difference between the trials for the same condition was 8.

Conclusion/ discussion

For the most part it was a success. I got data that showed that my orthotic did not significantly negatively impact typing speed which is how I was measuring the range of motion of the fingers that did not need to be restrained. Some problems I ran into were the base from and the orthotic fusing together while 3D printing. This either caused me to re-print or to leave some of the base on the orthotic because otherwise it would break. I also could not sculpt the orthotic to fit everyone exactly since I only had one functioning orthotic. If I could have a big budget I would by the two different types of orthotics that were discussed in the intro and see how the words per minute and aeration for all of them. I would also add some softer material like foam, mesh, or cloth were the plastic touches the skin to make it more comfortable.

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Silicone Grip Pads and Joints of 3-D Printed Prosthetic Hand

Sarah Berg

Abstract

Throughout the years, prosthetic devices have been explored and developed to create mechanisms that most closely mimic a real human hand. Great progress has been made through methods such as 3-d printing for affordable prosthetics. A multitude of various experiments have been done to create artificial muscles that would give a prosthetic hand ideal mobility. Despite these advances, there's still room for improvement. Creating a prosthetic that mimics all the qualities of a human hand is the ultimate goal. In this experiment, the mobility of the hand and the grip of the hand are addressed. All the parts of the hand were 3-d printed. Nylon casting lines were thread through the fingers to bend them. Alja-Safe Alginate was used to create molds of the finger joints and the links connecting the gauntlet (wrist) and the body of the hand. Mold Star pourable silicone rubber was then poured into these molds to create flexible joints. The silicone was also painted onto each section of the fingers to create grip pads. The angular displacement and the maximum weight the hand could pick up were measured. The greatest change in displacement comparing the two models was 90°. The original model wasn't able to pick of the cup while the modified model was able to pick up a max added weight of 50 g. Overall, the silicone greatly improved the mobility of the hand and made it able to better grip objects.

Prosthetic devices have been modernized and developed throughout the years, opening a world of vast possibilities. The range of different prosthetics has made it possible for amputees to perform daily tasks with ease. Many advancements have been made through methods such as 3-d printing, which makes prosthetic devices accessible and affordable.

Different materials have been explored to make an artificial muscle that would give maximum mobility to hand prosthetics in order to best mimic a human hand. Electroactive polymer actuators have been experimented with quite a bit and other polymers such as, ionic polymer metal composites (Biddiss, E., & Chau, T. (2006). Electroactive polymeric sensors in hand prostheses: Bending response of an ionic polymer metal composite. Medical engineering & physics, 28(6), 568-578). These have been proven successful as both artificial muscles and sensors. However, these are very complicated and not very easily accessible or affordable to the general public.

Another issue with prosthetics has to do with the ease of use and control the patient has over it. Researchers have developed a user-generic musculoskeletal model. Neuromuscular signals are tracked and with their new design, sensors pick up brain signals sending data to a computer which then conveys data to the prosthetic enabling it to move (North Carolina State University. (2018, May 22). New tech may make prosthetic hands easier for patients to use. ScienceDaily. Retrieved October 15, 2018 from www.sciencedaily.com/releases/2018/05/180522132703.htm). These improvements, though innovative and successful, are complex and expensive.

There is a huge need for prosthetics not only in the U.S. but in developing countries where they do not have access to these materials. These innovations are not reasonably affordable for the majority of the public but there is a high demand. With 3-d printing, this provides a solution to the issue of accessibility and affordability. 3-d printers are fast, allowing for mass production of prosthetics. Filament for these printers are also inexpensive making the resulting prosthetic affordable for a much wider range of people. The filament is also durable, making it long lasting and easy to ship across the U.S. and to other countries, giving access to those in need in developing countries. Creating a prosthetic that is easily accessible, affordable, comfortable to wear, and mimics all of the sensations and movements of a human hand, is the ultimate goal.

For this experiment, I attempted to increase the mobility of a 3-d printed prosthetic hand with easily accessible, yet effective, materials. I also addressed

the issue of gripping ability of hand prosthetics, attempting to strengthen it in order to make it easier to use for the patient.

Methods

The prosthetic hand was printed using a MakerBot Replicator plus with some of the smaller parts printed on a MakerBot Replicator. The material used to print was PLA filament. The fingers were sectioned off into 3 parts with inserts for joints, printed separately, in between each section. This allows the fingers to have multiple points where they are able to bend and mimic a real finger. There is a U-shaped attachment, called a gauntlet, at the bottom of the hand where the arm goes to bend and activate the hand. There are holes throughout the fingers and body of the hand for cables to run through. Thin nylon casting line was used to thread through the fingers. At the top of each finger, there are two holes for the nylon to loop through to tie it at the bottom in order to keep it in place when the cables are pulled. Pulling the finger from the top will also allow the hand to have maximum capacity for movement. There are small tensioners that stick out of the gauntlet with holes at the top in order to string the cables through, acting as an anchor for the cables. They are screwed at the bottom in order to keep them in place while also allowing the tensioner to adjust according to length of the cable. There are slits in the gauntlet for a Velcro strap to slide through and strap onto the person's arm for use. There's also a place in the middle of the palm for another Velcro strap loop to adhere onto for the top part of the amputated arm to slide in and help curl down and move the fingers. When the arm bends downward, the cables are pulled tight, pulling the fingers down in a curling motion.

Modifications to my prosthetic were made by using Mold Star pourable silicone rubber. To mix the solution, there was a part A and B that was mixed with a 1:1 ratio of each part. With this solution, I painted small squares on each section of the finger in order to fit the available area. I did this to avoid any complications with the silicone interfering with the cables running through the fingers or with the joints, possibly affecting the mobility of the prosthetic. The silicone is painted on the necessary area where the fingers are gripping objects in order to be most effective. These grip pads would have friction against any object they come in contact with, making it easier for hand to pick it up. The original joints were very stiff and broke easily, so Alja-Safe Alginate was used to make molds of the joints and the links between the gauntlet and the hand of the body. The silicone was then poured into these molds to set.

In order to test my prosthetic, I used a small paper cup with a diameter of 3 inches, and a set of small plastic weights to see what the max amount of weight the modified prosthetic would be able to hold. I started by testing if the prosthetic could hold just the cup which weighs about 8.5 grams. Then, weights increasing by 10 g increments were put into the cup, and it was tested to see if the hand could hold it. Previous studies have used silicone as a covering for prosthetics before, however, the silicone was used on a glove of some sort or put over the entire hand. There have also been prosthetics solely made of silicone but regarding 3-d printed prosthetics, there has yet to be experiments done with both silicone padding and silicone joints. With this specific design, it has been made with flexible filament, but not with silicone. By making small grip pads instead of a full silicone exterior, it allows the prosthetic to have full mobility, avoiding the possibility of the silicone interfering with the joints. Silicone joints will also allow the prosthetic to reach its maximum mobility and also serves as a durable joint that will last much longer that the 3-d printed PLA filament joints, which were very stiff and wore out quickly.

Results

Angular Displacement – Original Model	
Finger	**Displacement**
Thumb	15°
Pointer	9°
Middle	9°
Ring	11°
Pinky	11°

Angular Displacement – Modified Model	
Finger	**Displacement**
Thumb	105°
Pointer	75°
Middle	76°
Ring	81°
Pinky	59°

Modified Model – Grip strength	
Added weight in cup (g)	**Is the hand able to hold it?**
10 g	Yes
20 g	Yes
30 g	Yes
40 g	Yes
50 g	Yes
60 g	No

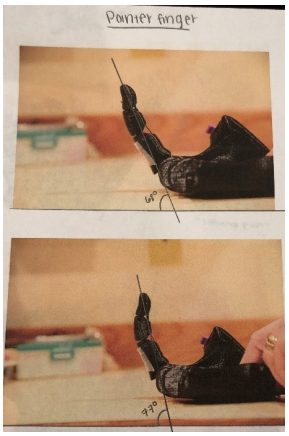

Fig. 1a. Angular displacement of original model, using the bottom of the picture as the reference.

Fig. 1b. Angular displacement of modified model, again using the bottom of the picture as a reference

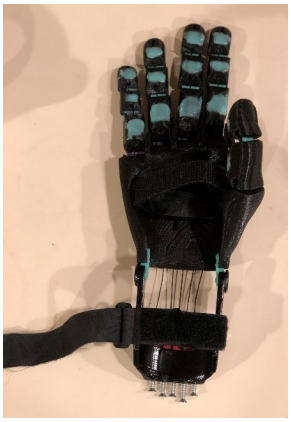

Fig. 2a. Final model fully assembled with both Velcro straps in place.

Fig. 2b. Final model assembled without bottom Velcro strap in order to show cable system running through the hand.

Conclusion

The silicone joints proved to significantly increase the mobility of the fingers. The maximum angular displacement of the finger on the original model was 15°. The maximum angular displacement of the finger on the modified model was 105°. These were both angular displacements of the thumb. The modified thumb was slightly different than the other fingers in that the base joint that was connected directly to the hand was made of silicone, while the others were not to give the fingers more stability. This gave the thumb much more mobility than it had before, but it was not very stable and during testing, the original 3-d printed joint was used. The angular displacement increased by a max of 90° between the original and modified model, this is also based on the thumb. The silicone pads also helped with gripping the paper cup. The original model wasn't able to even grasp the empty cup, this was also most likely due to the stiffness of the original 3-d printed joints and the lack of friction between the cup and the PLA filament material. The silicone grips allowed for the modified model to hold up to 50 g of added weight in the paper cup. This in combination with the silicone joints made it possible for the hand to grasp the cup. The design of the prosthetic puts the thumb in a slightly awkward position. While testing, I noticed that the very tip of the thumb came in contact with the cup unlike the tips of any of the other fingers. As an addition for the future, I would put silicone on the very tip of the thumb, which would allow it to aid in the process of gripping an object. Although the silicone greatly increased the mobility of the prosthetic, because it is so flexible, the fingers were not very stable and were hard to control. In the future I would use a material that was still very flexible, but had more rigidity to it so the fingers could return to their resting position easily after the cables are let loose. There have been past experiments with this particular design where it was printed using flexible filament. For this experiment, flexible filament wasn't available to use. For the future, I would definitely use that instead; it would increase the mobility of the fingers and would last longer as the joints wouldn't

wear out nearly as fast. This may also eliminate the need for silicone as the flexible filament may have enough friction against objects for the hand to pick them up. The flexible filament is also more rigid than silicone so it would make controlling the prosthetic much easier. Overall, the silicone joints increased the mobility of the prosthetic and the grip pads made it easier to hold a cup.

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Testing the Model of a Finger Prosthetic

Andrea Lee

Abstract

Finger prosthetics are used as a result of trauma, disease, congenital, or a tumor. The purpose of this study is to create a finger prosthetic that is affordable, easily maintained, and does not obstruct the purpose of a finger prosthetic. It is predicted that the prosthetic created would help fulfill these three main pieces of criteria. The final model is a finger prosthetic that can be slipped onto the finger and be used as a replacement for an amputated finger. A key feature of this model is that is able to be easily removed and cleaned to prevent infections or dirtiness to appear on the prosthetic. The results showed that all the criteria were fulfilled, with a slight error in measuring whether or not the model could be used as a fully functional finger prosthetic. Further developments or advancements can be made by improving the size of the finger prosthetic, implementing technology to help the movement of the prosthetic, and finally the design or look of the prosthetic.

Finger prosthetics are used by people for a variety of reasons. It could be because of trauma, disease, congenital, or a result from a tumor. The finger or body part is removed to prevent the rest of the body from being affected. The problem being solved is to help make finger prosthetics easier to maintain and be longer lasting, while having a sense of convenience. Currently, when finger amputations occur, a finger prosthetic is made to connect with remaining tissue left where the finger once remained. However, there is a high concern of the prosthetic being infected, so high maintenance is necessary to ensure that the prosthetic does not harm the body further (Light, C. M., & Chappell, P. H. (2000)).

The costs in maintaining and doing the procedure for this finger prosthetic are expensive, due to materials needed and the cost of performing the surgery of removing the finger and replacing it with the new finger prosthetic. Currently, finger prosthetics are also designed to fit the appearance of an actual human finger, improving aesthetics and creating an illusion or appearance of a normal hand.

The purpose of this study is to create a finger prosthetic that is affordable, easily maintained, and does not obstruct the purpose of a finger prosthetic. We predicted that the prosthetic created would help fulfill these three main pieces of criteria.

Methods

The final project is a finger prosthetic that can be slipped onto the finger and be used as a replacement for an amputated finger. It can be slipped on and off without difficulty with a sleeve that can be wrapped around the remains of the finger. There are two main parts to this model of the finger prosthetic. The first part is the finger sleeve. This model works especially well for people whose fingers are not fully removed, but partially. The second part is the finger itself. It is designed to look like a finger, keeping its shape and appearance. A piece of wire is used to ensure that the two parts don't separate, ensuring that when testing it, the model should not break apart and separate.

While the model is simple, it should fit the main three criteria being looked for this model – affordable, easily maintained, and fits the purpose of a finger prosthetic. The model is made with a 3D printer, using a material made of plastic. The wire is thin and made of metal, easily bendable to fit the needs and design of the model.

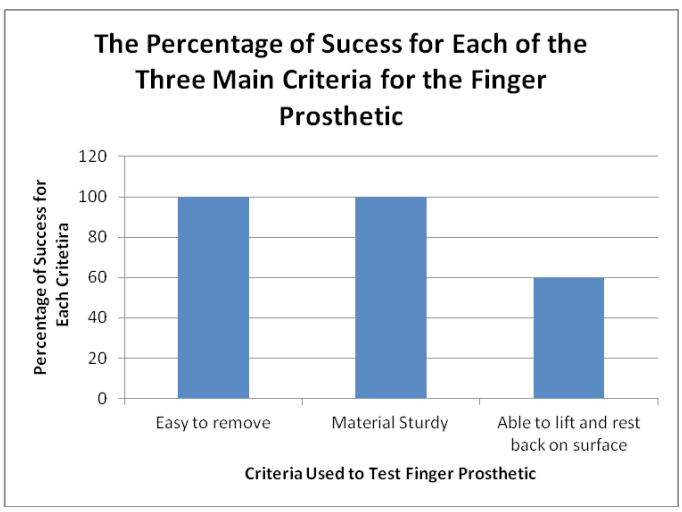
A unique feature of this model is that it allows the finger prosthetic to easily be removed off the finger, allowing the user to be able to easily clean the model to prevent infections from happening.

The prosthetic was tested by using the three criteria. The user was asked if the prosthetic was easily removed, whether the material seemed sturdy enough

for use considering its affordable material, and if it fit the purpose of a finger prosthetic. The user was asked to use the model on their hand and test to see if the finger was able to perform a task of lifting the finger prosthetic and resting it back onto a flat surface.

Results

Test #	Was the prosthetic easy to remove?	Was the material sturdy enough, considering its cheap material?	Was the finger prosthetic able to lift and rest back onto a flat surface?
1	Y	Y	Y
2	Y	Y	Y
3	Y	Y	N
4	Y	Y	Y
5	Y	Y	N
6	Y	Y	Y
7	Y	Y	Y
8	Y	Y	N
9	Y	Y	Y
10	Y	Y	N



Percentages were calculated by counting all the yes's (Y) as 1 and the no's (N) as 0. They were calculated out of 10, and then changed into percentages. Due to time constraints, only 10 tests were able to be completed.





The 3D model was able to be successfully printed.

Conclusion / Discussion

The model was able to be proven as a finger prosthetic that fit the criteria. It was affordable, made with plastic and was able to be used for long term use. The model was able to be maintained, it was easy to clean and could be removed easily. Finally, the model was able to function like a finger prosthetic. Due to time restraints however, the finger prosthetic was not able to be bent or moved to act more like the dominant fingers. Since this finger prosthetic was designed to fit a person with normal hands to be able to be tested, there were limitations in applying this model to actual finger prosthetic needing hands. A future improvement that needs to be made is to ensure that when the person desires a finger prosthetic with this design, the sleeve of the finger prosthetic must match the person's finger width and length of amputated finger. Another improvement is to implement a piece of technology, such as the Arduino, to allow the finger prosthetic to bend and move like a finger. A final improvement is to design the finger prosthetic so that it fits with the look and aesthetic of an actual finger, such as the finger prosthetics being used now.

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The Effect of a Forearm Cuff on Handwriting Speed and Agility in Patients with Arthritis and Parkinson's

Nicole Repede

Abstract

Patients diagnosed with Parkinson's disorder have proven to show difficulties with arm and hand stability when performing tasks. Arthritis and Parkinson's both reduce stable movement in the hands and arms. Difficulties include joint pain, deficiencies in stabilization and loss of balance. Several studies and experiments have been conducted as an attempt to accommodate these disorders; many have shown through experimental data that constraints and braces have been successful in providing support to the patients' wrist and forearm while performing detailed tasks. I have designed a supportive forearm cuff to relieve tension in the hand and provide support when writing for a prolonged amount of time. My results concluded that writing a paragraph without the cuff made the subject's hand cramp due to the tension of the hand. With the cuff, the subject was able to write the paragraph without discomfort. The cuff was successful in comfort, but efficiency with writing the paragraph however was declined. It took one subject 1 minute and 28 seconds to write 40 words, and a subject with the cuff on took 1 minute and 45 seconds to write 40 words. The average comfort level with the cuff was 4.25 on a scale of 1 to 5 and the average difference in time was 24 seconds. My conclusion about the experiment was that writing 40 words with the forearm support cuff was more comfortable and was going to be less efficient than writing without the support cuff. Although the time taken to complete the task with the cuff on was longer, the subjects may be able to complete lengthier tasks when using the cuff then when not due to the need for breaks cause by discomfort.

According to the Parkinson's Foundation (2019), Parkinson's disease affects around 10 million people worldwide and that number has been increasing. Effecting everyday tasks such as writing have become difficult to those with the disease because of the lack of comfort, tremors, and deficiencies in stabilization.

My prosthetic was designed around these symptoms, to relieve the discomfort and provide stabilization. Even with those who do not have the disease, the results prove that the cuff made a significant impact in the comfort level when writing for a long period of time. My design is aimed to help those who feel discomfort when writing with a simple approach. Other designs that aim to solve the same issue have been tested, but they were far more complex and not user friendly. For example, an entire arm brace was designed for orthopedic purposes and served as a base for my design; A forearm counterforce brace, as applied in this study, affects wrist joint proprioception and increases the pain threshold to passive stretching of the wrist extensors in subjects shown in the Journal of Orthopedic & Sports Physical Therapy (2004). I based my research on orthopedic comfort and functionality looking specifically at the different types of braces used to alleviate the disease symptoms.

Methods

The function of my final design is to accommodate those with difficulties writing and stabilizing the arm in relation to writing for a prolonged period of time. I have shortened the length of time to under 3 minutes, and on average there was an average of a 24 second difference between using the cuff and not using the cuff. The prosthetic's features are designed to easily attach and detach to the forearm. Specifically, I have implemented a joint, so the cuff opens and when put on and there is a lock to keep it secure. When designing the prosthetic, the main components I wanted to focus on were how to put it on the arm without causing discomfort. Based on my research, most forearm prosthetics are more intricate when it comes to detail making it more complex to actually

put on. I wanted an easy fix to some of those problems, so I made the design simple compared to most. Looking at other designs, most did not implement comfort and efficiency. I have included a foam-like material on the inside and black tape on the other layer for a more stable grip. Through multiple trials conducted, I had come up with ideas to tweak my design to fit my overall goal of comfort and efficiency. In the beginning I had asked my test subjects to rate comfort level as a part of my experiment. After implementing the foam and the tape to my design, the comfort ratings were greater than when there was no foam or tape attached. My procedure consisted of writing a 40-word paragraph and timing it with the cuff on and comparing the results to when the cuff was not worn. The average comfort level without the cuff on a scale of 1-5 was about a 2.3, compared to the comfort level when the cuff was worn at an average of 4.6. Although it is not considered a "one size fits all", the comfort level was doubled when the cuff was worn. This test was conducted on 25 people with ages ranging from 15-50.

Results

My data collection consisted of 25 people testing the amount of time it took to write 40 words. The average difference between the time it took to write 40 words was 24 seconds, and I tested 25 people, ages 15-50. My prosthetic was successful in delivering comfort while writing, it is designed to relieve tension in the forearm when writing. The width between the forearm and the surface the subject was writing on was about half an inch. That implementation lifted the subject's hand was a key component in the comfort aspect of the design. The printing process was difficult as I kept reprinting and testing, the final design was completed after multiple failed trials.

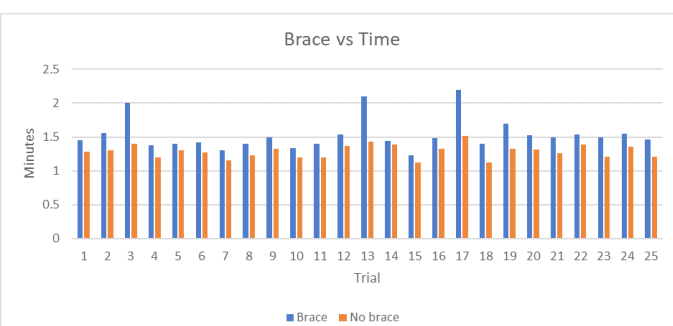

Figure 1.1

Figure 1.1 The time range that I tested was 0-2.5 minutes, the bar graph indicates the differences between the time taken to write 40 words with and without the brace attached. The data collection includes a bar indicating in blue the time taken to write a 40-word paragraph with the brace attached and a bar indicated in orange the time it took to write 40 words without the brace attached. The X axis label indicates the trial number for each subject; two trials per subject were taken for the experiment. The Y axis indicates the time range from 0-2.5 minutes.

Subject	Brace	No brace	Average Difference
1	1.45	1.28	0.17
2	1.56	1.3	0.28
3	2	1.4	0.6
4	1.38	1.2	0.18
5	1.4	1.3	0.1
6	1.42	1.27	0.15
7	1.3	1.15	0.15
8	1.4	1.23	0.17
9	1.5	1.32	0.18
10	1.34	1.2	0.14
11	1.4	1.2	0.2
12	1.54	1.37	0.17
13	2.1	1.43	0.67
14	1.44	1.39	0.05
15	1.23	1.12	0.11
16	1.48	1.32	0.16
17	2.2	1.52	0.68
18	1.4	1.12	0.28
19	1.7	1.32	0.38
20	1.53	1.31	0.22
21	1.49	1.26	0.23
22	1.54	1.39	0.15
23	1.49	1.21	0.28
24	1.55	1.36	0.19
25	1.46	1.21	0.25
		Average Difference:	0.2456

Figure 1.2 This figure represents my data collection. Column one indicated the subject, column two and three represent brace vs no brace on the arm and the time taken to write the paragraph. Indicated at the bottom is the average difference in time. The average comfort level was a 4.5 out of 5 with the brace attached compared to a 3.2/5 without the brace attached.

Conclusion

I believe my prosthetic was successful in providing support and comfort, there is room for improvement however. It is a great remedy for those who spend time writing or typing who have difficulties with hand cramps or even using their fine motor skills for prolonged periods of time. I decided to test a shortened amount of time and predict the success rate of us for a longer time. Different sizes could be the next step in this process, but the data was significantly successful in creating a comfortable way of stabilizing a hand while writing. I believe this can be implemented in a way that could help Parkinson's and arthritis patients in the realm of alleviating tension and providing comfort. There is a strain involved when writing for a prolonged period of time, so I decided to test and compare the difference between writing a paragraph with and without a brace attached. The limitations I ran into included my inability to find someone diagnosed with Parkinson's or Arthritis to test the success rate efficiently and accurately. Although I did test on ages ranging 15-50, the older ages did confirm the difference and how it helped them when performing the task. Overall, I believe my design is effective, comfortable and easy to use and it is highly generalizable.

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ParkinsonsFoundation.org

Engineering

Color Management in Image Capture and Display Leveraged with the Ambient Color Sensor

Tina T. Wen

Abstract

Many companies' sales are suffering because their customers are upset that the color of an item that they purchase is different from the color shown online. This project looks at a way to improve the color accuracy between an image captured at one light source and an image displayed at a different light source using the newly created Ambient Color Sensor. Using the Ambient Color Sensor and the camera sensor already embedded in the Microsoft Surface Pro 6, I investigated the hypothesis that using the Ambient Color Sensor would result in better color accuracy because it correctly adjusts the white point of the two environmental light sources to compensate for the differences in the lighting of the capture and display. Data was collected using a simulated color management pipeline with and without the Ambient Color Sensor at 3000K, 5000K and 6500K. The color error was determined for each of the twenty-four color patches by using the CIE76 color difference formula and the color accuracy was determined by comparing the color errors. It was found that using the Ambient Color Sensor in the color management pipeline had two effects: it significantly reduced the color error by 39.677% and improved color accuracy by 40.066% using chromatic adaption of the original light source. The hypothesis was accepted because the use of the Ambient Color Sensor significantly reduced the color error and increased the color accuracy of each color patch.

Consumers are becoming more and more aware of the concept of color. Recent surveys confirm that nearly seventy percent of consumers find it challenging to match an item's color from an online product and the product they received. People who shop online can experience dissatisfaction when the color of product they ordered online does not match the real color of the product when they receive the item. One root cause for this issue results from the color management pipeline from the camera to the computer display under different lighting conditions. An object's color results from the interaction of a light source, an object, and observer. For example, the same apple will appear as a different color at different light sources due to a difference in spectral power distributions of light sources, which can also be characterized by correlated color temperature and white point. The concept of color temperature arises from the apparent color changes of an object when it is heated to various temperatures. As the temperature increases, the color progresses from a very deep red through orange, yellow, and white and finally, bluish-white. An object may be viewed under various conditions; for example, it may be illuminated by sunlight, the light of a fire, or a harsh electric light.

In all of these situations, human vision perceives that the object has the same color: an apple always appears red, whether viewed at night or during the day. On the other hand, a camera with no adjustment for light may register the apple as having varying color. This feature of the visual system is called chromatic adaptation, or color constancy; when the correction occurs in a camera it is referred to as white balance. Nowadays, sensors have been applied to consumer devices to help improve the device quality and user experience. A new ambient light sensor developed by AMS has the capability to collect more precise ambient light conditions, which includes the white point of an ambient light source. This can used for functions such as display management and a camera's automatic white balancing for better color management. The purpose of this project is to determine if the addition of a sensor onto the capture and display sides of the color management process is necessary to improve the perceptual color matching.

Methods

Materials

- 1 Microsoft Surface Pro 6
- 1 X-Rite SpectraLight QC Lightbooth
- 1 ThousLight LEDCube Lightbooth
- 1 Konica Minolta CL-200A Chroma Meter
- 1 MTO55XPRO3 Aluminum Tripod
- 3 X-Rite ColorChecker Classic
- 1 MATLAB License
- 1 Photoshop License

Materials are supplied by Microsoft.

Procedure

First, I captured images with the camera's automatic white point under three different light sources (3000K, 5000K and 6500K) using the Microsoft Surface Pro 6 and recorded the sRGB data using Photoshop. Next, I determined the white point information of the light sources at 3000K, 5000K, and 6500K using the X-Rite SpectraLight QC Lightbooth. Using the camera images from step 1 as input, I generated display images by running display color management pipeline simulation with chromatic adaption using ACS for W4 case and CL-200A for the W2 case and recorded the sRGB data. Next, I displayed the images from step 3 for a color appearance evaluation under the 3000K, 5000K and 6500K light environments. The experiment was repeated with the W1, W3, and W5 methods. To analyze the data, I first converted the sRGB data into a CIE-XYZ color space image using a preset transformation matrix:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.4124564 & 0.3575761 & 0.1804375 \\ 0.2126729 & 0.7151522 & 0.0721750 \\ 0.0193339 & 0.1191920 & 0.9503041 \end{bmatrix} \begin{bmatrix} sR' \\ sG' \\ sB' \end{bmatrix}$$

Then, I converted the CIEXYZ data to CIEL*a*b* by using the following formulas:

$$L_2^* = 116f\left(\frac{Y}{Y_n}\right) - 16$$

$$a_2^* = 500\left(f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right)$$

$$b_2^* = 200\left(f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)\right)$$

Next, I calculated the Chromatic Adaptation Matrix [M] from the white point information of the light sources using the Bradford Method. From this, I determined the new CIEL*a*b* data by multiplying the matrix [M] with the CIEL*a*b* data. Using this new CIEL*a*b* data, I could calculate the color error by using the CIE76 color difference formula:

$$\Delta E_{ab}^* = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

Results

Based on the data collected, two conclusions could be made. First, the Ambient Color Sensor results in less color error when used during the camera capture and when displayed at the industrial standard sRGB D65. Secondly, it was also determined that displaying an image with chromatic adaptation to the original light source during the image capture would result in an increase in color accuracy. It was calculated that there was a 39.677% decrease in color error when the Ambient Color Sensor was used in the color management pipeline. Furthermore, the 40.066% increase in color accuracy was determined through the calculation of the chromatic adaptation matrix. The white point of the original light source (which was captured by the Ambient Color Sensor) is embedded into the captured image, which allows for a more accurate color.

Discussion

A future step for this experiment would be to test the reliability of the Ambient Color Sensor over a period of time. As technology ages, the speed and precision of its function does not match what it was once capable of. Testing the function of the Ambient Color Sensor over a period of five years would allow for more accurate data on its accuracy.

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Environmental Science

Determining the Most Effective Salt Concentration of Irrigation Water for Trichoderma harzianum to Confer Salt Tolerance Through Symbiosis to Oryza sativa Plants

Manasvini Calmidi

Abstract

As Earth's climate continues to rapidly change, rising sea levels and pressure on fresh water reserves have made many staple crop plants, especially rice, extremely vulnerable. With arable coastal land quickly becoming salty and unconducive to plant growth, it is more important now than ever to discover new ways to grow important crops in harsher environments. This project sought to find how different concentrations of salt in irrigation water affect rice plants in symbiotic relationships with the Trichoderma harzianum fungi species versus rice plants by themselves, testing the hypothesis that symbiotic plants irrigated with the highest salt water concentration will be the fittest. Rice plants with and without symbiotic relationships with the fungi species were grown for six weeks and irrigated with a range of solutions from fresh water to 300 mM salt water. The height of each plant, along with its color and wiltage on a 1-5 scale were measured each week as indication of its healthiness. The hypothesis was confirmed, showing that the plants grown in conjugation with the fungi and irrigated with a 300 mM salt water solution were the healthiest in terms of their growth rate, color and wiltage level, with a p- value of 0.002. This study showed the most efficient ways of utilizing fungal symbiosis in rice plants and taking advantage of the increased salt levels in coastal soils to generate healthier crops. These results can be applied to improve crop growth in the salt-degraded areas which compose 20 percent of the world's irrigated land.

Across the globe, more than 700 million people still remain undernourished. Much of this hunger is due to agricultural issues in the face of long-term climate risks. Increasingly, seawater has encroached into farmland in coastal regions and compromised its fertility, placing stress on the crops and threatening the productivity of the farmland. Research has shown that in habitats of high environmental stress, symbiosis between a host plant and its endophytic fungi allows for stress tolerance to confer from the fungi to the plant, leading to higher rates of plant survival (Rodriguez et al., 2004). Previous studies have discovered the ability of such endophytes to be removed from their native host plant and added to a new plant with success in improving the new host's tolerance, as well as how such a transfer would improve crop strength in climate-change- afflicted areas. (Rodriguez et al., 2008). This experiment seeks to investigate the most effective salt molarity of irrigation water to confer salt tolerance to Oryza sativa (Asian rice) plants from the Trichoderma harzianum fungus, which is very similar in properties to the Fusarium culmorum fungus. Fusarium culmorum is a pathogenic species derived from Leymus mollis plants, whose natural habitat is in salty coastal waters. Trichoderma harzianum is a non- pathogenic symbiont, so it is optimal for aiding in growing a crop which is grown for food security. Oryza sativa and Leymus mollis are both grasses, are genetically similar and will have corresponding stresses, so a similar relationship between rice and fungi is possible. The objective of this experiment is to test which salt concentration of irrigation water that will lead the most productive and healthy Oryza sativa plant in symbiosis with Trichoderma harzianum, in terms of height, color retention, and wiltage levels.

Methods

Germinating and Sterilizing the Seeds, and Introducing Fungi

The seeds were first sterilized in 0.5 L of sodium hypochlorite solution for 24 hours, then another 0.5 L of sterile water were added and the solution sat for another 24 hours. All of the rice seeds were

germinated on damp paper towels at room temperature under 16 hours of light per day for one week. The viable seedlings were separated into two equal groups. One bag was filled with 100 mL of the fungal solution, and the other with an equal amount of fresh water. One group of seedlings was placed into each bag, most of the air was removed, and the bag was allowed to sit for 24 hours at room temperature. Both bags were drained, the fungal solution was poured back into bottle, and add about 50 mL of sodium hypochlorite were added. The solution sat for 30 minutes before disposal. Both bags of seedlings were refrigerated until they were needed for transplantation.

Setup of Magenta Boxes

Magenta boxes are planter boxes which are commonly used in plant physiology.
They are designed to create controlled experiments in which nutrient levels are not affected by extraneous factors such as evaporation. A triple-decker box system was used in this study, allocating separate sections for water, soil, and extra space for the plant to grow through. A wicking system allowed the water, salt, and nutrients in the bottom box to be drawn naturally upwards by the plant. A sponge was placed in the lid to promote carbon dioxide and oxygen exchange without risking contamination, since the fungi can move throughout the air.

24 wicks were made by threading eight cm of rope into the bottom hole of the middle magenta box, tying a knot such that the rope does not slide back out, then allowing another 22 cm of the rope to hang out of the bottom. Each middle magenta box was filled with one cup of soil, and each bottom magenta box with 200 mL of water.
Each middle box was stacked on a bottom box. Connectors, lids, and sponges were added onto each middle box and. All boxes were autoclaved for one hour to sterilize.

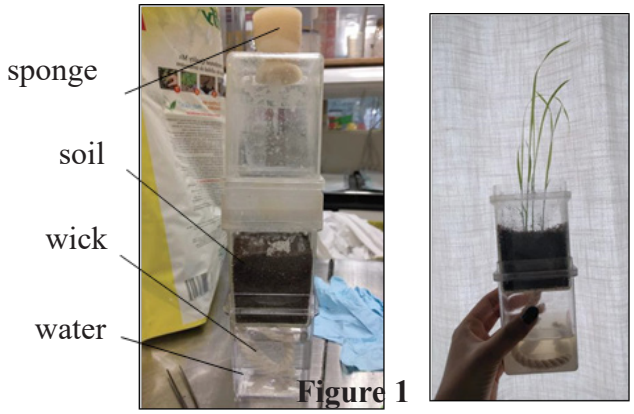

Figure 1

Making the Fertilizer and NaCl Solutions

In order to best control what entered the experimental environment, a fertilizer solution was made to mimic the effects of a standard commercial fertilizer which a farmer in the affected region may use. 7.35 grams of CaCl2 were added to one liter of distilled water and shaken well of 30 seconds to homogenize the mixture. 8 grams of NPK were added to one liter of distilled water and shaken well for 30 seconds to homogenize the mixture. 0.1 grams of Fe were added to one liter of distilled water and shaken well of 30 seconds to homogenize the mixture. 40 mL of each of these solutions were mixed together and added to each magenta box to serve as a fertilizer. 58.44 grams of NaCl were added to one liter of distilled water and shaken well of 30 seconds to homogenize the mixture. Various levels of NaCl solution were added to the different experimental groups. Solutions for each plant group were mixed according to the table below.

Magenta Box	$CaCl_2$ Solution (mL)	NPK Solution (mL)	Fe Solution (mL)	NaCl Solution (mL)	Distilled Water (mL)
Fertilizer + 0 mM NaCl	40	40	40	0	80
Fertilizer + 100 mM NaCl	40	40	40	20	60
Fertilizer + 200 mM NaCl	40	40	40	40	40
Fertilizer + 300 mM NaCl	40	40	40	60	20

Experimentation and Data Collection

Four seedlings were transplanted into each planter box. The plants were kept for 12 hours each day under fluorescent lights in a 21°C environment in the large Tupperware box. The top and sides of this larger box were sealed to ensure that the control and experimental groups were isolated from each other. Fresh water was added accordingly to keep the bottom tier filled. Following one more week of growth, the experimental plants' boxes was filled with the appropriate salt water concentration, rather than the sterile water. All plants received the fertilizer solution. Once every week following fungi introduction, the heights of all the plants (cm), the wiltage level, and the color of the leaves, were measured and recorded. The wiltage level and color retention were measured on a subjective scale from one to five. For wiltage, one represented a dead plant, three represented a moderately wilted plant with low levels of chlorosis, and five represented a fully upright plant. For color, one represented pale-yellow green (indicative of plant death), three represented

medium green, and five represented deep green. After all data collection was complete, the soil and plants were autoclaved for 15 minutes in order to prevent contamination.

In each trial, there were eight total plant groups, four with fungi (experimental) and four without (control). In both the experimental and control groups, one group was irrigated with sterile water, one with 100 mM NaCl water, one with 200 mM NaCl water, and one with 300 mM NaCl water. Each trial will contain the setup below.

experimental	experimental	experimental	experimental	Plants Inoculated with Fungi
control	control	control	control	Plants not Inoculated with Fungi
0 M	100 mM	200 mM	300 mM	

NaCl Molarity of Irrigation Water

Results and Analysis

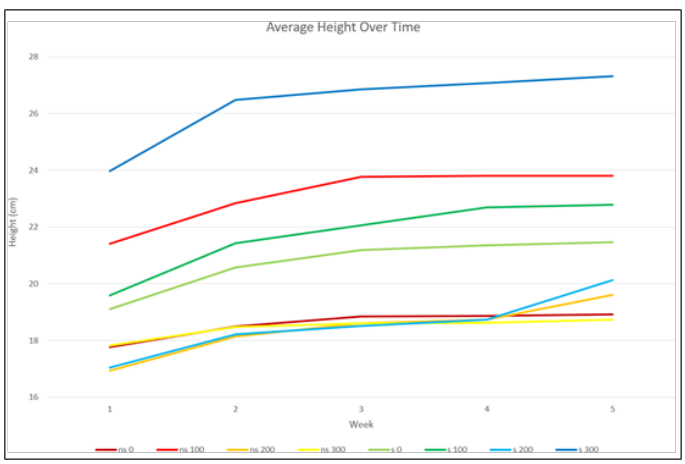

Figure 2

This graph shows the growth progression of each experimental group. The growth rate of the 300 mM symbiotic plants was determined to be the highest, followed by the 100 mM non- symbiotic plants. The 300 mM symbiotic plants were the tallest at week 0 and remained the tallest for the duration of the experiment. This may correlate to the fungal presence's impact on the overall health of the plants (Redman, 2018). The percentage changes in height of the symbiotic plant groups were greater than those of the non-symbiotic groups, with the greatest height change occurring in the symbiotic 200 mM group (18.1%).

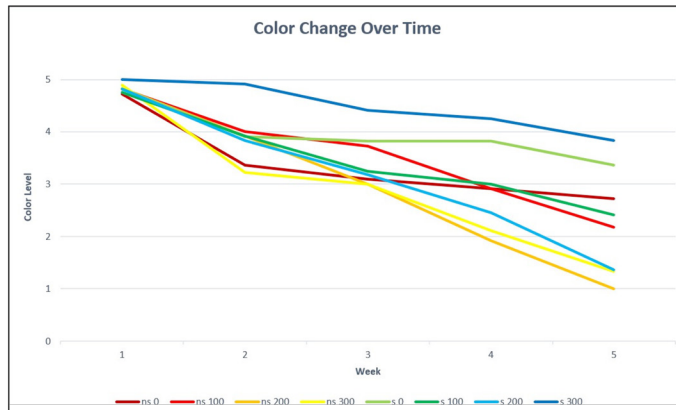

Figure 3

This graph shows the changes in color of the experimental groups over the five-week period. Using a subjective visual scale (from 1-5), it was found that most groups began with a deep green color, indicative of full health, and represented by a value of 5. The 300 mM symbiotic group retained the highest color value for the duration of the experiment. The 200 and 300 mM non-symbiotic plants had the lowest color values by week 2; and this trend continued through week 4.

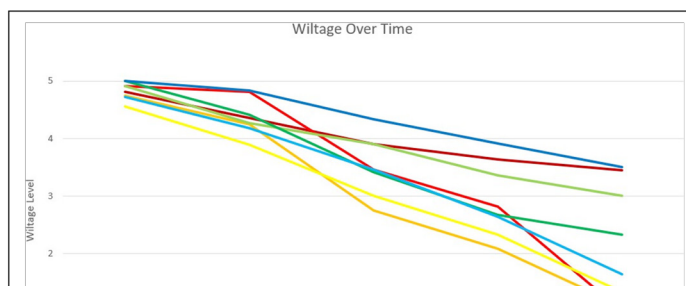

Figure 4

This graph shows the change in average wiltage level over time. To determine the plants' wiltage levels quantitively, a subjective visual scale was developed (from 1-5). Figure 2 shows that most groups had a value of 5 at the start of the experiment, which is representative of completely upright, fully healthy plants. The 300 mM symbiotic plants experienced a steady decline in wiltage values, but remained the most upright throughout the five weeks. The 200 and 300 mM non-symbiotic plants were consistently the most wilted, and ended the experiment with values of 1, which is indicative of plant death.

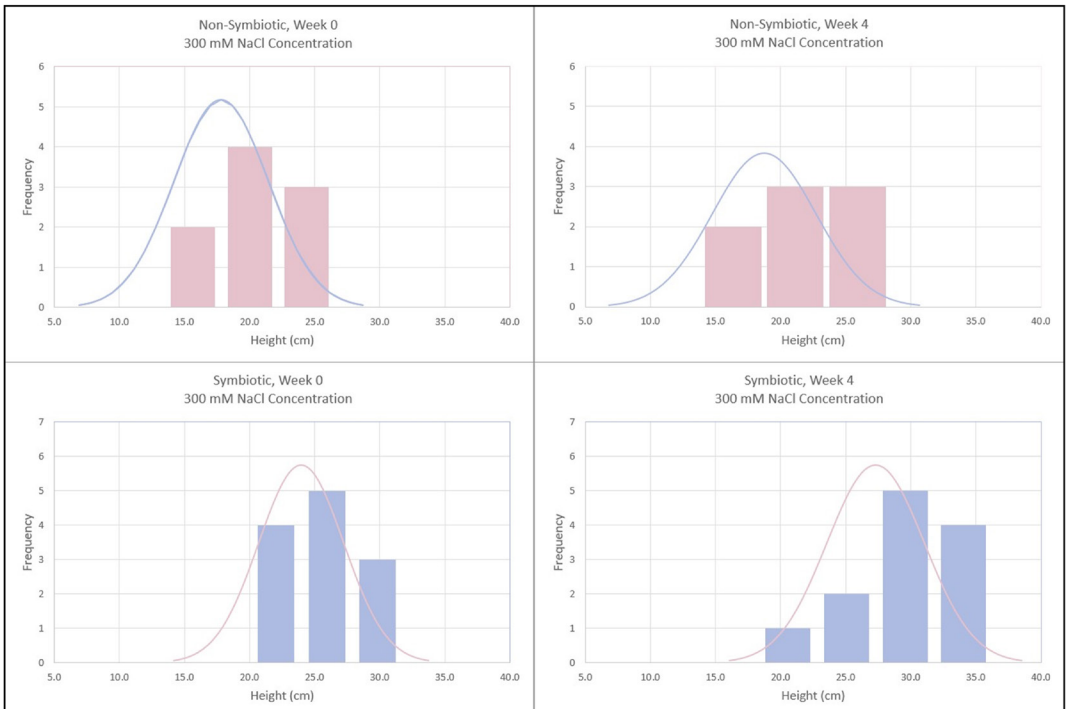

Figure 5

The above histograms and normal curves show the height distributions of the symbiotic and non-symbiotic plants irrigated with 300 mM water over the course of the study. The non- symbiotic plant groups experienced an almost negligible shift in height distribution between the beginning and end, which suggests that the plant growth was inhibited by the NaCl in the water. The symbiotic plants experienced a significant positive shift in height over the course of the study which suggests that the fungi plant relationship was successful in mitigating the stress of a saline environment.

Discussion

Experimental Limitations

Steps were taken to replicate the environment in which Oryza sativa is traditionally grown, in order to generate the most valid data. Lights were kept on for twelve hours per day, and heat mats and a space heater were used to regulate the temperature to a level similar to the tropical coastal regions where rice is grown. However, this experiment was isolated, and thus does not completely reflect how the rice and fungi would also interact with other organisms in their environment. Similarly, the plants were only monitored over the course of five weeks, so it is still unknown how they would fare in the process of growing to maturity and producing rice.

Conclusion

This experiment sought to find how different concentrations of salt in irrigation water affect rice plants in symbiotic relationships with the Trichoderma harzianum fungi species versus rice plants by themselves. Experimental methods were carefully implemented to ensure that the nutrient and salt concentrations were regulated, and that the risk of contamination between experimental groups was minimized.

The results demonstrated that the plant groups grown in conjugation with the symbiotic fungi had higher growth rates, lesser wiltage levels and greater color retention that plants growth alone. The differences between these factors for symbiotic and non-symbiotic plants irrigated with 300 mM salt water was found to be statistically significant using analysis with a t-test. P- values of 0.002 (growth rate), 0.00001 (wiltage) and 0.00006 (color) were derived, which mean that the null hypothesis can be rejected. It also meant that the hypothesis that this experimental group would be the most successful according to these factors was confirmed.

Future experimentation could include replication of this study in an environment in which Oryza sativa is traditionally grown, in order to see how the introduction of Trichoderma harzianum, a non-native species, would impact its new ecosystem. Such a field study would also provide insight into how this solution would fare in a less-controlled environment, and if it is reliable enough to become widely used.

Extending the range of salt water concentrations

tested would also be of value for determining the viability of the rice plant growth in areas where the salinity of ocean water in higher than average.

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Medicine

FasL Induced Apoptosis for the Bioartificial Pancreas

Suhani Arora and Anisha Karnik

Abstract

Type 1 Diabetes Mellitus (T1D) is an autoimmune condition in which the immune system attacks the insulin producing beta islet cells in the pancreas. Patients with T1D have high blood glucose levels and must use insulin injections and pumps to regulate blood sugar. As a treatment, researchers and scientists have come up with islet cell transplantation, where islet cells are removed from a donor pancreas and injected into the portal vein of the patient. The limitation of islet cell transplantation is that immunosuppressants must be used, which can be harmful to the patient and have many serious side effects. To prevent the use of immunosuppressants, a new innovation is under clinical trial: the bioartificial pancreas. The bioartificial pancreas encapsulates the donor islet cells into a porous hydrogel macrocapsule made out of soft polymers and alginate. This is supposed to block the immune system from entering but a recent study showed traces of immune cells like lymphocytes and macrophages in the macrocapsule. Though the immune cells can't directly cross the membrane of the macrocapsule, they release small chemical such as cytokines that can, which can kill the islet cells. To block the immune cells completely, we have incorporated FasL Induced Apoptosis into the bioartificial pancreas that detects the presence of immune cells and releases FasL, which binds to the immune cell and kills it.

Key Words: FasL, apoptosis, type 1 diabetes, bioartificial pancreas, islet cell transplantation

Type 1 Diabetes, or T1D also known as Juvenile Diabetes affects more than 3 million people in the United States. It is a chronic, autoimmune condition that occurs when the body's own immune system destroys the insulin-producing beta cells also known as islet cells in the pancreas. Over time, people with T1D are left with no pancreatic islet cells and cannot produce insulin. Insulin is a hormone that is essential for your body to use sugar found in the food you eat. Without insulin, glucose would stay in your blood. T1D patients must pump or inject insulin into their body every day to regulate blood sugar and stay alive.

Background

Islet Cell Transplantation

Islet cell transplantation is an experimental treatment currently used for patients with Type 1 Diabetes. Islets with healthy beta cells are removed from a donor pancreas of a deceased person and injected in the portal vein, which carries blood to the liver of the recipient. The transplanted beta cells then start to function properly, releasing insulin into the bloodstream. However, the recipient must take immunosuppressants which can cause serious side effects such as high blood pressure and kidney damage.

Bioartificial Pancreas and its Limitations

The bioartificial pancreas is a potential cure for T1D that is currently under clinical trial. It encapsulates a group of pancreatic islets in a semipermeable membrane which protects the islet cells from the body's immune system but allows insulin, waste products and small molecules like oxygen to pass through. Beta O2 Technologies developed the βAir Bioartificial Pancreas. The islets are implanted into a hydrogel structure within the macrocapsule which provides a viable environment for the cells to thrive. For the scaffold, two types of alginate are used: high glucuronic acid and high mannuronic acid saturated in a Tefflon membrane. Islet cells are one of the biggest oxygen consumers in your body. Insufficient amount of oxygen is one of the reasons why islet cells deteriorate over time. The βair has an oxygen replenishing device which actively provides ample oxygen to the islet cells. The patient must refill the air in the device every 24 hours by injecting oxygen into ports implanted under the skin.

Our Innovation

Hypoxia

Hypoxia is a condition in which a region of the

body is deprived of sufficient oxygen supply which is the case of the islets in the bioartificial pancreas. To address this issue in the bioartificial pancreas, we have incorporated the use of an oxygen generating biomaterial called polydimethylsiloxane (PDMS) encapsulated solid calcium peroxide (CaO2). Oxygen is generated from the decomposition of solid peroxides such as calcium peroxide (CaO2) through the following reaction: 2CaO2 + 4H2O 2Ca(OH)2 + 2H2O2 2Ca(OH)2 + 2H2O + O2. However, this reaction is too rapid and can cause hyperoxide conditions by releasing high concentrations of oxygen when coming in contact with water so, the CaO2 is encapsulated in a hydrophobic polymer known as polydimethylsiloxane (PDMS). This only lets limited water in, the amount necessary for the cells to survive. The restriction of water flowing through the material allows for more oxygen generation. The use of PDMS- CaO2 disks have been tested on rat islets and the results show that more insulin is produced and after 6 hours of islets being placed in the culture, a significantly larger amount survives in a PDMS-CaO2 disk (Fig. 1).

FasL Induced Apoptosis

Though the immune system cannot directly cross the membrane of the βair, it releases harmful chemicals such as cytokines that can. Cytokines bind to receptors on other cells of the body and kill them. In fact, a recent study showed CD3 stained lymphocytes and CD9 stained macrophages within the macrocapsule along with increased levels of antibodies after implantation. In FasL induced apoptosis, we will modify and use Fas ligand and receptor interactions, a naturally-occurring signal transduction pathway in the body to induce apoptosis in immune system cells that are detected close to the capsule. Fas ligand and receptor interactions play an important role in the regulation of the immune system. Most immune cells, such as B and T lymphocytes and macrophages have Fas receptors on their membrane. Fas ligand, or FasL which is generated by various cells of the body, mainly Sertoli cells in the testis of males, bind to the Fas receptor on their membrane, starting a signal transduction pathway in the cell. The pathway activates many proteins, kinases and includes many secondary messengers. The signal reaches the nucleus and codes for an enzyme that breaks down the nucleus and eventually causes the cell to burst into smaller parts. We will cover the PDMS CaO2 disc with a layer of HG alginate and line the alginate with genetically engineered Sertoli cells. We will modify the DNA of the Sertoli cells and deactivate all genes except for the ones that play a role in producing FasL. The FasL encoding genes will be turned off for most of the time and will be activated by a chemical signal sent by the Au electrode.

Gene Editing of Sertoli Cells

Genome editing is the insertion, deletion, modification or replacement of DNA at a specific site in the genome of an organism or cell. It is usually achieved in the lab using engineered nucleases also known as molecular scissors. To edit the Sertoli cells, we will be using Zinc Finger Nucleases, or ZFNs. Zinc Finger Nucleases are engineered DNA binding proteins that can be designed to bind to a wide variety of DNA sequences and function by introducing a double stranded break at a specified location in the genome (Fig. 2). They have two main parts: DNA-binding domain and DNA-cleaving domain. The DNA-binding domain is made of two-finger modules linked in a chain. The DNA-cleaving domain is made of the nuclease Fok1. Fok1 is an enzyme that is naturally found in Flavobacterium okeanokoites. In the Sertoli cells, we will use ZFNs to deactivate all the genes except for the ones that code for FasL. We will use a synthetic signal transduction pathway that will respond to the signal sent from the Au electrode. We will use the dCas9-TF Membrane Tethering and Protease-Mediated Release pathway. The nuclease-deficient type-II CRISPR-associated Cas9 protein (dCas9) is versatile molecule commonly used as an artificial receptor protein. dCas9 is off for most of the time and is only activated when a ligand binds to it. We will be using dCas9(C)-synVEGFR1 as the ligand and this will be produced by the Au electrode when immune cells are detected.

Au Electrode

Au electrodes are a new type of aptameter technology that contain aptasensors. It is a microfluidic device that has micropatterned sensing surfaces enclosed inside and are used to capture T cells from RBC lysed blood. Cytokines released by T cells are then detected in the form of redox signal at the neighboring electrode. This Au electrode then releases dCas9(C)-synVEGFR1 from a compartmentalized section in the electrode. This ligand binds to the

dCas9 receptor on the Sertoli cell, which produces FasL, killing the immune cells (Fig. 3).

Discussion

In the future, we would like to use the idea of FasL induced apoptosis to cure other autoimmune diseases, such as vitiligo, alopecia areata, rheumatoid arthritis, lupus, celiac disease and multiple sclerosis. We believe that genetically engineered Sertoli cells that produce FasL act as a natural immunosuppressant and are less risky than normal drugs given during immunosuppressive therapy. Sertoli cells only produce FasL when immune cells are detected which means it does not harm the function of the overall immune system. This also causes less symptoms to be present. We believe that in the future, our innovation can change the face of medicine and improve the life of millions suffering with autoimmune diseases.

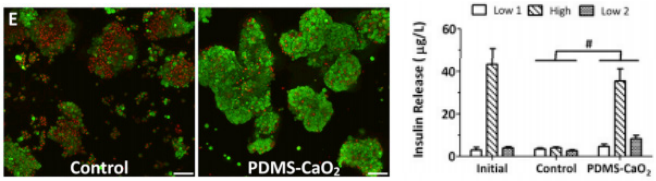

Figure 1. Islets that have survived after 6 hours. Green, alive; Red, dead

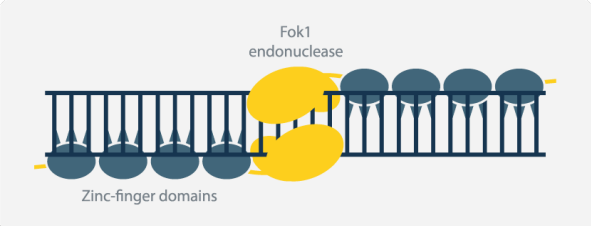

Figure 2. How Zinc Finger Nucleases (ZFNs) cut DNA

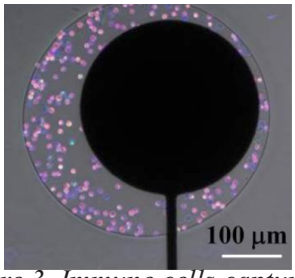

Figure 3. Immune cells captured next to sensing Au electrode (black circle)

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Synergism or Antagonism between Docetaxel and Finasteride in Prostate Cancer Model

Mirra Chinta

Abstract

Could the mixing of two drugs be the solution to prostate cancer? The purpose of this experiment is to test a combination of two drugs, known as Docetaxel and Finasteride. Docetaxel is a chemotherapy drug and Finasteride is an androgen reduction therapy drug. Chemotherapy drugs are known for their mechanism to cause apoptosis, or cell death. Androgen reduction therapy drugs reduce levels of androgens such as Testosterone and Dihydrotestosterone which are linked to prostate cancer. By combining these drugs, they will be observed for possible synergism. Synergism is the combination of two or more drugs that together have higher effectivity than the individual drugs in application. The drugs used are the independent variables and the effects of the drug applications are the dependent variables. The individual applications of the drugs to the cells are the controls. Docetaxel and Finasteride are added to the cells in varying concentrations, nanomolar and micromolar respectively. The combination of .12 nm (nanomolar) of Docetaxel with varying concentrations of Finasteride is added as well. Upon observation, Docetaxel needs a 24 hour buffer period before the cells start dying. The IC50s, or the concentration at which 50% of the cells die, of both drugs are noted. The IC50 for Docetaxel is 0.75 nM, the IC50 for Finasteride is 187.5 uM (micromolar), and the IC50 of the combination is 93.75uM. The statistical significance of the combination, taken from an f test, is 0.80431438. Therefore, there is no significant difference between the effect of the individual drugs or the combinations.

Rationale

Prostate cancer is one of the most common cancer, and is the third leading cause of cancer-related death in men in the US. In 2018, 164,690 new cases of prostate cancer were diagnosed, and 29,430 deaths have been reported. The lifetime risk of being diagnosed with prostate cancer is high at 1 in 9 men. (American Cancer Society, 2018)

Docetaxel, the primary chemotherapy drug used for treating Stage III and Stage IV prostate cancer, belongs to plant alkaloid class of chemotherapy drugs. It is part of the Taxane family or the family of drugs that are derived from the bark of the Pacific Yew tree (Taxus brevifolia). Docetaxel is a cell cycle specific chemotherapy drug wherein it targets certain cells during division. The difference between normal and malignant cells is that normal cells have resting stages as well as certain checks to limit the cell division. Malignant cells lose this ability, and have continuous cell division. (Chemocare). Docetaxel targets cells that aren't in their resting stages by inhibiting the mitotic spindle, and causes apoptosis (self- destruction of cell) by causing the phosphorylation of bcl-2, an oncoprotein that blocks the apoptosis inducing mechanism, yet there is some conflicting research as to the specifics of the inactivation of bcl-2(Dai, H., Ding, H., Meng, X. W., Lee, S. H., Schneider, P. A., & Kaufmann, S. H. 2013)

Finasteride is an oral medication, sold under brand names Proscar and Propecia is used to treat the primary stages of prostate cancer, such as treatment of the enlarged prostate. Finasteride is a 5□-reductase inhibitor, which works by decreasing production of androgen sex hormone, dihydrotestosterone, decreasing dihydrotestosterone levels in the blood by up to 70%. By inhibiting 5□-reductase, Finasteride reduces dihydrotestosterone which forms from testosterone in tissues of the body including the prostate gland, skin, and hair follicles. With the reduction of androgen signaling in the prostate gland, prostate volume reduces, greatly lessening the risk of prostate cancer in the patient. (European Urology)

This project seeks to investigate possible synergistic or antagonistic effects between Docetaxel and Finasteride.

Research Question Will Docetaxel and Finasteride have synergistic or antagonistic effects when applied to prostate cancer cell lines?

Hypothesis Since both drugs aim to treat prostate cancer, one addressing androgen reduction, the other being a cytotoxic chemotherapy drug, we hypothesize that Docetaxel and Finasteride will have synergistic effect in treatment of the prostate cancer cell lines.

Expected Outcome Docetaxel and Finasteride are expected to have synergism as both target prostate cancer, in separate ways.

Materials

1. PC3 and DU-145 cell lines (ATCC)
2. NIH3T3 cell line
3. Docetaxel (10 mg+ concentration 10 nM, 20 nM, 40 nM, 50 nM, 70 nM, 100 nM)
4. Finasteride (10 mg+ concentration 10 nM, 20 nM, 40 nM, 50 nM, 70 nM, 100 nM)
5. Growth medium (DMEM/EMEM)
6. 10% Fetal Bovine Serum
7. Tissue growth flasks
8. 96 well plate
9. CO2 incubator
10. Hood
11. Trypsin
12. Luminometer
13. Cell-Titer Glo assay

Method (Tsakalozou, Eckman, Bae, 2012)

1) Prepare tissue cell growth flasks labeled with cell line names, PC3 and DU-145
2) Collect cells from liquid nitrogen storage and thaw at 37°C water bath until there are 1 or 2 small crystals
3) Add thawed PC3 and DU-145 cells to a sterile test tube containing 10 ml of medium.
4) Gently spin the cells down (5-600 rpm in a table top centrifuge for 5 minutes)
5) Sterilely remove the supernatant, and resuspend the cells in fresh medium before transferring the to the tissue culure flask
6) After the 2-week growth period, add Trypsin to cells in flask to cleave adherence proteins
7) dilute the cells into fresh tissue culture medium with 10% FBS. FBS (like human serum) contains a protein called alpha-1 anti-trypsin that inhibits the trypsin used to detach cells from the plates. This step is important to get the cells to reattached to your 96 well plate.
8) Pipette cells into 96 well plate (7000 cells/well)
9) Place plate in CO2 incubator, and allow for recovery of cleaved proteins for 24 hours
10) Once the cells are plated in the 96 well plates, let them adhere for 24 hours. The advantage is that there is no need to sterilely remove the medium from each well and add fresh medium.
11) Divide plate into sections and apply increasing concentrations of Docetaxel
12) Apply increasing concentrations of Finasteride to another plate of cells
13) Add .12 nM Docetaxel with varying concentration of Finasteride.
14) Repeat 11,12,13 for other cell line
15) Place plate in CO2 incubator and wait for 72 hours to allow for drug action
16) For the other batch, wash out drugs, wait for 24 hours before counting
17) After 72 hours, use luminometer to measure living cells to ultimately calculate potency by LC50 to determine whether there is synergism or antagonism
18) Carry out 3 counts

Data Analysis

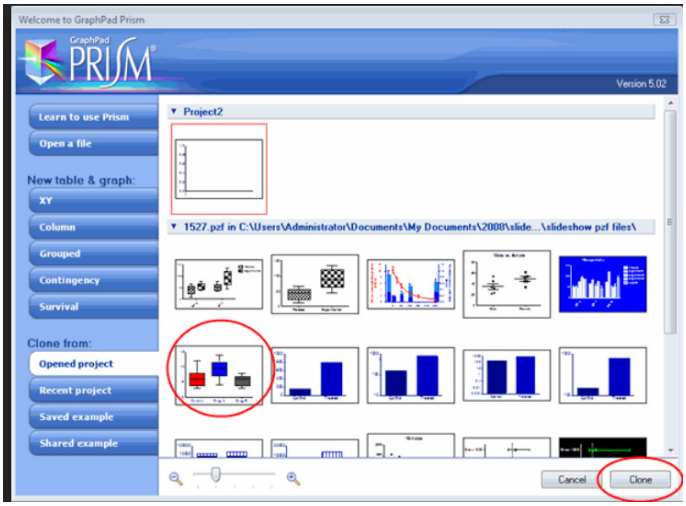
	one-tailed test		two-tailed test
hypothesis	$H_0 : \sigma_1^2 \geq \sigma_2^2$ $H_1 : \sigma_1^2 < \sigma_2^2$	$H_0 : \sigma_1^2 \leq \sigma_2^2$ $H_1 : \sigma_1^2 > \sigma_2^2$	$H_0 : \sigma_1^2 = \sigma_2^2$ $H_1 : \sigma_1^2 \neq \sigma_2^2$
test statistic (F distribution)	$F = \frac{s_2^2}{s_1^2}$	$F = \frac{s_1^2}{s_2^2}$	$F = \frac{\text{larger sample variance}}{\text{smaller sample variance}}$
deg. of freedom	$df_1 = n_1 - 1$	$df_2 = n_2 - 1$	
rejection	reject H_0 if $F > F_\alpha$		reject H_0 if $F > F_{\alpha/2}$

1. The F test is used to compare statistical models that have been fitted to a data set.
2. Create F test to see if results are statistically significant or not.
3. Develop a null hypothesis in which it is stated that all the drugs are antagonistic, so their combined LC50 is lower than the LC50 of either drug
4. The graphing program Prism will be used to statistically compare the LC50 curves
5. Prism will return the results of the F test, in

which the f ratio is returned (between group variance divided by within group variance) as well the p value/

6. If p value is equal or less than 0.05 it is statistically significant, therefore, null hypothesis would be rejected.

7. Complete f test for all three trials.



Risk Assessment

Due to the use of mammalian cells or the use of PC3 and DU-145 cell lines, the culture suffers the risk of contamination as well as environmental pathogens affecting them. The cell cultures (for this study will be placed in Fred Hutchinson's tissue cell facility and will be placed in a CO2 incubator (5% CO2) and well as suspended in 10% Fetal Bovine Serum, with various antibiotics including Penicillin, and a growth medium that will be changed every five days to mitigate the risk of pathogens. This will be carried out in Dr. Julian Simon's Fred Hutchinson lab's tissue culture hood at The Fred Hutchinson Cancer Research Center, Seattle, WA. Cytotoxic chemotherapy drug, Docetaxel as well as other potentially hazardous drug, Finasteride, will be employed in tumor suppressing quantities under adult supervision. I will be wearing appropriate lab gear and will be using micropipettes as well as a waste bin specialized for pipette tips. Unused compounds and solutions will be disposed of as chemical waste in accordance with Fred Hutchinson's Environmental Health and Safety regulations. These regulations include disposing biological waste into biohazard bags after packaging them and labeling them with lab information. Used cytotoxic agents will be disposed of in residual cytotoxic waste bins.

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The Effects of Ascorbic Acid on the Binding between Collagen and Catechin

Kristin K. Acheson

Abstract

According to PBS 21,000 cubic feet of untreated wastewater is dumped from tanneries in Bangladesh; one of the worlds most crowded cities. These tanneries use chromium, a heavy metal that when exposed to humans can cause chromium allergic dermatitis, respiratory tract related cancers, and cardiovascular collapse (CDC). An alternative method for tanning leather that does not use chromium involves the use of vegetable tannins such as catechin, but this method takes a substantial more amount of time to fully tan leather. This experiment seeks to speed up the chemical reactions that take place with tanning leather by comparing the time it takes collagen to bind to tannins in the presence or absence of ascorbic acid. Collagen can be seen at the UV spectra at 290 nm, so to test if the collagen is binding the different samples were measured to check absorbance at 290 nm (dependent variable). The solution that included ascorbic acid saw a peak at 290 nm with an absorbance of 0.264 (independent variable) and the calculated r-squared test of the experimental trial is 0.1309 showing that the results are not statistically significant. By incorporating ascorbic acid into the vegetable tanning process this binding can be further researched to see if it can be fully applicable to the leather industry. This research can be applied to replacing toxic chromium tanneries into the same fast processing plant with a non-toxic solution.

The 77-billion-dollar leather industry does not account for the pollution it causes in third world countries such as Bangladesh, one of the most intensely polluted cities in the world. The chromium that is expelled into the water systems can cause chronic respiratory problems and allergic dermatitis (Gizmodo.com). According to Gizmodo, tanning one ton of hide typically results in 20 to 80 cubic meters of wastewater with Chromium concentrations around 250 mg/L. The deadly chemicals make their way into vital rivers for the population of Bangladesh and the water is colored black from the toxic sludge. Although there have been some efforts to combat against this growing problem the workers are still effected by the mistreatment.

Research Question

Does adding ascorbic acid to collagen and catechin decrease the amount of time it takes to bind?

Hypothesis

If there is ascorbic acid present in a solution of polyphenols, water, and collagen then it will take less time for the number of polyphenols to decrease because the ascorbic acid is a catalyst which will help the hydrogen bonds bind between the collagen and the tannin.

Procedure

Using a UV-Vis test the controls (positive and negative) and experimental solutions at initial, two days, and six days.

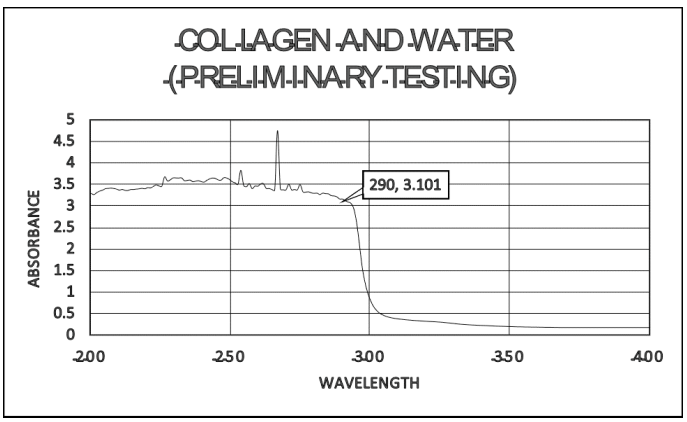
Conclusion

In this experiment the main goal was to identify if adding in ascorbic acid into the binding between catechin and collagen. The results do not support the hypothesis that adding in the antioxidant sped up the chemical binding process as compared to the controls without ascorbic acid present. The absorbance was tested over 6 days to test the change in absorbance. The r-squared value of the experimental test was 0.1039 showing a very weak correlation in the regression line. Although the most change did happen in the experimental trial as seen in the averages. The procedure was all controlled and all solutions were kept the same in concentrations, so the comparison could be weighted. There was only 20 grams of calf skin collagen available so to have more solution of collagen would have been more ideal. The

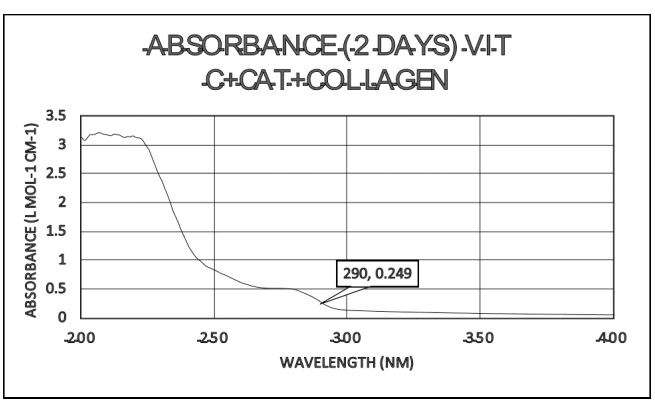
experiment could have used more trials and data points to make it more substantiated. The experiment was supposed to run for 30 days originally,

Type of Solution	Initial	Two days	Six days
Collagen and Water	0.073	0.08	0.069
Collagen and Catechin Stock	0.231	0.232	0.222
Collagen, Catechin Stock, and Ascorbic Acid	0.264	0.249	0.257

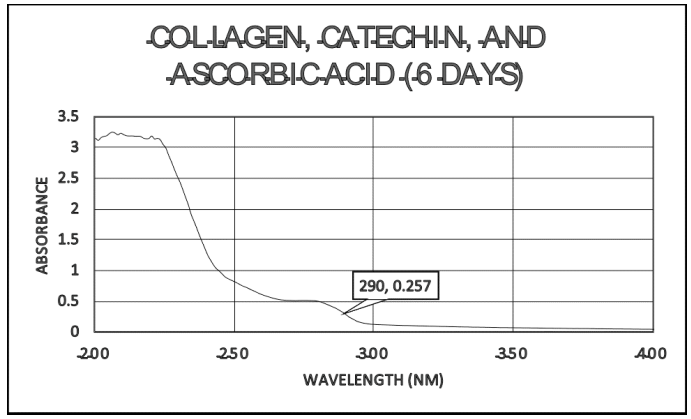
Table 1. Raw Data Table



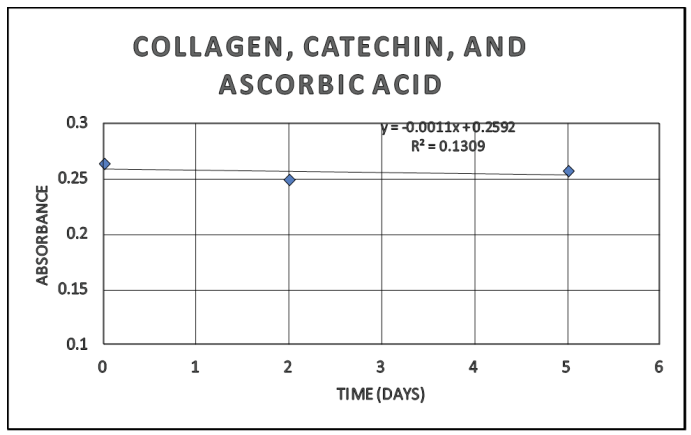
Preliminary testing for experimentation to find when collagen appears on the UV spectra



The experimental solution's wavelengths after 2 days.



The final recording of the experimental solution.



The graph made for the data analysis. The line of best fit equation and r-squared is included.

Further Research.

In the future there should be a comparison to the chrome tanning process to see the different effects on collagen. There should also be more time allotted to gather data points. This experiment only used catechin as the tannin or polyphenol, but to replace the catechin with a tannin used on leather would be ideal. If the data does stand out, then the experiment could then be applied to the actual raw hide used in the leather tanning process.

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A Novel Machine Learning and Western Blotting Approach to Understand Genomic Differences Between E-Cigarette Vapor and Cigarette Smoke and its Relation to Tumor Development

Nitisha Gautam, Arundhati Diya Basu

Author Note

This study was supported by Fred Hutchinson Cancer Research Institute and the University of Washington. The funding entities had a support role in the study design, data analysis, and paper preparation.

Abstract

Recently, e-cigarette smoking among teens and adults has risen by about 57% and is rising. The effects of e-cigarettes on tumor growth and long-term health effects are unknown as is its comparative relationship to cigarettes. This study examines the relationship between cigarettes and e-cigarettes using a machine learning clustering algorithm and western blot procedure based on gene expression to understand patterns in pathways, genes, and chromosomes in users and its relation to tumor development. The western blot lab was expected to show an upregulation of all tested proteins. The clustering machine learning algorithm was expected to show similarities in gene expression between the e-cigarette and cigarette affected pathways. In order to gain results from the machine learning clustering model, output variables were assigned to the cigarette and e-cigarette data points based on the risk of developing tumor tissue. Results showed that the lung cancer proliferation pathway and gene Cyclin Dependent Kinase Inhibitor 1A (CKDN1A) were both highly involved in the tumor growth in both the cigarette and e-cigarette cluster. The clusters show the varying genes and pathways involvement in tumor growth for either e-cigarette vapor exposed cells or cigarette smoke exposed cells. The hypothesis was proven correct that fibronectin 1, phosphoserine aminotransferase 1 and GRAM domain-containing protein 4 were upregulated in the lab data (with p-values: 0.00016, 0.00000045, and 0.000000069 respectively). These results show that e-cigarettes and cigarettes affect the lung cancer cell proliferation pathway similarly and suggests further inspection of the effects of e-cigarettes on diseases like diabetes, colon cancer, and liver cancer.

Key Words: e-cigarette, machine learning, lung cancer proliferation pathway, proteins, western blot.

In recent years e-cigarette smoking among middle schoolers, high schoolers, and young adults has risen by about 57% (Manzoli et al., 2015) and the numbers are continuing to rise. So far, the effect of e-cigarettes on tumor growth is unknown as is its comparative relationship to cigarettes. This study examines the relationship between cigarettes and e-cigarettes using machine learning, data mining, and a clustering algorithm based on gene expression to understand patterns in how the different attributes -- pathways, genes, and chromosomal data are expressed. These comparisons reveal similarities and differences between cigarettes and e-cigarettes and make a suggestion towards whether e-cigarette vapor causes tumor growth.

In previous studies people have looked at how e-cigarette vapor varies from cigarette vapor in terms of toxicity (Andreoli et al., 2003). This study combines the mutations found in gene expression data from previous studies with lab data, collected through a Western blot, to give suggestive findings on tumor growth and e-cigarettes. We combine lab data on the regulation of 3 specific proteins, in 11 different cancer cell lines, with data mining on more general patterns of gene regulation to examine the effect of e-cigarette versus cigarette exposure on genes that may be involved in tumor growth.

While e-cigarettes were originally given to cigarette users trying to wean them off their addiction, the inadequate distribution and regulation of e-cigarettes is causing the usage of e-cigarettes to be abused and leading scientists into uncharted territory on the effects of e-cigarette usage and its long-term effects on the human body (Manzoli et al., 2015).

The Food and Drug Administration (FDA) has

established that e-cigarettes contain "detectable levels of known carcinogens and toxic chemicals to which users could be exposed." Because many people do not know the risks of e-cigarette vapor, strong protocols and measures have not been placed to regulate it, leading to an epidemic of e-cigarette use. In a fMRI study that tested the impact on advertising for flavored e-cigarettes on young adults, they concluded that "this preference [choosing e-cigarettes] was demonstrated in nonsmoking youth (early experimenters) who were susceptible to future e-cigarette use, suggesting a potential impact of advertising for flavors on youth initiation of e-cigarette use" (Kathleen A. Garrison et al., 2017).

This demonstrates the susceptibility of young adults to e-cigarettes which can negatively affect their growing body and brain. The negative effects of regular cigarette smoke on the human body have been well established. According to the Centers for Disease Control and Prevention (CDC), in the United States, cigarette smoking is linked to about 80 to 90% of lung cancer deaths. Cigarette smoke exposure has been linked to tumor growth in lung cancer patients. Tumor growth occurs due to abnormal gene expression and cell growth.

Hypothesis

Western Blot Lab Hypothesis

If a western blot is done with human bronchial epithelial lung cancer cells, then there will be a general upregulation in the amount of protein for FN1, PSAT1, and GD4 because they are part of a metabolic and biosynthesis pathway which is altered as the oxidative stress increases due to the aerosols in the cigarette smoke which changed the protein expression levels in the cell lysates of lung cancer, colon cancer, liver cancer, and breast cancer cell lines; furthermore, this research and its incorporation with the cluster analysis can see if e-cigarettes will follow the same trend as the cigarettes.

Machine Learning Algorithm Hypothesis

We predict that after applying a EM Clustering Data Mining Algorithm to our data set, we will see many similarities between the pathways, genes, and chromosomes, over indexed for the expression tumor growth in e-cigarette vapor and cigarette smoke exposed cells.

Expected Outcomes

For fibronectin 1 (FN1), the expected outcome is that this protein will be upregulated (an increase in the protein levels) in human bronchial epithelial lung cancer cells. This is because Fibronectin 1 affects the ribosomal protein S6 kinase pathway which is involved in regulation of cell proliferation and protein synthesis. Since lung cancer caused by cigarettes and e-cigarettes has been seen to increase oxidative stress which puts pressure on protein synthesis, this would cause a drastic increase in FN1 as it tries to balance out the regulation of the disrupted pathway.

For phosphoserine aminotransferase 1 (PSAT1), the expected outcome is that there will be increased expression of this protein in the human bronchial epithelial lung cancer cells. This is because PSAT1, when increased, causes decreased cell motility, which results in clumping of cells. In cases of lung cancer/disease PSAT1 have been seen to be greater than the baseline, which can cause these problems in cell motility and eventually, tumor formation.

For GRAM Domain Containing Protein 4 (GD4), the expected outcome is that there will be an upregulation of the protein levels in HBE lung cancer cells. GD4 works with the p53 protein to suppress tumor growth and demise, which is dramatically affected in lung cancer cells.

Procedure

In this study, we used data from the supplementary tables of two studies: "Reduced biological effect of e-cigarette aerosol compared to cigarette smoke evaluated in vitro using normalized nicotine dose and RNA-seq-based toxicogenomic" (Minet et al., 2017) and "Gene Expression Signature of Cigarette Smoking and Its Role in Lung Adenocarcinoma Development and Survival" (Landi et al., 2008).

Data Preparation

In order to prepare the data for segmenting it in homogenous groups for the machine learning clustering algorithm, we had to pick the same input and output variables for both (e-cigarette and cigarette) data charts. The input variables included in the Minet et al. data were Gene Symbol, Gene Description, Chromosome, Pathway, Gene Expression Abundance (the amount of gene already present in the lysate), the gene expression at 24 hours and at 48 hours, and whether the gene/RNA was upregulated

or downregulated. We correlated this data with data from Landi et al. that recorded not only gene expressions of cigarette smoke exposed cells, but also their relation to tumor growth (this data set is referred to as our “tumor data”). We did this to identify genes that showed a significant increase in tumor growth when up or down regulated.

Using the tumor data, we labeled all the genes in our own data set with a value from 1-3 for the attribute, "Relation to Lung Tumors". In this scale: 1 represents a gene which was not differently regulated in treated versus control cells, 2 represents a gene which was differently regulated, but had no association with tumor growth, and 3 represents a gene which was differently regulated and did associate with tumor growth.

Defining Outcome for Each Gene

Once we gave each gene a “Relation to Lung Tumors” value, we also gave each gene a “score”. A “score” of 1, means the gene is up or down regulated in our data, is rated at a value of 1 for relation to lung tumors. A “score” of 5 means the gene is up or down regulated and is rated at a value of 2 for relation to lung tumors. A “score” of 10 means the gene is up or down regulated and is rated at a value of 3 for relation to lung tumors. In addition to this, we created the final output variable which was the overall risk factor given for that gene. The overall risk factor determines if an upregulated, downregulated or unchanged gene is at low, medium or high risk for developing a tumor. The calculation of this risk is based on the combination of "Relation to Lung Tumors" and "Score" as shown in the index below.

Regulation	Relation to Lung Tumors	Score	Overall Risk Factor
Up	1	1	L
Up	2	5	M
Up	3	10	H
Down	1	1	L
Down	2	5	M
Down	3	10	H
No Diff	1	1	L
No Diff	2	1	L
No Diff	3	1	L

Figure 1: Key to Calculate Scores for Each Data Point

Behind the Expectation Maximization (EM) Clustering Algorithm

Clustering is a method of machine learning that iterates over a set of data points in order to group them into clusters that contain similar attributes. Clustering models can identify underlying relationships in a data set that cannot be seen through a human-driven analysis. In this study, we used a clustering algorithm to recognize affected pathways, overlapping gene expression, and tumor development expression among our 804 data points. Specifically, we turned to EM Clustering to help us make conclusions about our data. EM Clustering is an algorithm that both refines an initial cluster model to mold to the input data and also calculates the probability that a data point is present in a certain cluster. The algorithm concludes running when the probabilistic model made, fits the data. Using the Microsoft SQL EM Clustering Algorithm, we were able to cluster our data into 5 groups based on several attributes and calculate the likelihood of tumor growth based on each of the clusters.

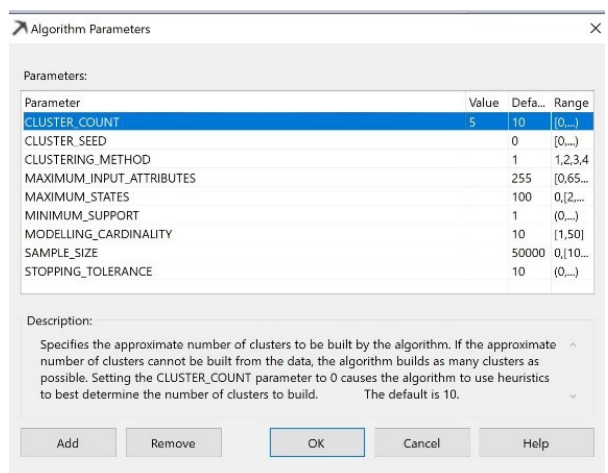

Figure 2 : E-cigarette algorithm parameter selection

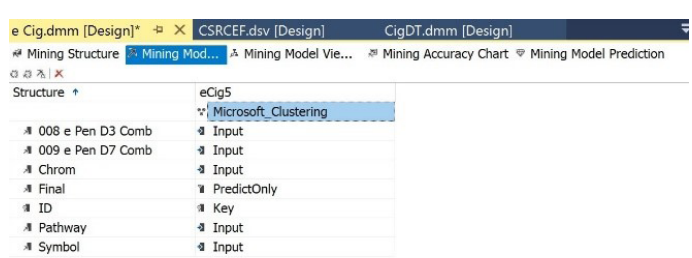

Figure 3: E-cigarette mining structure

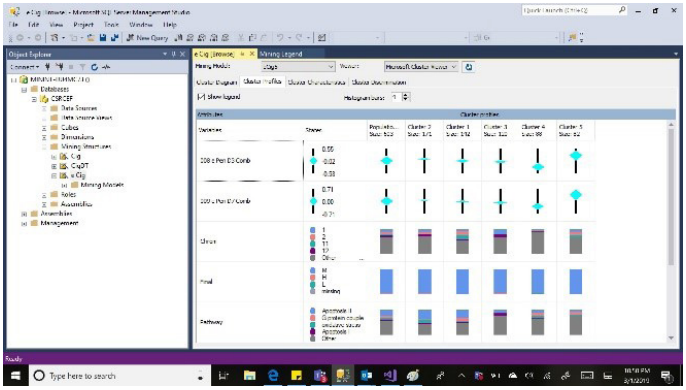

Figure 4: E-cigarette model viewer

Western Blotting

Western Blotting is a common process that detects and analyzes levels of proteins in cells. This process will help understand how certain proteins – fibronectin 1 (FN1), phosphoserine aminotransferase 1 (PSAT1), and GRAM domain-containing protein 4 (GD4) - are upregulated in multiple cell lysates, shown in figure 5. Furthermore, this process can enhance the understanding of how certain protein mutations affect specific biological pathways and if that can suggest any potential insight into relationships between the mutations and specific lung diseases. Western Blotting consists of 7 different steps: sample preparation, gel electrophoresis, blotting to a nitrocellulose membrane, antibody probing, detection, imaging, and analysis. All these steps need to be customized for the tested proteins and this will allow measurement of changes in protein levels after exposure to e-cigarette vapor.

Cell Line Name	Type of Cancer	Pre-existing Condition
A549	Lung cancer	Smoker
H2009	Lung cancer	Smoker
H460	Lung cancer	Smoker
H23	Lung cancer	Smoker
H1975	Lung cancer	Non-Smoker
H3255	Lung cancer	Non-Smoker
H1650	Lung cancer	Non-Smoker
MCF7	Adenocarcinoma from mammary gland	Unknown
HT29	Colon cancer	Unknown
SW260	Colorectal adenocarcinoma	Unknown
HEP2G	Hepatocellular carcinoma from liver	Unknown

Figure 5: Cell line information and order of cell lines in western blot wells

Gel apparatus setup

1. Make 500ml 1X running buffer from 5X stock
2. Fill inner chamber with buffer and outer chamber high enough to cover slit in gel and then load the samples.
3. Run gels at 20 mAmp each dye front reaches bottom of gel (about 1.5hr)
4. While gel is running rinse blotting materials
5. Make Transfer buffer
6. 10X Transfer Buffer, 10% MeOH
7. Equilibrate nitrocellulose in 1X Transfer buffer. Do not touch nitrocellulose, just touch blue paper.
8. Crack open plates with gel cracker, push down on gel poking out of slit.
9. Gently pull apart plates, try to get gel to lay on plate without slit, this will make orientation on nitrocellulose easier
10. Use sharp edge of gel cracker to trim off bottom thick piece of gel and wells.
11. Submerge scrubs and Whatman paper in water. Line up 1 scrub and 1 Whatman, place gel on top, then lay nitrocellulose down, make sure it is square with gel and rest of sandwich, place another piece of Whatman on top, then scrub. Slip cassette under sandwich, black side on bottom and clasp. Insert into transfer apparatus filled with 1X transfer buffer.
12. Transfer in cold room at 350 mAmp for at least 2 hours.
13. Block in 1% milk at least 20 min.

Immunoblotting Primary antibody

1. Make up antibody in 2 ml 1% milk (blocking buffer).
2. Put blot in seal a meal bag and add the antibodies.
3. Move blots to plastic containers and rinse with PBS. For the first rinse, make sure to keep the antibodies separate. Wash the blots in PBS for five minutes, twice.

Secondary antibody

1. Make up secondary in 1% non-fat milk, secondaries can be used at 1:10,000 so make up 10-20ml.
2. Incubate at least 40 minutes
3. PBS washes [3 washes, 5 minutes each].

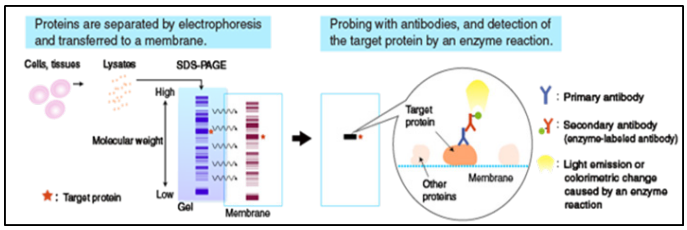

Figure 6: An example of a Western Blot and how to analyze its results.

Statistical Analysis

Western Blot Quantitative Analysis Procedure

1. Using ImageJ software, capture the area of each of the different bands for the selected protein using the Rectangular Square tool.
2. Then using ImageJ, calculate the area of each of the bands. Write this down in a data table.
3. Divide the antibody of interest (i.e. PSAT1, GRAMD4, or FN1) by the normalizer (GAPDH).
4. Then use the ratio in a standard one-sided t-test, to acquire the p-value score. If the p-value is lower than 0.001, then consider the changes in gene expression significant

Machine Learning Results Analysis

Our clustering and data mining methods provided us with insight into the overlap in e-cigarette vapor and cigarette smoke affected pathways. The majority of the highly significant genes ($p<0.001$) that were correlated to increasing tumor growth, differed between the two clusters. The overlapping gene that had a high expression index for tumor development was CDKN1A (cyclin-cyclin-dependent kinase). CDKN1A plays a role in the regulation of cell cycle progression and the p53 signaling pathway. Furthermore, we found that specifically the lung cancer cell proliferation pathway was over-indexed tumor growth and was found in both the e-cigarette and cigarette clusters that had a higher representation of tumor growth.

For cigarettes, we focused on cluster 5 which had the highest expression index for tumor growth (as seen in Figure 13). Genes PTGS2 and MMP9, as well as the glucose metabolism and inflammatory cytokines pathways had the highest expression in cluster 5 for cigarettes. For e-cigarettes, we repeated this process of finding the cluster with the highest expression index, which was cluster 3 (as seen in Figure 13). In this cluster, we found that the NFKB1 and JUN genes and the angiogenic growth factors as well as the oncogenes and tumor suppressors pathways, displayed high expression.

Western Blot Results Analysis

For the laboratory portion of our study, we were able to draw some significant conclusions from the results of our western blot, for all 3 antibodies. We found that proteins, Fibronectin 1 (FN1), GRAM domain protein 4 (GRAMD4), and Phosphoserine Aminotransferase 1 (PSAT1) were all significantly upregulated in smoker cell lines in comparison to nonsmoker cell lines ($p\text{-value}<0.001$). FN1 is most commonly involved in cell adhesion and migration processes like embryogenesis, wound healing, blood coagulation, host defense, and metastasis. It is involved in both the lung cancer and the oncogenes and tumor suppressor pathways. GRAMD4 is a mitochondrial effector of E2F1-induced apoptosis, or cell-death. This explains the key role of GRAMD4 in the apoptosis pathway. PSAT1 is involved in the glucose metabolism pathway; it affects the proliferation of cells. All 3 proteins have a direct relationship with cancer development and are seen to be upregulated in cigarette smoke caused lung cancer cells. This leads us to the suggestion that cigarette smoke can cause lung tumor development, a theory supported by years of research on cigarettes.

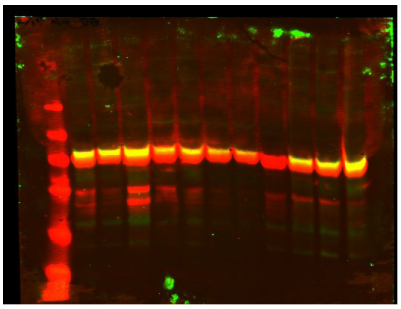

Figure 7: Western Blot of PSAT1 protein with control of GAPDH protein

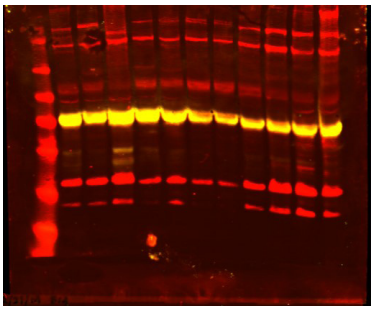

Figure 8: Western Blot of FN1 and GD4 protein with control of GAPDH protein

Genes	T-Test	P-Value	Mean	Standard Deviation	n-value
PSAT1	-10.507	$4.497*10^{-7}$	0.427	0.189	11
FN1	5.854	$1.608*10^{-4}$	0.675	0.313	11
GRAMD4	13.968	$6.922*10^{-8}$	0.254	0.177	11

Figure 9: Statistical Analysis Values for Western Blot

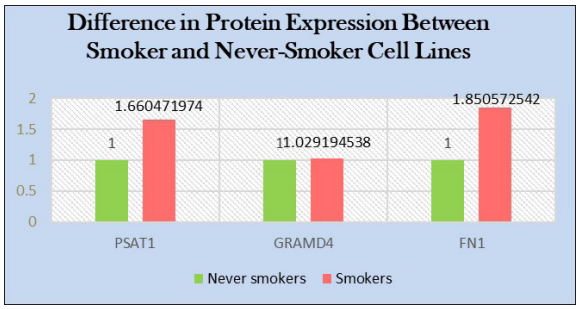

Figure 10: Graph representing the difference in protein expression between smoker and never-smoker cancer cell lines

Cluster	Top 5 Pathways	Index WRT whole Sample	Bottom 5 Pathways	Index WRT whole Sample
Cluster 1	Neurogenesis	3.25	G protein coupled receptors - S	0.35
	Apoptosis I	1.55	lung cancer	0.31
	Apoptosis II	1.52	common cytokines	0.00
	p53 pathway	1.51	glucose metabolism	0.00
	oxidative stress	1.02	inflammatory cytokines	0.00
Cluster 2	G protein coupled receptors	1.84	Apoptosis II	0.78
	Transcription Factors	1.47	lung cancer	0.65
	cancer	1.25	Apoptosis I	0.49
	G protein coupled receptors - S	1.10	glucose metabolism	0.00
	common cytokines	1.06	neurogenesis	0.00
Cluster 3	glucose metabolism	5.61	oxidative stress	0.66
	Apoptosis I	1.83	G protein coupled receptors	0.30
	Transcription Factors	1.82	common cytokines	0.00
	Signal Transduction	1.37	inflammatory cytokines	0.00
	lung cancer	1.34	neurogenesis	0.00
Cluster 4	common cytokines	2.89	Apoptosis I	0.53
	lung cancer	1.75	Apoptosis II	0.47
	G protein coupled receptors	1.70	Transcription Factors	0.33
	inflammatory cytokines	1.67	glucose metabolism	0.00
	tumor metastasis	1.57	neurogenesis	0.00
Cluster 5	glucose metabolism	7.71	p53 pathway	0.56
	inflammatory cytokines	3.50	Apoptosis II	0.55
	common cytokines	2.27	Apoptosis I	0.00
	G protein coupled receptors - S	1.87	neurogenesis	0.00
	lung cancer	1.83	Transcription Factors	0.00

Figure 11: Cigarette Clusters Resulting from EM Clustering

Cluster	Top 5 Pathways	Index WRT whole Sample	Bottom 5 Pathways	Index WRT whole Sample
Cluster 1	nephrotoxicity	4.30	Inflammatory response	0.00
	G protein coupled receptors	1.87	lung cancer	0.00
	tumor metastasis	1.54	oncogenes and tumor suppressors	0.00
	Apoptosis II	1.31	stress response	0.00
	Transcription Factors	1.28	TGFB signaling targets	0.00
Cluster 2	amino acid metabolism	3.47	Inflammatory response	0.00
	cell motility	3.47	nephrotoxicity	0.00
	cytoskeleton regulator	3.47	oncogenes and tumor suppressors	0.00
	oxidative stress	2.17	stress response	0.00
	Apoptosis II	1.57	TGFB signaling targets	0.00
Cluster 3	angiogenic growth factors	5.09	Inflammatory response	0.00
	oncogenes and tumor suppressors	2.54	nephrotoxicity	0.00
	lung cancer	2.30	oxidative stress	0.00
	cancer	2.06	stress response	0.00
	Breast Cancer	2.01	TGFB signaling targets	0.00
Cluster 4	G protein coupled receptors	1.98	Inflammatory response	0.00
	common cytokines	1.69	nephrotoxicity	0.00
	lung cancer	1.54	oncogenes and tumor suppressors	0.00
	oxidative stress	1.41	stress response	0.00
	p53 signaling	1.40	TGFB signaling targets	0.00
Cluster 5	Chemokines & tumor metastasis	6.99	angiogenic growth factors	0.00
	extracellular matrix and adhesion	6.99	cell motility	0.00
	Inflammatory response	6.99	cytoskeleton regulator	0.00
	stress response	6.99	nephrotoxicity	0.00
	TGFB signaling targets	6.99	p53 signaling	0.00

Figure 12: E-cigarette Clusters Resulting from EM

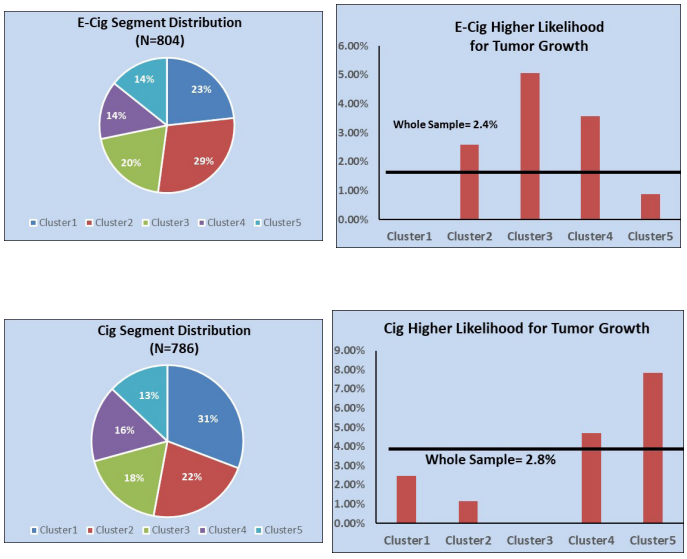

Figure 13: Clustering distributions and tumor growth likelihood for e-cigarettes and cigarettes

Conclusion and Discussion

Based on the significant data we studied in this project, we were able to make a series of conclusions about the effects of e-cigarettes on the human body compared to cigarettes and its relation to tumor development. Based on our clustering algorithm, the genes with high tumor growth expression seen in e-cigarette clusters, caused over-indexed tumor growth in the lung cancer cell proliferation pathway. This suggests that e-cigarette vapor may influence the progression of lung cancer, just as cigarettes have, even without tobacco content. For our lab data, we found that, as we predicted, all the proteins (FN1, GRAMD4, and PSAT1) were significantly upregulated in the smoker cell lines, when compared to the nonsmoker cell lines ($p<0.001$). This signifies that all these proteins can play a role in the development of lung cancer (and other cancers like colon and liver cancer) in smokers when compared to the data of nonsmokers. Since they are all involved in the lung cancer pathway, we can suggest that these proteins will have a similar response in e-cigarette users as well, because based on the cluster analysis, the lung cancer pathway gene expression changes are similar between e-cigarette and cigarette data.

In addition, we found that the gene, CDKN1A, was the key overlapping gene between cigarette and e-cigarette clusters. Both e-cigarettes and cigarettes displayed effects on the p53 signaling pathway as well as the regulation of the cell cycle at the G1 phase, both of which involve the gene CDKN1A. The G1 phase is a part of interphase, where the cell synthesizes mRNA (messenger RNA) and additional proteins, in preparation for mitosis (cell division). CDKN1A inhibits the activity of cyclin-cyclin-dependent kinase 2, therefore regulating the G1 phase. The CDKN1A protein is currently associated with disease like Gastrointestinal Neuroendocrine Tumors and Tongue Cancer, which suggests that e-cigarette and cigarette exposure tends to promote tumor growth, as supported with the high tumor expression indices found in our data.

We also found that in our cigarette clusters, genes PTGS2 and MMP9, were highly expressed, as well as the glucose metabolism and inflammatory cytokines pathways. Significant research on the glucose metabolism pathway has found that the growth of tumors reprograms this pathway and upregulates it to promote nutrient uptake for the cancer cells; research on inflammatory cytokines also suggests that tumor growth causes inflammation and as a result leads to an increase in inflammatory cytokines. Both these pathways are over-indexed in our cluster study which shows a direct correlation with a higher probability of developing cancer due to change in gene expression in these pathways. The PTGS2 and MMP6 were genes that we also found to exhibit high indexation for the development for tumors, and PTGS2 has a role in the inflammatory pathway and MMP6 has a role in the glucose metabolism pathway, which emphasizes the significance of these pathways tumor development affected by cigarette smoke. Because we found significance in the effects of e-cigarettes on the glucose metabolism pathway, there is room to study whether the use of e-cigarettes increases in the severity of negative impacts on diabetes patients.

Our e-cigarette data suggested the importance of the angiogenic growth factors, oncogenes and tumor suppressors pathways, and NFKB1 and JUN genes in the growth of tumors. Angiogenic growth factors were found to have a high index of expression in the e-cigarette cluster that is seen to promote higher amounts of tumor development; this growth factor pathway is known for leading to blood vessel restriction, blocking of receptors on endothelial cells, and reducing the immune response, all of which promote the growth of tumors in the body. The other pathway, oncogenes and tumor suppressors, was also over-indexed in the expression of tumor-inducing pathways, and this pathway directly relates with the development of tumors as it causes the upregulation and downregulation of genes that regulate the growth of cells. The NFKB1 and JUN genes were found to have a high index in the cluster that shows an increased expression of tumor growth, and since the NFKB1 and JUN genes are in the inflammatory response and tumor pathway and the angiogenic growth factor pathway, respectively, it furthermore supports our results in the relevance of these genes and pathways in the growth of tumors in e-cigarette exposed cells, and how it differs from cigarette exposed cells.

FN1 was involved in the oncogenes and tumor suppressors pathway, which can indicate that it may have a strong protein expression rate in e-cigarette users, potentially leading to the development of cancer. The other two proteins, GRAMD4 and PSAT1,

are involved in the apoptosis pathway and glucose metabolism pathway, respectively, and since this was not prominently found in e-cigarettes, it is not possible to state with full confidence that the results will be more emphatic in the e-cigarette exposed cells. Overall, due to the common pathway of lung cancer, it can be suggestively inferred that these three proteins will also be upregulated in e-cigarette cells and can potentially lead to tumor development. Although we don't know which element of e-cigarette toxicity is causing this tumor growth, it is something we can study in the future using these findings.

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Drug Combinations with Antibiotics and Curcumin to Combat Antibiotic Drug Resistance

Vidhi Jain, Aditi Ekbote

Abstract

Over 23,000 people die each year in the United States due to diseases caused by antibiotic-resistant bacteria. The purpose of this investigation is to compare a two-drug combination of antibiotics with a three-drug combination of antibiotics plus herbal medication in inhibiting the growth of E. coli bacteria. The hypothesis is that the two-drug combination will be more efficient in inhibiting the growth of E. coli when compared to the control plate with no drug and the three-drug combination. This is because Odoxil and Ciprofloxacin are water soluble, while Curcumin isn't which has antagonistic effects on the antibiotics when mixed together. The independent variable is the drug treatment type (two-drug, three-drug, or control); the dependent variable is the percentage change in the number of colonies. The E.coli grown on the plate exposed the three – drug combination to measure the effectiveness of Curcumin at killing bacterial colonies. E.coli colonies counted on the plate after 24 hours showed the final growth used then to calculate the percentage differences between the two and the three – drug combination. The percent difference in colony growth for each drug treatment: 98.95% decrease for the two-drug combination and 38.81% increase for the three-drug combination. Implications suggest that two-drug combinations of antibiotics with the same mechanism of action work best in inhibiting E. coli growth, improving the issue of bacterial growth.

According the Centers for Disease Control and Prevention (CDC),over 23,000 people die each year in the United States alone due to antibiotic-resistant infectious diseases caused by bacteria such as E. coli and S. aureus. Worldwide, however, this problem is even more alarming - especially in the developing world; in India, for example, upwards of 58,000 babies die each year because of antibiotic-resistant diseases. Bacteria are able to evolve and survive the toxic effects of antibiotics (Antibiotic, 2018). These surviving bacteria then multiply, the newer generation of bacteria also gain the immunity to antibiotic drugs. This process is known as "horizontal gene transfer". This means that new antibiotics have to keep being created, many of which have many debilitating side effects (Barlow, 2009). As per The Antibiotic Resistance Crisis by the National Center for Biotechnology Information (NCBI), the causes for the widespread antibiotic drug resistance problem are due to: an overuse, inappropriate prescription, and a lack of new and emerging antibiotics in the market. A potential solution to this problem lies in various drug combinations between existing antibiotics and even herbal remedies (Worthington, 2013). Research from reputable organizations, such as the European Molecular Biology Laboratory in Germany, has shown that a combination of several antibiotic drugs have effects that combine to reduce bacterial growth (Embl). Two important concepts with respect to drug combinations are: synergistic and antagonistic relationships between drugs. Synergism occurs when drug interactions cause an increase in the effectiveness of at least one of the drugs. Additivity occurs when the total effects of the combined drugs equals the sum of the effects of each individual drug. Synergism can happen when the drugs have different mechanisms of action, and additivity can happen when the drugs have the same mechanism of action. The Johns Hopkins University has done research on the anti-oxidative and antiseptic abilities of plant-based medications traditionally used in Ayurvedic and old Chinese cultures to stop bacteria from propagating (Complimentary). This project seeks to compare a two-drug combination of antibiotics to a three-drug combination of the antibiotics plus a herbal medication - Curcumin - in inhibiting the growth of E. coli bacteria.

Methods

Materials

Ethanol (20ml) × 1	$1.00
50 mL Falcon tube (7x) × 1	$4.00
Coffee Filter Pack × 1	$3.00
15 Petri dishes × 1	$3.00
LB Agar Media × 2	$4.00
Whatman Filter paper × 1	$1.00
Miscellaneous lab ware (Gloves, Pipette tips, etc.) × 1	$1.00
Researcher Membership - 1 month × 1	$50.00
Odoxil and Ciprofloxacin Antibiotics	$5.00
Beakers, pipettes, gloves, and lab coats	$0.00
TOTAL:	$72.00

Procedure

Labeling the Plates: (Lokesh, 2000)

Label the three plates accordingly:

a. The plate with the control (no drug, just nutrient agar) should be labeled as "Control Plate"

b. The plate with the two-drug combination of Odoxil and Ciprofloxacin should be labeled as "Two-Drug Combination"

c. The plate with the three drug combination of Odoxil, Ciprofloxacin, and Curcumin should be labeled as "Three-Drug Combination"

Preparing Antibiotics Procedure: (Smith, 2015)

For Odoxil and Ciprofloxacin

Find the minimum inhibitory concentration of Odoxil and Ciprofloxacin:

1. Weigh 10 tablets of each antibiotic
2. Using a mortar and pestle, crush the antibiotic tablets into a powder
3. Weigh the amount of the powder equal to 1/10 of the weight of the 10 tablets to get the weight of one tablet
4. Dissolve this amount in 100 mL of distilled water to obtain a concentration of 2500 ug/mL.
5. Take exactly 1.4 mL of the solution and, using distilled water, dilute it to a total of 100 mL (the concentration of the new solution will be 35 ug/mL)
6. Repeat this process for the second antibiotic

For Curcumin (Barve, 2018)

1. Weigh 10 grams of turmeric powder and place in a heating vessel
2. Vigorously stir the powder with 100 mL of coconut oil
3. Put the heating vessel over a flame for about 7 minutes, or until the oil becomes an even liquid
4. Take the vessel off the flame and let all the undissolved solids settle down
5. When all the solids are settled at the bottom, they should look yellow in color and this is the curcumin that was extracted from turmeric powder
6. Remove the solids and put into a container
7. When it is time to conduct the combinations testing, gently place the solids into plastic tubes that can withstand heat
8. Place the tubes with the solid curcumin into a water boiler until the boiler reaches 80 degrees Fahrenheit so that it can become a liquid again
9. After the boiler reaches 80 degrees F, take the tubes out.

Pouring and Storing Prepared Plates: (Sander, 2012)

1. Take 0.3 mg of Agar powder and mix it with 20 mL LB Agar Broth, repeating this for 3 different tubes
2. Place these tubes into an incubator for an hour
3. After one hour, take out the tubes, and, in a sterilized environment, use a stirrer to put .33 mg of the E. coli solution into each of the tubes
4. Pour the solution from each of the three tubes into the three different, empty, and labeled petri dishes
5. Using a sterilized glass stirring rod, carefully create wells by poking holes about 1 inch apart in the center of the plate
6. Use the two-drug combination mixture and pipette three drops into the respectively labeled plate
7. For the three-drug plate, pipette three drops of the two-drug combination and then pipette three drops of the curcumin extracted liquid into the respectively labeled plate
8. Seal and store the control plate (has no drug treatment)
9. Invert each of the plates and incubate for 24 hours
10. After 24 hours, carefully remove the plates and examine under the microscope and take pictures.

11. In addition to the Odoxil and Ciprofloxacin antibiotic disks previously prepared, add the Curcumin into the agar

End of Experiment

1. Ensure that all data is recorded in the data table
2. Perform calculations on the data table.

Risk and safety

The hazardous substances that used in this project are: the antibiotics Odoxil and Ciprofloxacin, non-infectious E. coli colonies, and curcumin in the form of turmeric powder. Potential risks with respect to these substances include: the spread of Ciprofloxacin and Odoxil resistant bacteria in the environment if the E. coli (BSL -1) are not disposed of safely. Additionally, ingestion or contamination by the three drugs may result in toxic side effects if precautions not taken or not properly suggested medical professional. The safety precautions taken during this experiment are: long hair being tied back, the use of pipettes, lab coats, gloves, pipette tips, goggles, and masks. Additionally, all hazardous materials such as the bacterial agents will be disposed of using an autoclave and all lab materials will be thoroughly cleaned and sterilized using bleach. Proper instructions will followed using a lab manual and with help from a lab manager.

Conclusion

The purpose of this investigation is comparing two-drug combination of antibiotics with three-drug combination of the antibiotics plus a herbal medication in inhibiting the growth of E. coli bacteria. The hypothesis is that the two-drug combination will inhibit the growth of E. coli when compared to the control plate with no drug and the three-drug combination because the antibiotics Odoxil and Ciprofloxacin have water solubility, while Curcumin doesn't. Curcumin will have antagonistic effects on the antibiotics. The hypothesis that the two-drug combination will have significantly less E. coli growth compared to the drug treatments was proved by our results - the percent difference in colony growth for each drug treatment was: 98.95% decrease for the two-drug combination and 38.81% increase for the three-drug combination.

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Identification of Potential Drug to Drug Interactions in the Cardiovascular System for Drugs from the European Union Using Machine Learning Algorithms

Tarini Srikanth

Abstract

As of 2018, 7,000 deaths occurred per year due to Potential Drug to Drug Interactions (PDDI's)alone. PDDI's can result in health complications, as 41.6% of prescriptions have at least one harmful PDDI, causing anywhere from 3.3 to 30% of hospitalizations a year in the US. Therefore, in the US, advancements have been made to decrease this number, with the creation of the National Institute of Health's (NIH) PDDI database which helps US citizens get access to important PDDI information. However, not a lot of countries have the means to identify their own country's PDDI's.This leads to the purpose of this project, which is to expand the scope of access of PDDI's to other countries, specifically focusing on the European Union. Using the Anatomical Therapeutic subgroup (ATC Code), a universal drug identification system which includes a drug's target organ and active substances, a non-US drug can be associated with the closest US drug, as similar drugs between countries will have similar ATC's. Using machine learning, through Excel and SQLite (a data manipulating software), a score can be calculated for each ATC, and a non-US drug can be mapped to interactions found in the NIH's PDDI database. A total of 46,500 interactions were identified for the Cardiovascular System, with a total of 53 risk types. Risk types, or factor analysis determines the factor is the most impacted by drug interactions. The two most common factors were a 47.8% prevalence of metabolism increase or decrease, and a 21.5% increase or decrease in serum (blood) concentration. Being conscious about potential interactions and creating awareness about the early detection of PDDI's can lead to lives saved, fewer hospitalizations, faster recovery and an overall healthier society.

Not being aware of adverse Potential Drug-to-Drug Interactions (PDDI's) can be extremely harmful to an individual's health, both for short and long-term time spans Research from the NCBI, National Center for Biotechnology Information database has shown that over 41.6% of prescriptions had at least one harmful potential drug to drug interaction. Furthermore, the Food and Drug administration released information that showed that PDDI's cause anywhere from 3.3% to 30% of hospitalizations a year in the US alone. Creating awareness and early detection of PDDI's can lead to improved outcomes: lives saved, fewer hospitalizations, faster recovery and a healthier society. Due to the lack of funding from the government, their citizens are not fortunate enough to have a fully developed drug interaction system and laws and processes that mandate precautions. A potential solution to this problem to increase the awareness of potential drug to drug interactions in developing countries is by using the data from the United States drug information system. The US has a well-developed drug information system called RxNav, which is funded by the National Institute of Health (NIH) and the US Government. This system which is available to the public, allows for users to access a variety of information on a specific drug, including its dosage, manufacturer, chemical composition and most importantly, drug to drug interactions. To develop a system like this for every country that doesn't have one is a great venture for the future but will take decades and great amounts of funding to complete. A near term, and possible immediate solution would be to map drug properties between different manufacturers across different countries and compare them to drug interactions found within the US drug information system. Drug manufactures across the world in collaboration with WHO, have established a hierarchical classification system to organize the all prescription drugs. Each classified drug has an Anatomical Therapeutic Drug Code, ATC for short, which details the drug's organ or organ system they bind to, the active substance's properties, and therapeutic subgroup, (like cardiovascular system or blood forming organs), and the

drug's daily dosage all in one code. Between countries, most drugs manufactured for similar purposes, have similar chemical compositions. However, these drugs are branded and packaged differently, making it very difficult to assess drug information on a foreign dataset. Hence, a drug's ATC code can be used to determine similar and/or identical drugs manufactured within and outside of the US.

Literature Review

This article seeks to study the relationship between pharmacokinetics (the branch of pharmacology that studies chemical metabolism and the elimination from the body) and pharmacodynamics (the study of biological effects of drugs on human and microorganisms). In this study, both the pharmacokinetics and the pharmacodynamics for the drugs were previously known and documented. The assumption was that drugs with similar 2D chemical structures will have similar drug interactions. These chemical structures include target proteins, enzymes, and transporters. With these chemical structures, this study created a logistic regression graph. From this logistic regression, the study can then find similar drugs and therefore, similar drug interactions. This study was not conducted on any humans or animals, as it was a computational study. Similar to the project I seek to study, this study is examining the various techniques used to identify potential drug to drug interactions. This study is also using a similarity-based system to predict drug interactions. Ideas of logistic regression, similarity index and clusters are similar between the two project ideas. To improve the accuracy of these predictions, my projects aims to use ATC codes, which are unique to certain groups of drugs, and hopefully eliminate false positives from occurring

After the data was accessed through a variety of databases (PubChem substance and compound database) the researchers sorted out the drugs based on their pharmacokinetics and pharmacodynamics subgroups. These data values were then compared to each other in the database and grouped based on similarity. Each similarity grouping is associated with certain known drug interactions, so as new drugs are introduced into this system, they will be grouped into the closest similarity and predict their drug interactions. Results were then compared by interquartile ranges for the dataset. The results shown prominent potential in predicting drug to drug interactions. One interesting note that this study found is that even with a dissimilar pharmacokinetics and pharmacodynamics 2D structure, many drugs can have similar drug interactions. This may be because of similar chemical function and metabolism between drugs, which decreases the accuracy of the drug to drug interactions prediction. The study's main finding was that the structure of chemical metabolism is significantly important in identifying drug to drug interactions, but not a decisive factor.

Takeda, T., Hao, M., Cheng, T., Bryant, S. and Wang, Y. (2018). Predicting drug–drug interactions through drug structural similarities and interaction networks incorporating pharmacokinetics and pharmacodynamics knowledge. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5340788/

This study seeks to study the relationship between a drug's ATC code, and its availability on RxNorm, a US governmental database that highlights drug interactions for specific drugs. ATC codes have specific meanings to their structure. The ATC code is comprised of anatomical subgroup, therapeutic subgroup, and daily dosage based on the adult weight of 70 kg. This study seeks to judge the scopes of ATC codes in the RxNorm database through the mapping of ATC codes. RxNorm has a system where each ingredient or drug is represented only once in their database, while ATC codes have multiple codes for different drugs based on their therapeutic groups. Because of this, there will often be multiple ATC codes for a given RxNorm mapping. There were no human or animals used in this study. My project is heavily dependent on ATC codes as well as the RxNorm database. For my algorithm, the ATC codes are what define the similarity between the drugs, so my algorithm is based on the similarity in ATC codes between two drugs. Furthermore, RxNorm is a credible and accessible database that provides drug interactions for US country drugs. With the drug's ATC code and drug interactions provided by RxNorm, the similarity between the drugs can be identified and so can their drug interactions. The amount of ATC codes concentrated in RxNorm is critical to my project, as the information provided by RxNorm's drug interactions and ATC codes are crucial to the success of the prediction algorithm.

In this study, the ATC mapping was restricted to single ingredient clinical drugs. In RxNorm, there is a system for single ingredient level mapping, which

was used in this study. In RxNorm, the administration route (tablet vs syrup) is expressed by the Dose Form Group (DFG). In ATC codes, the administration is expressed by 22 codes. Using this information, the researchers mapped all off the DFG's to the ATC administration codes. For drugs that do not have a specific daily dosage, the researchers in this study used methods like assigning administration codes based on ATC code levels. This study found that 68% of the RxNorm database had complete mapping to ATC codes. The study also found that RxNorm categories all 22 of the ATC code administration codes, so each DFG from RxNorm is associated with an ATC administration code. As for ATC codes in general, 28% of them are missing an administrated code, which RxNorm did not classify. Throughout the entire RxNorm database, 97% of the drugs were mapped to at least one ATC code, through the main ingredient and administration codes. Moreover, 95% of the RxNorm drugs found in the database were also found in drugs associated with a specific ATC code. The main result found through this study was that drug ATC codes were thoroughly represented in RxNorm.

Olivier Bodenreider, L. (2018). Analyzing U.S. prescription lists with RxNorm and the ATC/DDD Index. [online] PubMed Central (PMC). Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4419961/ [Accessed 20 Dec. 2018]. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4419961/

Materials

1. RxNorm Database
2. EU Commission Database
3. Pandas and String libraries from Python
4. MySql Database (for storing and manipulating the data)
5. Computer
6. Kmeans and KNN machine learning algorithms, Sci-Kit Learn

Procedure

1. Explore hospitalization record to identify which specific drugs are the cause of most hospitalizations, and find one or two drugs categories that are the have the most adverse drug reactions (The prediction algorithm below will be restricted to these drugs)

a. Decide which area to research based on the ATC codes of the drug. Since the first letter stands for the anatomical subgroup, choose 2-3 anatomical subgroups to analyze for this project.

2. Gather data and format it in a readable manner to the computer.

a. 2 data sets are involved in the data analysis of this project

i. RxNorm and RxClass Dataset: This database details all the prescription drugs in the United States, and includes data on their ATC code, chemical composition and drug interactions, along with the severity of those interactions. Data can be accessed here: http://ec.europa.eu/health/documents/community-register/html/atc.htm

ii. European Commission Drug Data: Drug data for all the countries in the European Union, detailing the drug's ATC Codes, and chemical composition, but not drug interactions, (as many countries do not have the funding to catalog and identify their drug interactions). Data can be accessed here:

b. Transform the data using Python and file reading software

i. Standardize the data, make the units and data types are comparable between the two data sets

ii. The data should be formatted with rows for each drug, and columns indicating the drug's ATC Code, chemical composition, daily dosage, manufacturer and drug interactions. Any unknown value for the drug should be named "N/A"

1. Converting all the different units to a standard unit, and a standard data type. Standardize the data to the following rules.

a. ATC Code will be of type: String

b. Daily dosage will be of type: Integer

c. Units for the daily dosage of solids will be: Milligrams

d. Units for daily dosage of liquids will be: Milliliters

e. Chemical composition and drug interactions: String

iii. Parse that data to eliminate everything else except the drug data

1. Using python's String and Pandas (a table manipulation library) methods identify the ATC Codes and drug interactions of the datasets and isolate them from the rest of the miscellaneous information in the datasets, to achieve a clean and error free dataset to start the analysis on.

2. Based on the dataset, identify which type Machine Learning algorithm will be most fit

a. 2 types of Machine Learnings:

i. Supervised: Predictions from the machine will be in the form of a named identity. (ex: name of the drug interactions)

ii. Unsupervised: The machine learning predictions will group different objects into categories (algorithm will not return a name or object, will group items together based on their properties)

iii. For this project, a combination of unsupervised and supervised learning will be used. Unsupervised learning will be used for clustering algorithms to group similar drugs together. Supervised learning will be used to identify the known interactions, after grouping the new drug into a cluster.

4. To group drugs into clusters, the drug properties must be quantified in some manner. In this project, this encoded value will be determined by the following factors.

a. This encoded value is determined by:

i. The ATC Code

1. The different subgroups can contribute to an improved identification
2. There are 14 different anatomical subgroups (the first digit of the ATC Code)
3. The second element consists of 2 digits, representing the therapeutic subgroup
4. The third element represents pharmacological subgroups and consists of one letter
5. The fourth level consist of chemical subgroup and consist of one letter
6. The fifth level consists of 2 digits, representing the chemical substances

a. Encoding each drug into a numeric representation is critical to group similar drugs together. To calculate the encoded value of a drug, there will be a cumulative number, representing the drug's ATC code. Digits will be calculated as digits, and letters will be represented by their respective number in the alphabet. For example, A=1, B=2. These numerical values will then be multiplied and added together to achieve a single number.

b. Each element will be weighted from 1-5 using a linear weightage system. Element 1 will get the highest weightage of 5, element 2 will get a weightage of 4, and so on. Based on experimentation, a different weighting algorithm like an exponential may be applied.

c. The encoded value will be mainly based on the ATC Code, but other factors including the following (if included for the information of the specific drug) will improve the accuracy

i. Dosage

ii. Drug delivery (tablets vs syrup)

iii. The Secondary Chemical Composition

1. When the ATC Codes are identical, the secondary chemical composition will help to differentiate between similar and truly identical drugs 5. Repeat step 4 for every drug in the database

a. This can be more efficiently done using a for loop to run through the entire database, and create values in a list, corresponding to the drugs in the database.

5. Verify that an encoded value is created for every drug in the database

a. This can be done by comparing the number of values that was just computed with the number of drugs in the database, to see if they match. The number of unique drugs in the database should match the unique encoded values computed.

6. Once all the encoded values are created, the distances between drugs need to be computed. Calculate the distance between all the US Drugs and all the Out of Country drugs

a. This can be done using the distance formula:

$$\sqrt{(\text{Drug 1 encoded value})^2 - (\text{Drug 2 encoded value})^2}$$

b. This will calculate the distance between any two drugs, , repeated for the number of drugs there are in the database.

c. Save these distances in a list, making sure to keep track of which two drugs are corresponding with which distance.

7. Once the distances are calculated, decide what machine learning algorithm to use

a. K means clustering algorithm

i. https://en.wikipedia.org/wiki/K-means_clustering

ii. https://en.wikipedia.org/wiki/K-nearest_neighbors_algorithm KNN

8. The smaller the value of distance, the closer the drugs are to each other

a. This is called the similarity index, or the degree of similarity one drug is to the other drug. For this project, the similarity index runs on a scale between 0 and 1, the closer the number is to 0, the higher the similarity.

b. Convert the distances calculated in step 8 into a scale of 0 to 1, setting the highest distance value to 1, and the lowest to 0, and scaling the remaining values from there to match the 0 to 1 scale. This can be done using log transformation.

9. Decide the criteria in which new clusters and groups should be made

a. Each cluster should have a cutoff point based on the similarity index, as to when to break off into a new cluster

i. For this project, clusters will be grouped based on the difference of 0.05 in similarity index. This will yield 20 clusters for the entire database.

10. Once the criteria are decided for the clusters, group the data into their respective cluster

a. Place all drugs of a 0-0.05 similarity index is one cluster, another cluster for 0.050.1, similarly, until the similarity index reaches 1. The clusters will be based off 0.05 differences in the similarity index.

11. Once this step is completed, identify the US drugs in each cluster. Each cluster should have at least one US drug. As the clusters were based off the similarity index, the US drugs in each cluster should be identical or very similar to each other.

12. Once the US drugs have been identified for each cluster, search through the database and identify the drug interactions for those drugs in each cluster.

a. When there are multiple US drugs in the same cluster, identify the drug interactions for all the drugs, and save them in a list.

13. At this step, there should be a list of drug interactions for each cluster in the algorithm. After this is done, sort through each of the drug interactions lists and remove repeated drug interactions.

a. This is the final drug interaction list for each cluster. The amount of drug interactions corresponding with each cluster will vary depending on how many US drugs are present in the cluster, as well as the number of drug interactions those US drugs have.

14. After all the clusters and related drug interactions have been made, a test for this algorithm will be applied.

a. To test this algorithm, enter in US drugs that have known drug interactions and verify that the algorithm releases the correct information

b. Test out of Country drugs that have known drug interactions based on the cluster that they landed in and see if the algorithm is correct

c. Keep record of which drugs the algorithm displayed correctly, and which drugs the algorithm did not display correctly. (Make sure to keep record of what the algorithm did wrong)

i. Go back through the code and try to fix the mistakes that the algorithm gave.

15. At this point, the algorithm should be as accurate as it can be.

16. The following will be procedure for when a new drug, with no known drug interactions is entered into the database, including the drug's ATC Code.

a. Using the drug's ATC code, calculate the point-based value for the drug

b. Using this value, identify the drug's similarity index in relation to the other drugs

c. Use this similarity index to place the new drug into an existing cluster

d. Using the drug interactions corresponding with the specific cluster output the drug interactions for the new drug.

Data Analysis

a. The testing for this algorithm must be based from known interactions

b. Create a random sample of known, RxNorm drugs

c. Random number generator will be used to determine how many drugs are inputted and which drugs are inputted. Get the corresponding drug interactions for each drug used from RxNorm.

d. After this is done, the output from the algorithm should include the RxNorm drug interactions

e. This algorithm can have more drug interactions as the algorithm is outputting a cumulative drug interactions list.

f. A percentage calculation would be calculated by comparing the RxNorm drugs and the drugs that the algorithm produces.

g. Calculated by:

i. ((Number of correctly identified drugs based on the predictor)- (Original
Drug Interactions identified by the corresponding US drugs))/ (Original Drug Interactions identified by the corresponding US drugs) Health and Safety:

There are no human participants in this project. All data used is through open access and is anonymous.

Conclusion and Future Study

The algorithm accurately represents the drug interactions for a specific non-US drug. The ATC mapping, matching a non-US drug to a US drug has a 100% accuracy rating, as all the non-US drugs are associated with a US drug, either directly matching or closest ATC. After the interactions were developed, an average of 1,017 drug interactions were found for a single drug. After developing the drug interactions, a more

thorough analysis can be performed, with risk factors. Risk factors can be determined by keyword matching and categorizing, to find that the 2 most common risk types, were metabolism increase or decrease, and Serum concentration increase or decrease. Future goals would be to expand algorithm to more drug systems as only Cardiovascular is being analyzed as of now. Additionally, creating better graphic to display the interactions, including search menus and dropdown options. Also including all the US interactions into the specific country's drug names, making each interaction specific to each country, expanding the algorithm to analyze more country's drugs and analyzing more risk factors and create a more thorough analysis of the factors.

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Neurosciences

Implementing Cognitive-Behavioral Therapy and Mindfulness Principles Within an App to Improve the Mental Health of Refugees

Roshni Srikanth

Abstract

15-40% of all refugees and 50-90% of refugee children suffer from severe mental health problems such as PTSD and depression. This problem is exacerbated by the lack of access to proper mental health care facilities in refugee camps, as well as the stigma around mental health. The purpose of this project is to develop an app to manage and improve the mental health of refugees facing traumatic stress by engaging the user through a series of questions, periodic notifications and progress badges. This app builds upon the current methods used by mental health practitioners in refugee camps by increasing accessibility to mental care while ensuring user privacy, thus providing a self-service capability with long-term progress tracking for the user. This prototype was built using C++ in Visual Studio and tested for both efficiency and a Net Promotor Score (NPS) in order to determine user friendliness and market feasibility. Survey questions were defined across 5 different dimensions using a Likert scale. A chi-squared test was performed on the data, with an expected value of 2.5 with 5 degrees of freedom. The goodness of fit chi-squared test resulted in a value of 1.6, which is less than the critical value of 7.82 for $p = 0.05$. This result shows that the app is both user friendly and feasible in the market, paving the way to improve the mental health of refugees in the future.

In our world today, there are 65.6 million refugees forcibly removed from their homes because of war and other life-threatening conditions. Refugees are faced with a multitude of challenges as they make their way to host countries where they seek asylum. Sadly, even at refugee camps, their troubles have not yet come to pass. In many refugee camps around the world, 10 out of 100 children are malnourished. Diseases like Hepatitis A and cholera run rampant, and rape and violence against children are frighteningly common. In addition to these difficulties, many refugees are faced with growing incidences of mental illness. According to one study, 55% of Palestinian refugees living in Lebanon are psychologically distressed (Habib et. al 2012), with most largely going undiagnosed or being ignored completely. There is also a strong correlation between poor mental health and poor living conditions, with an average odds ratio of (1:53) (Habib et. al 2012)

Outside of the context of refugees, apps have been used as a proxy for the treatment of mental illness for a long time. Mental health apps are largely preferred for rural communities as they are widely accessible, easy to use, and provide the user with a flexible schedule. Although many mental health apps have not been tested and do not have empirical evidence, studies analyzing mHealth apps relating to psychotherapy have shown that features like symptom monitoring, Cognitive Behavioral Therapy (CBT) recommendations, and positive reinforcement were all effective. (Lui et. al. 2017) This project incorporates a 5-item survey, CBT activities, positive reinforcement, and long-term answer visualization in an app to help refugees improve their mental health.

Literature Reviews

Palestinian refugees have been displaced to Lebanon for over 60 years. They face many challenges including poor living conditions, discrimination, and many economic disadvantages. This study examined the physical and mental health, as well as the living conditions of Palestinian refugees currently living in Lebanon to determine trends in the data set. The investigation was conducted on a representative sample of refugees. A proxy respondent from each household was interviewed, providing the responses for all members of the household when applicable. Trained social workers were sent to each household along with a structured questionnaire that contained questions about health, housing conditions, expenses, illness, and other factors.

These social workers conducted interviews and also performed assessments of mental health using a 5-item mental health inventory. The data was analyzed using logistic regression to determine trends between factors.

Out of the 2501 households that responded to the survey, 52% of the respondents had chronic illness, 28% had acute illness, and 55% of all people interviewed were psychologically distressed. The prevalence of poor mental health increased with a crowded home, the presence of water leakage, low levels of household assets, and illness. As shown by this study, mental health problems are becoming increasingly prevalent, and to combat this, accessibility to mental health care must be improved. (Habib et. Al, 2012)

Although the levels of mental health have been well recorded among the individuals and children of the refugee population, few studies have been conducted to investigate the effect of maternal traumatic distress of refugees on family functioning and the mental health of children. This study investigates how traumatic stress in mothers can detrimentally affect family life. For this study, 327 South Asian refugee families (from Vietnam and Cambodia) were chosen to participate in a set of interviews. These interviews were based off of a questionnaire that was used to assess parent/child relations, involvement, depressive/antisocial behavior, problems in school. And may other factors. The data was then analyzed to determine trends.

The results of this study show that children, regardless of ethnicity, are detrimentally affected by maternal traumatic distress. But children born in the US, and outside the US were affected at different levels. After accounting for changes in family cohesion, maternal traumatic distress was associated with depressive symptoms and antisocial behavior. Mental health problems can be passed down through generations, even affecting the children who have never faced trauma. Effective tools are needed to help combat the effects of traumatic distress in order to prevent these problems from passing through the generations. (Sangalang et. Al., 207)

Engineering Goals

Develop an app that will manage and improve the mental health of refugees facing traumatic stress through:

1) Symptom Monitoring: prompting the user to answer questions three times a day using push notifications to remind them to answer the questions. Over time, the data will be visualized in a graph showing the user's progress.

2) A quick screening test: research has shown that a simple, 5-part questionnaire is relatively reliable when screening for common mental disorders. This test will be used to determine the activities that the users will be directed to perform.

3) Users will be directed to preform activities to help improve their mental state, like mindfulness or CBT activities and will earn progress badges for the activities they complete.

4) Users will be able to easily operate the app, and the app will implement a simple, straightforward interface that can be used without specific training.

Procedure

1) Conduct thorough research into app market, refugees and apps, and mental health treatment in apps and document research into log book.

2) Layout flow and procedure of app, including features and UX.

a. Write down a list of the core features of the app.

b. Using paper or a wireframe sketching program, design the frames that the user will see when using the app.

c. Use arrows to connect screens, and write down which features will be shown on each of the different screens of the app.

3) Through programming with Java in Android Studio, create an app that integrates all the features listed in the wireframe. This will be the prototype.

a. Download and install Android Studio from https://developer.android.com/studio/.

b. Download and install the Java Development Kit (JDK) from https://developer.android.com/studio/.

c. Create a new project, and using Java, program the core features in the app.

d. Using the emulator, run the program to test for syntax and runtime errors.

4) Design background of the app, including cloud connections, databases, user accounts, privacy, and safety.

a. Use android packages found at https://developer.android.com/reference/packages as a resource

to implement cloud connectivity, user accounts and data storage.

b. Integrate user privacy policy and develop safety features into app background using Android APIs and packages found at link above.

c. Define which data will be stored on the cloud, linked to user's account, and which data will be stored locally on the device without being synced to the cloud.

5) Redraw wireframe and refine user experience, including the services which will be running in the background as part of the diagram.

a. Using paper or a wireframe sketching program, design the frames that the user will see when using the app.

b. Use arrows to connect screens, and write down which features will be shown on each of the different screens of the app.

6) Describe tests for app, keeping in mind the edge cases, and run the prototype through rigorous testing.

a. Design tests for users:

i. Without access to WIFI

ii. Who speak different languages

iii. When developing app, keep in mind cultural norms and stigmas against mental health

7) Iterate through steps 6 and 7 and continue until all edge cases are met and the app is complete.

8) Design a survey for quantifying user friendliness

9) Conduct the survey by asking people to explore the app's features and rate the user friendliness on a scale from 1 to 5.

a. Create a list of all known contacts above the age of 18 who have agreed to be a part of this survey, and assign numeric values to each of the contacts

b. Using a random number generator, randomly select ¾ of the contacts to participate in the survey

c. Give all participants in the survey an informed consent form and have them sign it.

d. Ask the participant to explore all the features of the app, providing a checklist of all the screens they need to view.

e. Once the user has navigated through all screens of the app required by the checklist, ask the user to rate the ease of navigation, the ease of understanding, and the ease of use on a scale of 1-5.

f. Ask the user to provide any feedback or suggestions for improving the app design.

Data Analysis

Calculate mean, median, mode, and standard deviation of the data set. If the mean and the median are both above 2.5, and the standard deviation is below 1, (using the range rule) the app has passed the tests for user-friendliness.

Risk and Safety

There are no foreseeable risks involved in participating in this study other than those encountered in day-to-day life.

All data collected will be confidential, and no personal information will be stored

All participants will be healthy adults over the age of 18.

Human participants research

a. Participants: Adults over the age of 18. All races and genders can be surveyed for this study.

b. Recruitment: Participants will be found through word of mouth, and they will be invited to this survey through word of mouth.

c. Methods: Participants will be asked to explore all the features of a given app by using a checklist of the different screens to find. After they explore all of the features of an app, they will be given a survey to rate the ease of navigation, the ease of understanding, and the ease of use on a scale of 1-5. The exploration of the app and the survey afterwards should take approximately 5 minutes.

d. Risk Assessment: There are no foreseeable risks from participating in this survey except for risks that occur in day-to day life. Approximately 5 minutes of the participant's time will be taken to complete this survey. There are no benefits to the participant while participating in this survey, however the data from this survey will help to improve the usability of an app that will help refugees improve their mental state.

e. Protection of Privacy: No private data such as names, addresses, phone numbers etc. will be collected over the course of this survey. After the study, data will be analyzed in order to determine mean,

median, and standard deviation

f. Informed Consent Process: Informed consent will be obtained before the survey is conducted.

Informed Consent Form:

Informed Consent Form for Survey Regarding App User Friendliness. You are invited to participate in a web-based online survey on improving mental health in refugees through the use of an app that employs Cognitive Behavioral Therapy and Mindfulness. This is a research project being conducted by Roshni Srikanth, a student at Tesla STEM High School. It should take approximately 5 minutes to complete.

Participation:

Your participation in this survey is voluntary. You may refuse to take part in the research or exit the survey at any time without penalty. You are free to decline to answer any particular question you do not wish to answer for any reason. This app is for personal use only and is not intended to give a medical diagnosis.

Benefits:

You will receive no direct benefits from participating in this research study. However, your responses may help us learn more about the user friendliness of the app.

Risks:

There are no foreseeable risks involved in participating in this study other than those encountered in day-to-day life.

Confidentiality:

The survey response will be collected by Google Forms, where the data will be stored
stored in a password protected electronic format. You will not be asked to provide your name or any other personal information, so your responses will remain anonymous. No one will be able to identify you or your answers, and no one will know if you participated in the study.

Contact:

If you have questions at any time about the study or the procedures, you may contact me, Roshni Srikanth through Nicola Tesla STEM High School, https://tesla.lwsd.org

Signing below indicates that you are 18 years old or older, are participating voluntarily, and have read the above information.

_____

_____

(Name and Signature) (Date)

Data Analysis

Data Analysis:

g. Conduct an analysis on the data provided by the survey. The survey will be asking users to rate ease of navigation, ease of understanding, and overall ease of use on a scale of 1-5. (Fig 1.)

i. Calculate mean, median, mode, and standard deviation of the data set

ii. If the mean and the median are both above 2.5, and the standard deviation is below 1, (using the range rule) the app has passed the tests for user-friendliness.

Results

The prototype was tested to determine user friendliness and market feasibility. Survey questions were defined across 4 different dimensions using a Likert scale (1-5). A chi-squared test was performed on the data, for an expected value of 2.5 with 1 degree of freedom. The test resulted in a value of 2.920, which is less than the critical value of 3.84 for $p = 0.05$. This result shows that the app is both user friendly and feasible in the market, paving the way to improve the mental health of refugees in the future.

Next steps include translating the app into multiple different languages to facilitate use even without an English background, perfecting user interface and design through the implementation of A/B testing with multiple iterations, and integrating this app into a cloud database to store user information privately and securely.

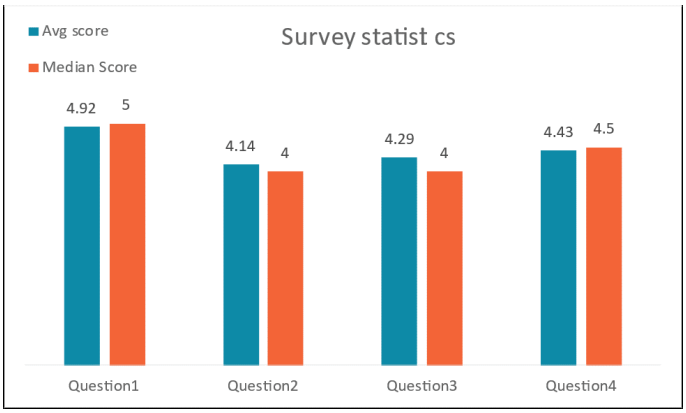

Figure 1. Shows the average and the median scores for each of the questions asked during the survey.

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Improving the Accuracy of Bitemark Analysis in Forensic Odontology

Parbeen Sekhon, Rhea Shinde

Abstract

According to the National Academies of Science, the three largest issues with bite mark analysis, a component of forensic odontology, are: the uniqueness of human dentition has not been established, the ability of dentition to transfer and be maintained has not been established, and a standard for minutiae required to be of evidentiary value has not been established. In order to strengthen the use of forensic odontology in law cases, and to ensure the accuracy of bitemark analysis, a standard must be set for identifying teeth. A threshold has to be set for an amount of dental class characteristics to be identifies before a match can be declared. We used Photoshop to acquire measurements from dental molds, dental plasters, and wax strips. We then converted it into an algorithm which outputted a code. This code is in the hexadecimal number system, a number system made up of 16 symbols used in computer science. The algorithm represents and provides each participant with a nine-digit code, which serves as a unique identifier to each individual. The algorithm uses the following categories: measurements numbers, categorized numbers, binary number system, and hexadecimal number system. We identified several teeth class characteristics, set a statistically significant standard to make a positive identification, and tested the procedure with bitemarks and dental molds to discern how unique bitemarks truly are. We set the following five standards: length of teeth, width of teeth, spacing between teeth, distance between the molars, and missing teeth. Using these standards, we had a 100 percent accuracy rate identifying, indicating how unique bitemarks of each individual are. If forensic odonatologists adopted our standards, they would see a 40% increase in the accuracy of identification.

In 2009, the National Academy of Sciences issued a report titled, "Strengthening Forensic Science in the United States: A Path Forward." Forensic science is relied upon every day by judges and juries to provide reliable evidence in a case and is crucial to making a conviction. The report detailed the areas of forensic sciences that needed strengthening in order to be admissible in court, calling for review on all sub¬fields except for DNA evidence. One of the areas identifi¬ed as needing further research was forensic odontology, which is the application of dental knowledge in legal proceedings. Forensic odontologists use their knowledge to identify unknown remains and analyze bite marks. Forensic odontology, according to the NAS, has several shortcomings. There is no uniformity in how many characteristics must be the same between two pieces of evidence to be considered a match, no standard terminology, insufficient research on the uniqueness of a person's dental setup, and no way to avoid practitioner bias. This project focuses on strengthening bite mark analysis in forensic odontology.

Research Plan

Molds

1. Put on gloves
2. Set the scale to grams
3. Put a cup on the scale and zero it out
4. Put 7 grams of the Cavex Color Change powder into the cup
5. In a graduated cylinder measure 25 ml of water
6. Put the 7 grams of Cavex Color Change powder into the graduated cylinder
7. Mix until there is a smooth paste
8. Put the mixture into the clean dental tray
9. Put the dental tray into the subject's mouth and press it until it is secured by the teeth
10. Wait 30 secs before taking out the dental tray
11. Rinse the dental mold with water until it is clean
12. Take the mold out of the dental tray
13. Clean the dental tray with hot water and alcohol
14. Put the molds into a numeric labeled plastic bag
15. Repeat steps 3-14 for each participant

Plaster

1. Put on gloves
2. Use scissors to trim a corner of the PerfectCast bag.
3. Pour the desired amount of water into a clean container using a ratio (by volume) of one-part water to three parts PerfectCast. Make sure you select a container you are willing to discard.
4. Add the PerfectCast to the water and stir it to reach a smooth consistency. Once done, wash the stirring utensils immediately with warm water and soap.
5. Gently tap the container on a hard surface for a minute or so to bring any air bubbles to the surface.
6. Pour the PerfectCast into the molds.
7. Gently tap the molds on a hard surface to release any remaining air bubbles.
8. Allow the PerfectCast to set for at least 30 minutes before removing from the molds.
9. Once removed, let the casts dry for several hours (or longer depending on weather) before painting or staining.

Wax Strips

1. Put on gloves
2. Open the box with the strips
3. Put the wax sheets into halves
4. Ask the participant to bite into the wax strip
5. Label the wax strip with the corresponding number and put it in a ziplock
6. Repeat steps 4-5 for each participant

Photoshop

1. Using a human teeth dental chart identify the all the present teeth and note them in your data table by numbers.
2. In photoshop, use the measuring tool and measure the length and width of the crown of the tooth
3. Take the measurement in millimeters, and record in your data table
4. Take a ruler took and measure the base of the tooth to the top of the tooth, the base of the tooth is closest to the gum
5. Take the measurement in millimeters, and record in your data table
6. Repeat steps 3-5 for each tooth
7. Measure the spacing between each tooth, beginning at the molar on the most left-hand side of the jaw, and working around to the right-hand side, noting each space in millimeters
8. Measure and record the distance between the molars
9. Repeat step 7-8 for each participants' bite mark

Algorithm

1. Open excel on computer
2. Use the measurements you acquired from photoshop and put it in excel sheet 1
3. Copy number of participants, distance between molars, length and width until teeth 8, and paste it into excel sheet 2
4. Calculate the maximum and minimum of those characteristics to find a range, which can then be put in 4 categories.
5. Then convert all the measurements into the 4 categories on table 2
6. Then convert all the categorized numbers into the binary number system in table 3
7. Then convert 4 bits of information (height and width of a single tooth) into the hexadecimal number system in table 4
8. Then combine the hex numbers into a single cell in table 5

Results

The data table demonstrates the measurements we acquired from the molds, plaster and wax strips. The graphs visualize the measurements the left second molar to show the individuality of characteristics across participants. The excel table tables show the steps from the measurements numbers to the categorized numbers to binary numbers and then to hex numbers, which results in the unique 9-bit code assigned to each participant. The percent accuracy of matching bitemarks to dental molds has a 100% accuracy, which is displayed in the calculation below.

Item Number	Item Number 2	Item Number 3	Item Number 4	Item Number 5	Item Number 6	Item Number 7	Item Number 8	Item Number 9	Item Number 10	Item Number 11	Item Number 12	Item Number 13	Item Number 14	Item Number 15	Item Number 16	Item Number 17	Item Number 18
1	57	9	10	9	9	7	6	6	7	4	7	1	6	1	8	1	9
2	42	7	10	8	11	7	6	4	8	1	6	1	5	1	6	1	5
3	50	9	9	7	10	6	6	6	7	2	7	1	6	1	9	1	9
4	49	10	7	7	10	5	6	4	6	na	na	1	5	1	4	1	5
5	40	7	8	8	8	na	na	na	na	5	5	1	5	1	8	1	8
6	57	9	10	9	9	7	6	6	7	4	7	1	6	1	8	1	9
7	41	7	10	8	11	7	6	4	8	1	6	2	4	1	6	1	5
8	50	9	9	7	9	6	6	6	7	2	7	1	6	1	9	1	7
9	49	10	7	7	10	5	6	3	6	na	na	1	5	1	4	1	5
10	58	9	10	9	9	7	6	6	7	4	7	1	6	1	8	1	9
11	41	7	10	8	11	7	6	4	8	1	6	2	5	1	6	1	5
12	49	9	9	7	10	6	6	6	7	2	7	1	6	1	9	1	9
13	49	10	7	7	10	5	6	3	6	na	na	1	5	1	4	1	5
14	40	7	10	9	10	6	5	5	5	1	7	1	5	1	8	1	8
15	42	7	10	8	11	7	6	4	8	1	6	1	5	1	6	1	5
16	50	9	9	7	10	6	6	6	7	2	7	1	6	1	9	1	9
17	49	10	7	7	10	5	6	4	6	na	na	1	5	1	4	1	5
18	50	9	9	7	9	6	6	6	7	2	7	1	6	1	9	1	7
19	49	10	7	7	10	5	6	3	6	na	na	1	5	1	4	1	5
20	56	9	10	9	9	7	6	6	7	4	7	1	7	1	8	1	9
21	42	7	10	8	11	7	6	4	8	1	6	2	5	1	6	1	5
22	40	7	8	8	8	na	na	4	7	5	5	1	5	1	8	1	8
23	57	9	10	9	9	7	6	6	7	4	7	1	6	1	8	1	9
24	41	7	10	8	11	7	6	4	8	1	6	2	4	1	6	1	5
25	50	9	9	7	9	6	6	6	7	2	7	1	6	1	9	1	7
26	49	10	7	7	10	5	6	3	6	na	na	1	5	1	4	1	5
Average																	
Min	40	7	7	7	8	5	5	3	5	1	5	1	4	1	4	1	5
Max	58	10	10	9	11	7	6	6	8	5	7	2	7	1	9	1	9

Table 1

1	5	2	3	2	1	2	1	3	2	3	2	0	2	0	3	0	3
2	0	0	3	1	3	2	1	1	3	0	1	0	1	0	2	0	0
3	3	2	2	0	2	1	1	3	2	1	2	0	2	0	3	0	3
4	3	3	0	0	2	0	1	1	1	###	###	0	1	0	0	0	0
5	0	0	1	1	0	###	###	###	###	3	0	0	1	0	3	0	3
6	5	2	3	2	1	2	1	3	2	3	2	0	2	0	3	0	3
7	0	0	3	1	3	2	1	1	3	0	1	1	0	0	2	0	0
8	3	2	2	0	1	1	1	3	2	1	2	0	2	0	3	0	2
9	3	3	0	0	2	0	1	0	1	###	###	0	1	0	0	0	0
10	6	2	3	2	1	2	1	3	2	3	2	0	2	0	3	0	3
11	0	0	3	1	3	2	1	1	3	0	1	1	1	0	2	0	0
12	3	2	2	0	2	1	1	3	2	1	2	0	2	0	3	0	3
13	3	3	0	0	2	0	1	0	1	###	###	0	1	0	0	0	0
14	0	0	3	2	2	1	0	2	0	0	2	0	1	0	3	0	3
15	0	0	3	1	3	2	1	1	3	0	1	0	1	0	2	0	0
16	3	2	2	0	2	1	1	3	2	1	2	0	2	0	3	0	3
17	3	3	0	0	2	0	1	1	1	###	###	0	1	0	0	0	0
18	3	2	2	0	1	1	1	3	2	1	2	0	2	0	3	0	2
19	3	3	0	0	2	0	1	0	1	###	###	0	1	0	0	0	0
20	5	2	3	2	1	2	1	3	2	3	2	0	3	0	3	0	3
21	0	0	3	1	3	2	1	1	3	0	1	1	1	0	2	0	0
22	0	0	1	1	0	###	###	1	2	3	0	0	1	0	3	0	3
23	5	2	3	2	1	2	1	3	2	3	2	0	2	0	3	0	3
24	0	0	3	1	3	2	1	1	3	0	1	1	0	0	2	0	0
25	3	2	2	0	1	1	1	3	2	1	2	0	2	0	3	0	2
26	3	3	0	0	2	0	1	0	1	###	###	0	1	0	0	0	0

Table 2

1	0101	10	11	10	01	10	01	11	10	11	10	00	10	00	11	00	11	5	B	9	9	E	E	2	3	3	5B99EE233
2	0000	00	11	01	11	10	01	01	11	00	01	00	01	00	10	00	00	0	3	7	9	7	1	1	2	0	037971120
3	0011	10	10	00	10	01	01	11	10	01	10	00	10	00	11	00	11	3	A	2	5	E	6	2	3	3	3A25E6233
4	0011	11	00	00	10	00	01	01	01	###	###	00	01	00	00	00	00	3	C	2	1	5	_	1	0	0	3C215..100
5	0000	00	01	01	00	###	###	###	###	11	00	00	01	00	11	00	11	0	1	4	_	_	C	1	3	3	014....C133
6	0101	10	11	10	01	10	01	11	10	11	10	00	10	00	11	00	11	5	B	9	9	E	E	2	3	3	5B99EE233
7	0000	00	11	01	11	10	01	01	11	00	01	01	00	00	10	00	00	0	3	7	9	7	1	4	2	0	037971420
8	0011	10	10	00	01	01	01	11	10	01	10	00	10	00	11	00	10	3	A	1	5	E	6	2	3	2	3A15E6232
9	0011	11	00	00	10	00	01	00	01	###	###	00	01	00	00	00	00	3	C	2	1	1	_	1	0	0	3C211..100
10	0110	10	11	10	01	10	01	11	10	11	10	00	10	00	11	00	11	6	B	9	9	E	E	2	3	3	6B99EE233
11	0000	00	11	01	11	10	01	01	11	00	01	01	01	00	10	00	00	0	3	7	9	7	1	5	2	0	037971520
12	0011	10	10	00	10	01	01	11	10	01	10	00	10	00	11	00	11	3	A	2	5	E	6	2	3	3	3A25E6233
13	0011	11	00	00	10	00	01	00	01	###	###	00	01	00	00	00	00	3	C	2	1	1	_	1	0	0	3C211..100
14	0000	00	11	10	10	01	00	10	00	00	10	00	01	00	11	00	11	0	3	A	4	8	2	1	3	3	03A482133
15	0000	00	11	01	11	10	01	01	11	00	01	00	01	00	10	00	00	0	3	7	9	7	1	1	2	0	037971120
16	0011	10	10	00	10	01	01	11	10	01	10	00	10	00	11	00	11	3	A	2	5	E	6	2	3	3	3A25E6233
17	0011	11	00	00	10	00	01	01	01	###	###	00	01	00	00	00	00	3	C	2	1	5	_	1	0	0	3C215..100
18	0011	10	10	00	01	01	01	11	10	01	10	00	10	00	11	00	10	3	A	1	5	E	6	2	3	2	3A15E6232
19	0011	11	00	00	10	00	01	00	01	###	###	00	01	00	00	00	00	3	C	2	1	1	_	1	0	0	3C211..100
20	0101	10	11	10	01	10	01	11	10	11	10	00	11	00	11	00	11	5	B	9	9	E	E	3	3	3	5B99EE333
21	0000	00	11	01	11	10	01	01	11	00	01	01	01	00	10	00	00	0	3	7	9	7	1	5	2	0	037971520
22	0000	00	01	01	00	###	###	01	10	11	00	00	01	00	11	00	11	0	1	4	_	6	C	1	3	3	014..6C133
23	0101	10	11	10	01	10	01	11	10	11	10	00	10	00	11	00	11	5	B	9	9	E	E	2	3	3	5B99EE233
24	0000	00	11	01	11	10	01	01	11	00	01	01	00	00	10	00	00	0	3	7	9	7	1	4	2	0	037971420
25	0011	10	10	00	01	01	01	11	10	01	10	00	10	00	11	00	10	3	A	1	5	E	6	2	3	2	3A15E6232
26	0011	11	00	00	10	00	01	00	01	###	###	00	01	00	00	00	00	3	C	2	1	1	_	1	0	0	3C211..100

Table 3

Conclusion

The measurements we acquired from photoshop and then converted to an excel data table, in which we saw that all measurements we exactly the same no matter the material. Which then helps to prove our hypothesis correct. The algorithm converts the measurements of the characteristics of bitemarks, then converts it into categorized numbers and then to binary number system and then compiles the length and width of a single tooth to a hex number system. Moreover, the algorithm successfully resulted in a 9-bit code from the hex number system, which is unique to each participant. This process can be applied to all the other characteristics and will result in a 9-bit code that is unique to each participant. After preforming percent accuracy on matching bitemarks to dental molds and plaster, we have a 100% percent accuracy rate. Which proves our hypothesis correct, that we would result in a 100% accuracy in matching bitemarks across different material. We reject our null hypothesis.

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The Correlation Between Posting Publicly on Social Media and Anxious Sleep Patterns in Teenagers

Madison Messina, Eden Netz

Abstract

Oftentimes people stray away from posting on social media due to increased anxiety induced by the fear of criticism. In the United States alone, 77% of the population owns a smartphone, granting unlimited access to social media platforms. This results in major sleep deficits. These platforms consume valuable sleep time and lead to anxiousness, which lowers rapid eye movement sleep (REM). REM is generally regarded as the most important stage of sleep because people must go through all other stages of sleep to reach it, therefore it is the most representative stage of your sleep quality. The hypothesis for this project is, when publishing a photo on social media, with a caption, people will experience changes in their sleep cycle such as increased restlessness, decreased REM, and reduced sleep quantity. For this correlational study, participants completed a series of various activities, such as having no phone exposure, enduring blue-light exposure, writing private captions, and posting with captions on Instagram. This was done fifteen-minute prior to falling asleep for four nights. To detect the sleep stages mentioned, Fitbit wrist monitors were given to each participant as well as surveys. Fitbit wrist monitors are digital watches that calculate the period of time a body experiences restless sleep, light sleep, deep sleep, and REM sleep. Participants within this study typically began with experiencing 45% light sleep and 20% REM sleep. On the final night, where they were asked to post, participants experienced 65% light sleep and 8% REM sleep. An R-Value, which detects the negative correlation of the study, was -0.725. Because this value was close to -1, the hypothesis is correct and there is a very strong negative correlation between sleep quality and posting on social media.

Rationale

In the United States alone, up to 77% of the population owns a smartphone, which grants unlimited access to social media platforms, which leads to major sleep deficits as these platforms consume valuable sleep time. As reported by the University of Pittsburgh, PA in 2016, 67% of cell phone users have reported social media becoming a distraction when trying to fall asleep, and as a result of these distractions, they have reported poor health. Secondly, social media (SM) posting is known to be an extremely stressful process. It creates a subconsciously competitive environment for participants, where they compare their follower count, posting feed, "likes" and much more. These competitive users become obsessed with these platforms, resulting in endorphins being released whenever their page gains more recognition through followers. This leads to an aggressive addiction causing a plethora of hours continuously being devoted to social media and phone usage. To solve part of this issue, proving social media posting, especially before bed, effects sleep will allow us to educate adolescents about the harm of these platforms. Through the following experiment we will be able to see if the process of posting to the public results in anxious behavior, that will deteriorate the quality of our sleep, such as reduced rapid eye movement (REM) in sleep, long durations of the users sleep cycle in light sleep, number of "wake ups", and this experiment will allow the new generation and new parents to be informed when permitting children to create social media accounts and allowing them to use technology before bed. These results will be obtained through the following procedure and through self-reported data.

Research Question

What is the correlation between posting publicly on social media and anxious sleep patterns in teenagers?

Hypothesis

When one is publishing a personal photo with a unique, typed caption on social media, one will experience worsened sleep quality, such as reduced periods in rapid eye movement (REM) sleep and higher percentages of restlessness.

Potential Risks and Safety Precautions

a. Participants: Range in ages 13-17 years old. Variation in ethnic composition and race. All genders. The vulnerable population includes minors.

b. Recruitment: Participants will be gathered through random outreach such as advertisements on social media, flyers around local malls, grocery stores and coffee shops, etc.

c. Methods: Participants will be involved for a total of four nights. They will be asked to sleep, use their social media (Instagram), caption pictures, wear a Fitbit and fill out a questionnaire asking about their sleep and other self-reported data.

d. Risk Assessment: Could include some induced stress from being in an experiment or knowledge of being tested through a questionnaire and wearing a Fitbit. Stress could include an increase in rapid heartrate. As shown in previous studies participants results may become invalid due to fear and anxiety directed towards intimidating but harmless equipment. Study might also cause sleep to be severely affected and therefore in the following days one could experience sleep deprivation. Risks will be minimized with participants being informed that they are being tested on their sleep quality. Benefits could include increasing the knowledge of the effects social media has and ultimately help teenagers recive better sleep quality and the outcomes of that would greater sleep quality and a better understanding of social media.

e. Protection of Privacy: The only identified information that will be collected is the participant's age, social media statistics (followers), and knowledge of any pre-existing physical or mental health problems. This information will be kept anonymous and will be stored in an excel spreadsheet online and within our student researcher log books. The student researchers (us) and the adult sponsor will be the only people that have the access towards this information. The information will be collected though an anonymous survey that will contain the questions regarding age, health issues and social media statistics. Finally the information will be deleted after the experiment comes to an end.

f. Informed Consent Process: Participants will be given the information and purpose of this experiment, what they will be doing within the experiment (apart from knowing they will post on social media as that could result in our volunteers being only people who are comfortable posting, and not a group of mixed opinions) and the knowledge that they have the right to leave at any given time through the informed consent form which they will all be required to fill in advance as they are minors.

Procedure

Procedure A.

Researchers will get volunteers initially through random outreach such as advertisements on social media asking people to participate as well as flyers in libraries, coffee shops, and other popular areas. Between the two of us we plan on reaching out to random portions of people involved in activities in Lake Washington School District and other extra-curricular social groups seeing the advertisements. From those participants, we will remove those who take sleep medications or have persisting sleep disorders. Then use a random number generator to choose the final participants.

Procedure B.

1. Gather volunteers following the volunteer protocol (see procedure A).
2. Volunteers all will take the pretest survey which should take 10 minutes at a maximum. Participants should not take the test with their fellow participants present, as this could induce anxiety and alter the test's result. The tests should be printed on physical paper.
3. Record baseline or initial heartrate while awake (at 8:30pm before bed) to see the participants natural response to the Fitbit monitor, and record if the heartrate increases of decrease dramatically within the first half hour (8:00pm-8:30pm). After the half hour the Fitbit can be removed as the baseline reading will be complete. This step is important as it can explain if stress from sleep is caused by wearing a new apparatus, the Fitbit.
4. Each night, regardless of the variable being tested or the testing environment, have each volunteer wear the wrist monitor (Fitbit) to receive the base line tests for:

o Heart rate while sleeping (BPM)
o Amount of Rapid Eye Movement (REM in hours and minutes) sleep
o Percentage of restlessness during sleep (Provided directly from the Fitbit monitor)
o Number of times one wakes up (Provided directly

from the Fitbit monitor)

5. After receiving baseline tests for heartrate, begin splitting participants into two groups of five, as there are only 5 Fitbits that are available use each day.

6. Give each of the five participants in the first group (out of two groups) a charged Fitbit monitor with a Fitbit charger (Versa Three model).

7. Explain to the participants that they will be conducting a series of four tests regarding sleep and social media and they will be wearing a Fitbit for the next four nights but do not explain what activities they will be taking with their phone each night as this could induce anxiety.

8. Begin night one, where participants will complete the first activity. No technology, apart from the Fitbit, should be present in the room, and the Fitbit should be covered with black tape to ensure the blue light of the monitor isn't visibly being emitted by the monitor. Results should be recorded from the time the participants go to bed which should begin at lights out at 10:30. The time should stop being recorded when they wake up, and they remain awake for over 2 hours, implying they are beginning their day. The Fitbit itself is also aware of when the participant no longer sleeps.

9. Researcher will record the conditions from step three if evident in the results of the Fitbit monitor. Additionally, all graphs recorded by the Fitbit should be printed, and labelled [with what day the results were from (ex: Day 1)]. All information should be recorded in a private excel document that only the research team has access too, to ensure that confidentiality is maintained. Lastly, provide the test subject with the Sleep Log Survey (see survey section) each night.

10. Beginning on night two, participants will have the smartphone they own and have social media on, in the room for 20 minutes. Within those 20 minutes the light intensity will be set at 100% and the screen will only consist of a white screen. Participants will be asked to hold it and look at it for the time duration (10:10-10:30). At exactly 20 minutes the phone will be shut off and the user will go to sleep under the same conditions as night one. Once again the Fitbit screen should be covered with black duct tape.

11. Repeat the recording procedure above from step 9.

12. Beginning on night three, participants will be asked to write a caption for photos on their phone that they would consider posting but make sure participants are completely aware they will not have to post the photo. The participant must browse and write photo captions for 20 minutes (10:10-10:30). This test will determine if poor REM sleep is induced by writing captions, or increased brain activity as they need to sleep, or if it's the idea that posting on Instagram and its very public (available for everyone), that causes fear.

13. Repeat the recording procedure above from step 9.

14. Begin night four where participants are asked to create a different a caption regarding a different photo but now post that photo onto the social media platform, Instagram, and wait for responses for 20 minutes (10:10-10:30). Remind participants that they cannot respond to comments or likes but they should continuously refresh to see likes, comments, etc.

15. Ask participants to complete a final survey about their thoughts on the experiment (see survey's at the end of research paper)

Analyzing Data

Through the process of the Fitbit analyzing data on one's phone application researchers will analyze the information by processing the percentage of time one was in a stage of "awake", "REM", "light", and "deep" and at what time through-out the night these stages were active. Such as through heart rate changes (BPM), amount of rapid eye movement (REM) (hours and minutes recorded), percentage of restlessness sleep, and number of times woken up (beta waves) recorded by the wrist monitors compared to the variable of what "type of sleep" was occurring. Such as normal sleep, sleep exposure to blue light, private writings, and sleep followed by posting captions with photos that the public will read from social media. We will run a pilot session receive the baseline and initial results unique to each volunteer. Followed by an in depth break down of the frequencies and amplitude of brain waves. In order to find these results we will be using correlation coefficient.

1. Using Microsoft Excel, enter the sleep results of each percentage into a personal spreadsheet for each participant. Take the REM values from each night and put it into its own section.

2. Find the R value of the REM values by selecting the values, going to Formulas > Math and Trig > CORREL and for Array 1 select the REM values and

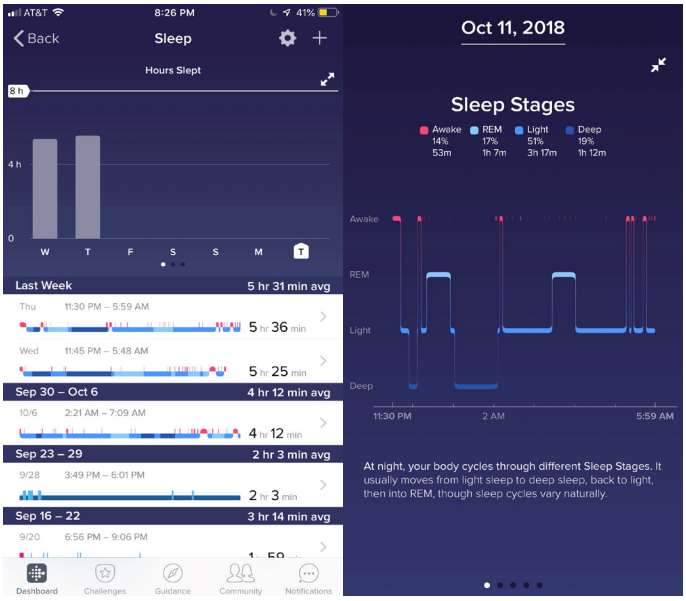
for Array 2 select another table with the number 1, 2, 3, 4 to show the progression of days.

3. The closer the R value is to -1 the closer our hypothesis is correct in that this shows a strong negative correlation. For all results be sure to take note of survey answers of external stress factors.

4. Determine the mean R value for all participants by adding all the R values and dividing the sum by the total number of participants.

Materials

- 5 Fitbit Versa Three wrist monitors with chargers
  - home provided
- A phone with social media applications
  - Instagram application
- Paper Surveys with pencils for each participant (five surveys for each participants)
- A phone charger



Fitbit Sample

Daily Sleep Log

Activity #:_____ Date:_____

Time I consistently go to bed: Time I generally wake up:

How do I think I slept last night?

★ ★ ★ ★ ★

1 star - Barely slept
2 star - woke up a lot
3 star - woke up a few times
4 star - slept decently
5 star - slept well and comfortably

Why do I think I slept the way I did?

Could my results be a result of the activity or from poor or good sleep on the other nights?

Did I exercise close to bedtime? If so, how many hours after I exercised did I go to sleep?

What time did I eat my last meal?

Did anything exciting or stressful happen during my day?

Post Experiment Log

Date:

On a scale from 1 – 5 (1 being panicked and 5 being extremely calm and relaxed) how stressed was I on night 1 (no phone)? Why?

On a scale from 1 – 5 (1 being panicked and 5 being extremely calm and relaxed) how stressed was I on night 4 (posting)? Why?

How many followers do you have on the account you posted on?

Do you know your followers personally?

How long have you had Instagram?

How often do you post typically?

How often do you scroll through your Instagram feed?

Was it difficult for you to refrain from checking the status of your post when you posted? Why?

Did knowing I was in an experiment induce stress? If so, what were my concerns?

Do I consider myself a generally anxious person? Does this generally affect my sleep?

What are my usual sleep patterns?

What nights do I think were the most stressful?

Do I regularly use my phone before bed?

Why is this experiment important in my life?

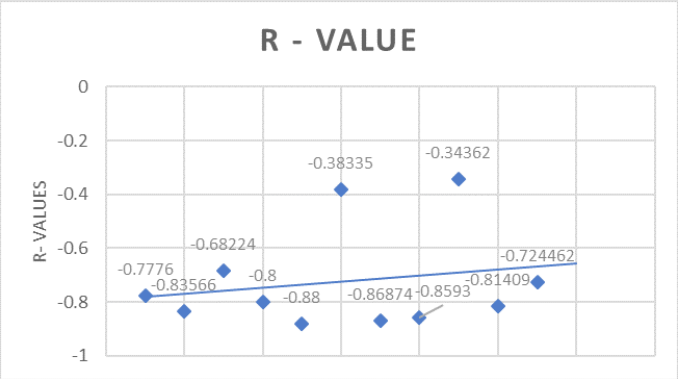
Excel Sheets and Results

Sample of a subjects recorded percentages recorded for each night. The left-most column represents the day number the participant is on.

	A	B	C	D	E
1	Subject 2	awake	REM	light	deep
2	1	12.30%	2150.00%	41.20%	24%
3	2	15.10%	15.60%	47.60%	21.70%
4	3	11.60%	19.80%	44.20%	24.40%
5	4	11.70%	8.20%	66.20%	14%

The following table shows the R-values for all participants and mean R-value. The closer each R-value is to -1 the stronger the negative correlation. The strong negative correlation means our hypothesis is correct in that posting on social media prior to going to sleep results in anxious sleep patterns, specifically worsened sleep quality. Reduced REM is highly linked to anxiety which shows posting on social media is the cause to the worsened sleep.

	A	B	C	D	E	F
1	Subjects	R - Value				
2	Subject 1	-0.7776				
3	Subject 2	-0.83566				
4	Subject 3	-0.68224				
5	Subject 4	-0.8				
6	Subject 5	-0.88				
7	Subject 6	-0.38335	Poor Sleep from Fitbit for Nights 1 &2			
8	Subject 7	-0.86874				
9	Subject 8	-0.8593				
10	Subject 9	-0.34362	Stressed Night 2			
11	Subject 10	-0.81409				
12	**Mean**	-0.72446				



Graph showing the correlation of each participant and their R-values.

Conclusion

As days progressed and activities became more interactive with cell phones and Instagram usage, light sleep percentages measured from the Fitbits increased. This is best seen in subject one with an increase of 25% in light sleep. As days progressed and activities became more interactive with cell phones and Instagram usage, REM sleep percentages for participants began to decrease. This is best seen in subject five with a decrease of 14% in REM sleep. In regard to social media, the Final post experiment surveys addressed the number of followers and number of years each participant has had Instagram. The findings proved that participants with under 300 followers had far more intimate relationships with followers proving more stress when posting. The surveys regarding social media also concluded that each participant had been on Instagram for three to five years emphasizing that they cared about their followers and likes per post, causing an increase in stress when posting. As the hypothesis stated, the expected outcome was to see a correlation coefficient, R, close to the value of -1. This hypothesis proved to be correct as the R-values were: -0.7776, -0.83566, -0.68224, -0.8, -0.88, -0.38335, -0.8593, -0.34362 creating a total mean R-value of -0.7145011111. These results proved that the data showed a strong negative correlation. Although the results proved to be successful, it is important to note several confounding variables. Several participants slept inconsistent hours, ranging from two-nine hours which could have caused false sleep percentages. Participants may have experienced stressful events during the experiment causing difficulty in falling asleep.

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Using Involuntary Muscle Contractions to Determine if Someone is Lying or Telling the Truth

Hemant D. Dhokia

Author's Note

Backyard Brains Muscle SpikerBox Pro - $265

Abstract

Many methods of detecting deception are inaccurate. The inexpensive commonly-used polygraph has up to 50% accuracy. Other more expensive methods like an fMRI have up to 95% accuracy. Due to the drawbacks of these lie detection methods, this research uses a muscle SpikerBox to see if there is a difference in the muscle activity in the stomach when a person lies versus when they tell a truth. The hypothesis for this experiment is that if a participant lies, then the muscle activity in the stomach of the participant will increase, indicating that the person is lying. This was tested by five participants who were hooked up to the SpikerBox and then they lied five times and told the truth five times. The independent variable is whether the participant told a lie or a truth and the dependent variable is the muscle activity resulting from the response of the participant. According to the data collected in the experiment, the average muscle activity for all the participants who told the truth was 1.454 millivolts. But the average muscle activity for all participants who told a lie was 1.7208 millivolts. The resulting p-value of 0.0482 means that this data is statistically significant. The results indicate that muscle activity increase says when lying. This further proves that a muscle baseline detection system works. Further research could determine specific areas in the human body that can indicate that a person is lying and accuracy testing against a polygraph.

Keywords: ***SpikerBox****: A machine that can detect the electricity in the muscles of the human body and measures them in millivolts.* ***Stomach:*** *The stomach was used because it is an involuntary muscle and it is an area where people hold their tension*

In prison systems in the United States, Canada and other countries, there is a major issue with innocent people serving sentences in prisons and in some cases, they are on death row. In the United States alone, there are over two million people in jail or prison, serving sentences to various crimes. A recently conducted survey (add citation) estimated that approximately 100,000 of those people affected are innocent, but they are serving sentences which they were not supposed to be accused of. On top of that, many of those convicted have to take lie detector tests. But, many of the methods used today are very inaccurate. For example, according to the American Psychological Association, the polygraph, the most commonly used method, can be up to 50% accurate. This was due to the polygraph using heart rate, respiration rate, and blood pressure to detect deception. However, these can be controlled and could mistake a lie for a truth and a truth for a lie. The method is used because it is an cost-effective method Other methods of lie detection do exist, and one of them is an fMRI scan. This can be up to 95% accurate due to detecting brain activity, but is very expensive to operate. Due to the various drawbacks of these methods, this research determines if a muscle-based lie detection system can differentiate a truth and a lie to determine if it is a viable method at determining deception.

Literature Review

Jensen, A. M., Stevens, R. J., & Burls, A. J. (2017, November 03). Muscle testing for lie detection: Grip strength dynamometry is inadequate. Retrieved November 4, 2018, from https://www.sciencedirect.com/science/article/abs/pii/S1876382017302159

This article is about the testing of grip strength and lie detection in humans. Their reason for testing this method is because muscle response testing (MRT) is a method that police can do for lie detec-

tion purposes. Also, dynamometric muscle testing (DMT), which measures the strength of the muscle could potentially be used to determine truth from lies because in a lie detector test environment, people tend to react toward the test and so an increase in strength could potentially prove that this person is lying. Therefore, Jensen, Stevens, and Burls were testing grip strength on lie detection. Their procedure was to make the participants look at random pictures and they were told whether to tell the truth or lie and then the participants would take a grip strength test or DMT. Each participant did 20 total DMT's 10 with each hand and 5 of the 10 times the participant would say a truth and the other 5 times, the participant would say a lie.

Article 2

Tarase, G. M., Haveripeth, P. D., & Ramadurg, M. (2013, January 1). Scientific And Legal Procedure Of Polygraph Test. Retrieved November 4, 2018, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3285070/

This article talks about the commonly used Polygraph test in which this article explains about the history, testing methods, and how the test is used to catch lying people. The article also explains how the polygraph works and the methods the operators use to detect lies in the person being tested. In testing the polygraph in the past and for the article, humans were used as the testing method for the polygraph. Testing the polygraph required the participant to me in a chair, arms on the arm rests and feet flat on the ground, looking straight and remaining still. The operators will then put on the necessary equipment for the test, such as a elastic belt around the chest for respiration rates, an arm cuff for blood pressure, heart rate, and rate features. Then the operators test to make sure the equipment works properly, then the examination of the subject begins. This consists of yes or no questions about the crime or relevant information to ask the person being tested. The resulting graph from the test can tell if the person is telling the truth or lying.

Article 3

Liu J, Ying D, Rymer WZ, Zhou P (2015) Robust Muscle Activity Onset Detection Using an Unsupervised Electromyogram Learning Framework. PLoS ONE 10(6): e0127990. https://doi.org/10.1371/journal.pone.0127990

The article is about the muscle activity going on inside of our body and how the researchers used a learning system to analyze our bodies. The researchers say that this is used for posture and gait analysis, myoelectric control, or on prosthetic or orthotic devices. The computers are using machine learning software and coding to analyze muscle activity graphs and for them to learn for better prosthetic limbs and other sorts of items like that. Their method involved an unsupervised or unrestricted electromyogram (EMG) and this allows for better muscle activity detection. The researcher's method intends to work with extremely low muscle activity to extremely high muscle activity. There were no human or animal participants involved in this study; this was all done via computer. The way the researchers tested their theory was to do trial and error and code the machine to learn the muscle activity signals. Then the machine was given sample responses to see how the machine reacted to the inputs.

Article 4

Kuo, I. Y., & Ehrlich, B. E. (2015). Signaling in Muscle Contraction. Retrieved November 4, 2018, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4315934/

The muscle contractions that we feel are from a variety of muscles such as cardiovascular muscles and skeletal muscles. There are two specific types of muscles and they are striated muscles and smooth muscles. Striated work by receiving a neurotransmitter and then when the neurotransmitter binds, the channel depolarizes and sends calcium through the channel which creates a muscle contraction. For a smooth muscle, specific receptors like GQ receptors have to bind and then the calcium flows through the channel and then it begins the muscle contraction.

In this case study article the method of research involved using older research and older experiments done on human muscles. For this case study they compiled data from existing articles relating to the topic of muscle signaling.

Hypothesis

The hypothesis for this experiment is that if a participant lies, then the muscle activity in the stomach of the participant will increase, indicating that the person is lying.

Method

Five participants were hooked up to the Spiker-Box and then were instructed to tell five lies and five truthes. The independent variable is whether the participant told a lie or a truth and the dependent variable is the muscle activity resulting from the response of the participant.

Results

According to the data collected in the experiment, the average muscle activity for all the participants who told the truth was 1.454 millivolts. But the average muscle activity for all participants who told a lie was 1.7208 millivolts. The resulting p-value of 0.0482 means that this data is statistically significant. The results indicate that muscle activity increase says when lying.

Participant 1:

Graph #	Truth/Lie	Average
1	Truth	1.38
2	Lie	1.52
3	Lie	1.41
4	Truth	1.43
5	Lie	1.6
6	Truth	1.4
7	Truth	1.36
8	Truth	1.41
9	Lie	1.7
10	Lie	1.99

Participant 2:

Graph #	Truth/Lie	Average
1	Truth	1.93
2	Lie	3.7
3	Truth	1.68
4	Truth	1.58
5	Lie	1.8
6	Lie	2.21
7	Truth	2.2
8	Truth	2.16
9	Lie	2.1
10	Lie	2.42

Participant 3:

Graph #	Truth/Lie	Average
1	Truth	2
2	Truth	1.3
3	Truth	1.37
4	Lie	1.2
5	Lie	1.86
6	Truth	1.4
7	Lie	1.47
8	Truth	1.4
9	Lie	2.09
10	Lie	1.79

Participant 4:

Graph #	Truth/Lie	Average
1	Truth	1.38
2	Truth	1.4
3	Lie	1.5
4	Truth	1.42
5	Lie	2.04
6	Lie	1.63
7	Truth	1.39
8	Lie	1.6
9	Lie	1.51
10	Truth	1.5

Participant 5:

Graph #	Truth/Lie	Average
1	Truth	1.03
2	Truth	1.11
3	Lie	1.1
4	Truth	1.01
5	Lie	1.18
6	Lie	1.2
7	Truth	1.02
8	Truth	1.09
9	Lie	1.24
10	Lie	1.16

Averages Table:

Participant #	Average mV Truth	Average mV Lie
1	1.396	1.644
2	1.91	2.446
3	1.494	1.682
4	1.418	1.656
5	1.052	1.176
Average	**1.454**	**1.7208**

Limitations

In this research, there were a few limitations. One of the limitations was to how this experiment could be conducted in a manner that would put pressure on the participant to answer a question but would not require asking and lying personal questions. Additionally, due to the questions being yes or no questions, the experiment was not realistic or mimicking the style of how lie detector tests are conducted in a legal case. This may have caused the data to be more forced instead of being more realistic.

Another limitation was the number of participants that were tested and the race of those participants. In this research, the participants were aged between 30 and 50 and were all people from India. This makes the data less applicable to a general population due to the race of the participants and the number of participants tested.

A third limitation came from the software used to analyze the muscle activity of the participants. The program was not very intuitive and would crash often and was generally time consuming to analyze the data. This may have caused data to have been altered and some peaks may have been missed due to the nature of the program.

Conclusion

The experiment was successful in the regard that the hypothesis was proven to be correct. When a person lies, the muscle activity on the stomach increases. The data shows that when someone tells a truth, the average muscle activity was 1.454 millivolts. This number increases when the person lies to 1.7208 millivolts. When these two values are entered into a chi-squared test, the resulting value is 0.0482, which means that the null hypothesis is rejected and the results are statistically significant. This data also provides evidence that a muscle-based system can differentiate between a lie and a truth by using muscle activity alone in the stomach. This further proves a system like this can function. In the future, there could be accuracy testing between a polygraph and other lie detection methods, how does lying affect the other parts of the body, how does a full or empty stomach affect the system and more. There are lots of future research that can be done on this system.

References

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Liu J, Ying D, Rymer WZ, Zhou P (2015) Robust Muscle Activity Onset Detection Using an Unsupervised Electromyogram Learning Framework. PLoS ONE 10(6): e0127990. https://doi.org/10.1371/journal.pone.0127990

Kuo, I. Y., & Ehrlich, B. E. (2015). Signaling in Muscle Contraction. Retrieved November 4, 2018, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4315934/

Achievements/Awards

Future Business Leaders of America (FBLA) Nationals, (June 2018)

Business Ethics

6th place - Ila Sharma, Aashna Sheth, Amrita Narasimhan

Graphic Design

3rd place and $200 – Akshay Murthy

Public Service Announcement

8th place - Ranveer Thind, Aakash Ramachandran

HOSA International Leadership Conference, (June 2018)

Barbara James Service Award:

Silver Medal - Jessica Singh

Intel International Science and Engineering Fair (ISEF) - May 2018

Engineering Mechanics - Third Award

ENMC043 — *Implementation of Gyroscopically Leveled Spherical Drones Optimized Through Neuro-Evolution of Augmented Topologies for Reconnaissance and Imaging of Martian Environ ments* - William Wang, Nikola Tesla STEM High School, WA, United States of America

Technology Student Association (TSA) Nationals, (June 2018)

Biotechnology

6th place - Victoria Alkin, Kushal Kedia, Jadrian Png, Thalia Tsai

Engineering Design

1st place - Dharini Sribalaskandarajah, Ila Sharma, Sashwatha Shankar

Extemporaneous Speech

Victoria Alkin

Promotional Design

9th place - Akshay Murthy

STEM Careers

2nd place - Sashwatha Shankar

4th place - Ranveer Thind

Structural Design and Engineering

1st place - Lahari Nidadavolu, Jakob Bjorner

2019 Sustainability Video and Poster Challenge

High School Poster Winners

1st Place - Laura Anker

2nd Place - Maile Hori

3rd Place - Neha Krishnakumar

American Association of University Women (AAUW) Awards for Outstanding Female Students in the World of STEM

Math

Rachel Alwan

Science

Rishika Veeramachaneni

Technology

Esther Wang

Biology Olympiad Open Exam (Mar 13, 2018)

Semifinalist (Scored in Top 10%) - Maxwell Soh, Jiachi (George) Zhang

Central Sound Regional Science and Engineering Fair (CSRSEF)

Animal Sciences; Plant Sciences; Earth and Environmental Sciences (ERTH)

2nd place - Annie Denton, *"Forecasting the Effects of Climate Change on the Distribution of the Pacific Sideband Snail"*

3rd place - Elisabeth Berger, *"Powering a Solid State Fermenter with Compost Cogeneration To Produce Spores for Use as a Myopesticide"*

Behavioral and Social Sciences (BEHA)

1st place - Madison Messina and Eden Netz, *"Assessing the Effects of Posting Publicly on Social Media in Correlation to Anxious Sleep Patterns in Teenagers"*

2nd place - Roshni Srikanth, App to *Improve the Mental Health of Refugees*

3rd Place - Rachel Alwan and Anika Ghelani, *"A Behavioral and Neurophysiological Analysis of False Memories"*

Honorable Mention - Marton Teichner, *"Investigating the Effects of Education on the Impact of Astroturfing"*

Biochemistry, Cellular and Molecular Biology, Microbiology (CELL)

1st place - Mirra Chinta, *"Synergism or Antagonism between Docetaxel and Finasteride in Prostate Cancer Model"*

2nd place - Anusha Srivastava, *"Assessing the Apoptotic Effect of the Bacteriocin Nisin on Metastatic Breast Cancer Cell Viability"*

3rd Place - Aditi Ekbote and Vidhi Jain, *"Drug Combinations with Antibiotics and Curcumin to Combat Antibiotic Drug Resistance"*

Biomedical Engineering (BMEG)

3rd place - Nitisha Gautam, Arundhati (Diya) Basu, *"Genomic Differences Between E-cigarette Vapor and Cigarette Smoke and its Relation to Tumor Growth"*

Biomedical and Health Sciences (BMED), Translational Medicine (TMED)

1st place - Aditi Subramanyam, *"Identifying TEAD Proteins and Disrupting the YAP1/TEAD Complex to Inhibit Oncogenic YAP1 Fusion Proteins"*

Honorable Mention - Anirudh Iyer, *"Analyzing miRNA Expression in Glioblastoma Patients to Identify Candidate Markers"*

Chemistry; Chemical Energy; Material Sciences (Chem)

3rd place - Mintra Frazzini, *"Engineering Environmentally Friendly Sunscreen Using Metal Organic Frameworks"*

Honorable Mention - Saketh Dhulipalla, Yuchen Li*, "Access to Clean Potable Water Via Fog Harvesting"*

Environmental Engineering (ENEV)

1st place: Romanpreet Kaur, *Menstrual Hygiene Period*

3rd Place - Max Reisman, *"Solar Desalination System Utilizing Salt-Rejecting and Solar Absorber Technology for Quick and Efficient Technology"*

Honorable Mention - Kishan Baliga, *"Using Synthetic Aperture Radar Data to Create a Machine Learning Algorithm Capable of Identifying Oil Spills"*

Mechanical Engineering (MCEG)

2nd place: Tristan Stevens and Maxwell Wang, *"Using a Bi-Layer Geogrid System to Decrease Vertical Stress and Deflection of Pavement Applications"*

Physics; Mathematics; Physical Energy; Embedded Systems (Phys)

Honorable Mention - Akshay Murthy, *"Greet Sense: A Facial Recognition and Obstacle Detection*

Device for the Visually- Impaired and Blind"

Robotics (ROBO)

2nd place - Mathias Foster, *"Development of a Perpetual Solar-Powered Blimp to Aid Urban Search and Rescue"*

Software Systems; Computational Biology & Bioinformatics (COMP)

Honorable Mention - Sunya Mohammed, *"Implementing Eye-Tracking Technology for the Advancement of Driver Training"*

Special Category Awards

American Chemical Society (ACS) Prize:

Mintra Frazzini, *"Engineering Environmentally Friendly Sunscreen Using Metal Organic Frameworks"*

American Institute for Aeronautics and Astronautics Award:

Mathias Foster, *"Development of a Perpetual Solar-Powered Blimp to Aid Urban Search and Rescue"*

American Psychological Association (APA) Award:

Madison Messina and Eden Netz, *"Assessing the Effects of Posting Publicly on Social Media in Correlation to Anxious Sleep Patterns in Teenagers"*

Excellence in Bacteria Research-Environmental Science Award:

Anusha Srivastava, *"Assessing the Apoptotic Effect of the Bacteriocin Nisin on Metastatic Breast Cancer Cell Viability"*

Inspiring Excellence in Scientific Research:

Roshni Srikanth, App to *Improve the Mental Health of Refugees*

Materials Science Special Category Award:

Mintra Frazzini, *"Engineering Environmentally Friendly Sunscreen Using Metal Organic Frameworks"*

Office of Naval Science Research Award:

Sunya Mohammed, *"Implementing Eye-Tracking Technology for the Advancement of Driver Training"*

Ricoh Sustainable Environmental Science Award:

Elisabeth Berger, *"Powering a Solid State Fermenter with Compost Cogeneration To Produce Spores for Use as a Myopesticide"*

WSSEF Award:

Akshay Murthy, *"Greet Sense: A Facial Recognition and Obstacle Detection Device for the Visually- Impaired and Blind"*

Supernova Awards

Isha Murali, *"Exploration into Analyzing the Auditory Cortex in Relation to Attention as Measured by Alpha Waves"*

Parbeen Sekhon and Rhea Shinde, *"Setting Minutiae Standards in Forensic Odontology"*

Kristin Acheson, *"The Effects of Ascorbic Acid on the Binding of Collagen and Tannins"*

Tarini Srikanth, *"Modeling Potential Drug to Drug Interactions Targeted Towards Cardiovascular Systems"*

Manasvini Calmidi, *"Determining the Salt Concentration of Irrigation Water for Trichoderma to Confer Salt Tolerant Oryza sativa Plants"*

Marko Milovanovic and Denis Chelan, *"Water Purification Via Hand-Powered Pump"*

GRAND PRIZE WINNER (one of three)

Aditi Subramanyam for her investigation with *"Identifying TEAD Proteins and Disrupting the*

YAP1/TEAD Complex to Inhibit Oncogenic YAP1 Fusion Proteins". Aditi will compete at ISEF.

2019 Northlake Solo & Ensemble Festival

Solo First Alternate

Clarinet - Ashwin Naresh
Timpani – Emily Zhao

Future Business Leaders of America (FBLA) State Competition

Broadcast Journalism

7th place - team of Anika Ghelani, Isha Murali

Business Communication

3rd place - Hamsa Shankar

Business Ethics

2nd place - team of Pinakin Kanade, Saanav Somani, Claire Yang

Business Financial Plan

6th place - team of Oleg Ianchenko, Shrey Srivastava and Varun Wescott
9th place - team of Sophia Ling, Aran Punniamoorthy, Nihal Thomas

Business Law

2nd place - Siddharth Shende

Business Plan

4th place - team of Surya Gorantla, Graham Sabin and Amar Sood

Coding and Programming

1st place - Henry Liao 2nd, Rishika Veeramachaneni

Computer Game and Simulation Programming

4th place - team of Shrey Srivastava, Deepayan Sanyal, Varun Wescott

Computer Problem Solving

6th place - Varun Sridhar
10th place - Pinakin Kanade

Cybersecurity

1st place - Varun Sridhar

Digital Video Production

7th place - team of Adi Gottumukkala, Nihal Thomas, Michael Halim
10th place - team of Anika Ghelani, Eman Khatri, Qing Hui Xie

E-Business

1st place - team of Akshay Murthy, Siddharth Shende, Maxwell Wang

Entrepreneurship

2nd place - Siddharth Shende

Impromptu Speaking

2nd place - Siddharth Shende
5th place - Zofia Kierner

Introduction to Business Presentation

6th place - team of An Doan, Claire Yang, Mihika Vankamamidi

Introduction to Financial Math

4th place - Jennifer Hu

Introduction to Public Speaking

5th place – Michael Halim

Job Interview

1st place - Ritika Iyer
3rd place - Zofia Kierner

Journalism

1st place - Ritika Iyer

Management Decision Making
2nd place - Samarjit Kaushik
5th place - team of Eesha Kunisetty and Jennifer Hu
Management Information Systems
1st place - team of Graham Sabin and Maxwell Wang
Organizational Leadership
2nd place – Jiachi (George) Zhang
Public Service Announcement
1st place - team of Sahil Kancherla, Parum Misri, Varun Wescott
Publication Design
1st place - team of Akshay Murthy, Ritika Iyer
9th place - team of Neerja Natu, Emily Zhao and Deveshi Thakur
Sales Presentation
4th place - Zofia Kierner
Securities and Investments
3rd place - Deepayan Sanyal
Word Processing
7th place – Qing Hui Xie

Glacier Peak Robotics Competition

1st place – EHS/Tesla STEM Top Gun Team: Yash Kulkarni, Ishika Mukherjee, Thomas Stahura

Holocaust Center for Humanity Contest

https://holocaustcenterseattle.org/programs-events/writing-art-film-contest

Art
1st place: Tichada Tantasirikorn
2nd place: Lina Chai
3rd place: Elisabeth Berger
Honorable Mention: Esther Wang
Film
2nd place: Amrutha Srikanth
3rd place: Annie Denton
Honorable mention: Max Reisman

Writing
1st place: Aditi Joshi

HOSA – Future Health Professionals State Leadership Conference)
Washington State HOSA President – Anika Ghelani

Barbara James Service Award, Gold Medal – Jessica Singh
MRC Volunteer Award, 1st place – Jessica Singh

Individual Events

Clinical Specialty
5th place – Prakriti Shukla
Extemporaneous Writing
1st place - Christine Lee

3rd place - Ankita Menon

HOSA Individual Events cont.

Human Grown and Development

4th place - Ankita Menon

Medical Terminology

3rd place - Prakriti Shukla

Nutrition

2nd place - Ananya Nandula

Pathophysiology

5th place - Jessica Singh

Research Persuasive Writing and Speaking

2nd place - Anusha Srivastava

3rd place - Suhani Arora

Team Events

Biomedical Debate

1st place - Amrita Narasimhan, Eesha Murali, Megha Mattikalli

4th place - Anika Ghelani, Rachel Alwan, Anusha Srivastava

Community Awareness

2nd place - Laura Mangov, Jessica Wang, Jennifer Hu, Leo Ribeiro de Brito

4th place - Samarjit Kaushik and Anirudh Iyer

Exiting Medical Innovation

1st place - Ayushi Desai and Reeteka Kudallur

3rd place - Anisha Karnik and Suhani Arora

Forensic Science

2nd place - Amrita Narasimhan and Sonika Tayade

4th place - Anika Ghelani and Rachel Alwan

Health Career Display

2nd place - Jennifer Hu and Aheli Dutta

3rd place - Laura Mangov and Ojas Rayaprolu

Health Education

3rd place - Sameera Balijepalli and Nitisha Gautam

Original Medical Innovation

1st place - Anagha Polapragada and Jessica Singh

3rd place – Arundhati (Diya) Basu and Nitisha Gautam

4th place - Sameera Balijepalli and Ananya Nandula

Hunt theWumpus

Student Choice Award

Team "Sytax Errors": Noah Charleson-Sterritt, Michael Halim, Pinakin Kanade, Samarjit Kaushik, Aran Punniamoorthy

2nd Runner Up

Team "How to Train Your Viddy": Kishan Baliga, Viddy Baskar, Gabe Ervin, Yukito Shida, Jack Tribolet, Shaurya Vashisth

3rd Runner Up

Team "Artesian Code": Saihajveer Gulati, Hans Koduri, Daniel Popa, Raj Sunku, Joshua Venable, Brian Yang

2nd Place, Innovation

Team "Oh, No!": Kion Bidari, Brayden Brackett, Kinner Parikh, Archit Patankar, Varun Wescott, Azhan Zaheer

1st Place, Implementation

Team "Faze Clans": Viraj Goyal, Raymond Guo, Sahil Kancherla, Nadav Levanoni, Lucian Petriuc, Niranjan Sahi

Knowledge Bowl - State Competition

2A Division

2nd place - Yuchen Li (captain), Matthew Lam, Maxwell Soh, Saketh Dhulipalla, Atharv Dixit

2019 MATE ROV Competition for PNW

Moving on to International Competition in Kingsport, Tennessee

2nd place

Team SeaPreme.: Graham Sabin, Ayan Gupta, Devesh Sarda, Qing Hui Xie, Lahari Nidadavolu Arnav Sacheti, Adam George, Alvin Liu, Minu Padhye, Yusei O'Leary, Jakob Bjorner, Pamela Cheema, Edward Vanica

NCWIT Award for Aspirations in Computing

Aspirations in Computing Educator Award

Ms. Melissa Wrenchey

Affiliate Award

Aashna Sheth, Daniela Shuman, Tarini Srikanth, Thali Tsai

Affiliate Honorable Mention

Maya Chhong, Vidhi Jain, Aditi Joshi, Amrita Narasimhan, Roshni Srikanth

National Honorable Mention

Daniela Shuman, Tarini Srikanth, Thali Tsai

Pacific Model United Nations State Competition

Outstanding Delegate

Christine Lee, Human Rights Council

Position Paper

Jessica Singh, "Committee on the Peaceful Uses of Outer Space"
Sowmya Pratipati, "Economic & Social Commission for Asia & the Pacific"
Esther Wang, "Security Council"

National Merit

Alexia N. Friedman

National Merit Presidential Scholars Semi Finalist

Pranav Sukuma

National Merit Presidential Scholars Candidates

Alexia Friedman, Pranav Sukuma

National Merit Scholarships Corporate

Lauren E. Kim and Christine Lee

National Merit Semi Finalists

Victoria Alkin, Alexia N. Friedman ,Lauren E. Kim, Christine Lee , Hamsa Shankar, Sonika S. Tayade

Pacific Northwest Regional High School Science Bowl

3rd place

Team: Vedantha Venkatapathy (11th), Samarjit Kaushik (10th) and 9th grade students, Yuchen Li, Saketh Dhulipalla, Maxwell Soh

Individual Medal

Yuchen Li - Answering the 3rd most toss up questions.

PTSA Reflections

Literature

Award of Merit - Ankita Menon: "Unknown Heroes"

Outstanding Interpretation - Leonardo Ribeiro de Brito: "The Educator, a Paintbrush, and a Hero"

Music Composition

Award of Merit - Caitlin Lam: "Unseen Heroes"

Outstanding Interpretation -Evan Klansnic: "The Savior"

Visual Arts

Honorable Mention - Jeremy Yang: "The Graveyard Shift"

Outstanding Interpretation - Lina Chai: "A Cape of Heroes"

Technology Student Association (TSA) - State Competition

Board Games

4th place -Team of Shubhu Purohit, Aditya Balasubramanian, Rohan Anand, Yash Kulkarni, Aakash Ramachandran

Children's Stories

4th place – Qing Hui Xie, Annie Denton

CAD 3D Engineering

3rd place - Maxwell Wang

Engineering Design

1st place -Team of Jakob Bjorner, Devesh Sarda, Anirudh Iyer, Sebastian Wick, Mathias Foster

2nd place -Team of Dharini Sribalaskandarajah, Sashwatha (Sashu) Shankar, Ila Sharma

3rd place -Team of Kevin Yap, Laila Kuhn, Anirudh (Rudy) Banerjee, Annie Denton

Fashion Design

2nd place -Team of Tichada Tantasirikorn, Annie Denton

Future Technology Teacher

1st place - Samarjit Kaushik

Music Production

4th place-Amrutha Srikanth, Rachel Alwin

Robotics Challenge

2nd place - Team of Brian Yao, Aakash Ramachandran

Software Development

3rd place - Team of Aakash Ramachandran, Surya Gorantla, Varun Venkatesh, Aditi Balasubramanian, Devesh Sarda, Pranav Sukumar

Structural Engineering

3rd place-Team of Lahari Nidadavolu, Jakob Bjorner

Webmaster

4th place -Team of Mathias Foster, Akshay Murthy, Tristan Stevens, Ranveer Thind

Coding

4th place - Maxwell Wang

Extemporaneous Speech

4th place - Ranveer Thind

Technology Problem Solving

1st place - Team of Tristan Stevens, Maxwell Wang

VEX Robotics

1st place-Team of Brian Yao, Aakash Ramachandran
2nd place - Team of Tristan Stevens, Mathias Foster, Maxwell Wang

Washington State Esri ArcGIS Online School Competition 2019

N. Tesla STEM students took top five places with Top Prize moving on to Nationals

Top Prize – Daniel Rashevsky, *"The State of Seattle's Homeless Population"*
https://tinyurl.com/y6ksj8gg
Rishika Veeramachaneni, Minu Padhye, *"Pacific County Shellfish"*
https://tinyurl.com/y2up4xvl
William Erignac, Theo Devant,*"Salmon: The Indicators of the Environment"*
https://tinyurl.com/yyq5kyo4
Francessca Rossi, *"The Tacoma Smelter"*
https://tinyurl.com/y6ae2nga
Tichada Tantasirikorn, Qing Hui Xie, *"Yakama Tribe"*
https://tinyurl.com/y53yhhgm

Washington State National History Day contest (May 4, 2019)

**All three students moving on to National competition at the University of Maryland in June*

Senior Individual Documentary category

1st place - Amrutha Srikanth, *"Behind the Screen: The Rise of Women Animators in Walt Disney's Studios"*

Senior Group Documentary category

2nd Place - Anusha Srivastava, Esther Wang, *"Unfulfilled Promise: Emerging Conflicts Between Zionists and Arab Nationalists Shaped by British Policy in Post WWI Palestine"*

WSPTA//Game Development Competition

Best Game

1st place Team - The Rude Goldbergs, with "poTem". Alex Pujol, Anirudh (Rudy) Banerjee, William Erignac,

Best Game Design

The Rude Goldbergs, with "poTem". Team Members: Alex Pujol, Anirudh (Rudy) Banerjee, William Erignac,

Washington State Science and Engineering Fair (WSSEF)

**Tesla STEM had a record 8 of the 16 projects (50%) pulled for further judging in consideration for being an ISEF Finalist at WSSEF*

Aditi Ekbote and Vidhi Jain, *"Drug Combinations with Antibiotics and Curcumin to Combat Antibiotic Drug Resistance"*

- 1st place in Microbiology Category, Senior Division

Nina Gupta, *"Human Chorionic Gonadotropin Home Pregnancy Test to Detect Early Stages of Ovarian Cancer in Postmenopausal Women"*

- 1st place in Biomedical and Health Sciences Category, Senior Division
- Pacific Science Center Certificate of Achievement special category award
- Ohio Wesleyan University Outstanding Achievement in Science Scholarship ($20,000 renewable scholarship, total of $80,000)
- Wolfram Research, Inc. Mathematica Certificate of Achievement
- Side note: was also pulled for ISEF judging and almost won a trip to Phoenix

Nitisha Gautam and Arundhati (Diya) Basu, *"A Novel Machine Learning and Western Blotting Approach to Understand the Genomic Differences Between E-cigarette Vapor and Cigarette Smoke and its Relation to Tumor Development"*

- 1st place in Computational Biology and Bioinformatics Category, Senior Division

Akshay Murthy, *"Greet Sense: A Facial Recognition and Obstacle Detection Device for the Visually- Impaired and Blind"*

- 2nd place in Embedded Systems Category, Senior Division
- Do Real Things Award of Excellence in Science and Engineering
- IEEE - Seattle electro-technology special category award, $125
- SPIE - International Society for Optics and Photonics special category award, $150

Anusha Srivastava, *"Assessing the Apoptotic Effect of the Bacteriocin Nisin on Metastatic Breast Cancer Cell Viability"*

- 2nd place in Cellular and Molecular Biology Category, Senior Division

Sebastian Wick and Varshan Muhunthan, *"Car Exhaust Carbon Capture and Filtration by Implementing Synechococcus 7942 in a Photobioreactor"*

- 1st place in Environmental Engineering category, Senior Division
- National Oceanic $ Atmospheric Administration (NOAA) special category award, $75

Callie Wharton and Mychal Miller, *"The Effect of Age on the Presence of Implicit Bias"*

- 1st place in Behavioral and Social Sciences, Senior Divison
- American Psychological Association special category Award

Tarini Srikanth, *"Modeling Potential Drug to Drug Interactions Targeted Towards Cardiovascular Systems"*

- 1st place in the Computational Biology Category, Senior Division

Tristan Stevens and Maxwell Wang, *"Development of a Bi-Layer Geosynthetic to Decrease Road Deflection"*

- 1st place in Engineering Mechanics Category, Senior Division
- Washington State University - Voliland College of Engineering and Architecture $8000 scholarship for each student
- Wolfram Research, Inc. Mathematica Certificate of Achievement
- Ohio Wesleyan University Outstanding Achievement in Science Scholarship ($20,000 renewable scholarship, total of $80,000)

- Side note: was also pulled for ISEF judging and almost won a trip to Phoenix

Rachel Oommen, *"The Efficacy of Mindfulness Regimen On the Inattentive Behavioral Symptoms Among Emerging Adults"*
- 1st place in Behavioral and Social Sciences Category, Senior Division

Parbeen Sekhon and Rhea Shinde, *"Improving Accuracy Rate of Bitemark Analysis in Forensic Odontology"*
- 1st place in Biomedical and Health Science category, Senior Division
- US Army - Biomedical Sciences special category award
- U.S Airforce special category award

Marton Teichner, *"Investigating the Effects of Education on the Impact of Astroturfing"*
- 1st place in Behavioral and Social Sciences Category, Senior Divison
- American Psychological Association special category Award

Sowmya Pratipati, *"Creating a More Cost-Effective Hydroponics System to Compete with Conventional Agriculture"*
- 2nd place in Plant Sciences category, Senior Division

Anirudh Iyer, *"Analyzing miRNA Expression Levels in Glioblastoma Patients to Identify Candidate BioMarkers"*
- One of top 6 projects in entire Fair - won an all expense paid trip to Phoenix, ISEF Finalist
- 1st place in Biomedical and Health Sciences, Senior Division
- Evergreen State College, one-year full-tuition scholarship
- Pacific Science Center Certificate of Achievement special category award
- Ohio Wesleyan University Outstanding Achievement in Science Scholarship ($20,000 renewable scholarship, total of $80,000)
- Wolfram Research, Inc. Mathematica Certificate of Achievement Award

Elisabeth Berger, *"Powering a Solid State Fermenter with Compost Cogeneration To Produce Spores for Use as a Myopesticide"*
- 1st place in Environmental Engineering Category, Senior Division
- Wolfram Research, Inc. Mathematica Certificate of Achievement
- Side note: was also pulled for ISEF judging and almost won a trip to Phoenix

Marko Milovanovic and Denis Chelan, *"Water Purification Via Hand-Powered Pump"*
- 2nd place in Environmental Engineering category, Senior Division
- US Army special category award in life sciences special category award

Roshni Srikanth, *"Integrating Cognitive Behavioral Therapy and Mindfulness Principles Within an App To Help Manage and Improve the Mental Health of Refugees Facing Traumatic Stress"*
- 1st place in Behavioral and Social Sciences Category, Senior Division
- Wolfram Research, Inc. Mathematica Certificate of Achievement Award
- Side note: was also pulled for ISEF judging and almost won a trip to Phoenix

Anika Ghelani, *"A Behavioral and Neurophysiological Analysis of False Memories Implanted Through Imagination Inflation and Misinformation Effect for the Distinction of False Memories"*
- 1st place in Behavioral and Social Sciences category, Senior Division
- Wolfram Research, Inc. Mathematica Certificate of Achievement Award

Mirra Chinta, *"Synergism or Antagonism between Docetaxel and Finasteride in Prostate Cancer Model"*
- 2nd place in Biomedical and Health Sciences category, Senior Division

Kristin Acheson, *"The Effects of Ascorbic Acid on the Binding Between Collagen and Catechin"*
- 1st place in Chemistry Category, Senior Division
- American Chemical Society-Puget Sound Section special category Award, $25
- Ohio Wesleyan University Outstanding Achievement in Science Scholarship ($20,000 renewable scholarship, total of $80,000)
- Wolfram Research, Inc. Mathematica Certificate of Achievement Award
- Side note: was also pulled for ISEF judging and almost won a trip to Phoenix

Madison Messina and Eden Netz, *"The Correlation of Posting Publicly on Social Media and Anxious Sleep Patterns in Teenagers"*
- 1st place in Behavioral and Social Sciences Category, Senior Division
- Wolfram Research, Inc. Mathematica Certificate of Achievement Award

John (Van) Monday, *"Examining the Correlation Between County Demographics and the Effectiveness of Major Environmental Legislation"*
- 1st place in Earth and Environmental Sciences Category, Senior Division

Manasvini Calmidi, *"Determining the Most Effective Salt Concentration of Irrigation Water for Trichoderma harzianam to Confer Salt Tolerance Through Symbiosis to Oryza sativa Plants"*

Bronze Prize Grand Champion Award, all expense paid trip to Phoenix, ISEF Finalist
- 1st place in Plant Sciences Category, Senior Division
- Washington State University - College of Arts and Sciences $16,000 scholarship
- Seattle Pacific University scholarship - $8000 over 4 years
- Wolfram Research, Inc. Mathematica Certificate of Achievement Award
- Puget Sound Institute of Food Technologies special category award
- Ohio Wesleyan University Outstanding Achievement in Science Scholarship ($20,000 renewable scholarship, total of $80,000)
- Plant Sciences Achievement special category Award, $150
- Pacific Science Center Certificate of Achievement special category award

Romanpreet Kaur, *"Menstrual Hygiene Period"*
- 1st place in Environmental Engineering Category, Senior Division

Mathias Foster, *"Development of a Perpetual Solar-Powered Blimp to Aid Urban Search and Rescue"*
- 1st place in Robotics Category, Senior Division

Toma Itagaki, *"Examining the Activation of Default Mode Networks in Non-Visual Blinks"*
- 1st place in Behavioral and Social Sciences category, Senior Division
- US Army special category award in Life Sciences Special Category Award

Max Reisman, *"Low Cost Solar Desalination System Utilizing Salt-Rejecting and Solar Absorber Technology for Quick and Efficient Desalination"*

- 2nd place in Environmental Engineering category, Senior Division
- Marine Sciences Outstanding Research in Biology, Chemistry, Physics and Geology special category award
- Olympic College Outstanding STEM project special category Award
- Washington National Guard Top Scientific or Engineering project Certificate of Excellence, $200

Sunya Mohammed, *"Implementing Eye-Tracking Technology for the Advancement of Driver Training"*

- 1st place in Systems Software category, Senior Divison
- US Army special category award in Mathematics and Computer Sciences Special Category Award
- Health and Safety (PNS-AIHA) Excellence Award

Isha Murali, *"Exploration into Analyzing the Auditory Cortex in Relation to Attention as Measured by Alpha and Beta Waves"*

- 1st place in Behavioral and Social Sciences category, Senior Division

Annie Denton, *"Forecasting the Effects of Climate Change on the Distribution of the Pacific Sideband Snail"*

- 1st place in Animal Sciences category, Senior Division
- USDA Forest Service Pacific Northwest Research Station award, $50
- Wolfram Research, Inc. Mathematica Certificate of Achievement Award
- Ohio Wesleyan University Outstanding Achievement in Science Scholarship ($20,000 renewable scholarship, total of $80,000)
- Side note: was also pulled for ISEF judging and almost won a trip to Phoenix

Hemant Dhokia, *"Involuntary Muscle Contraction to Determine If Someone is Lying or Telling the Truth"*

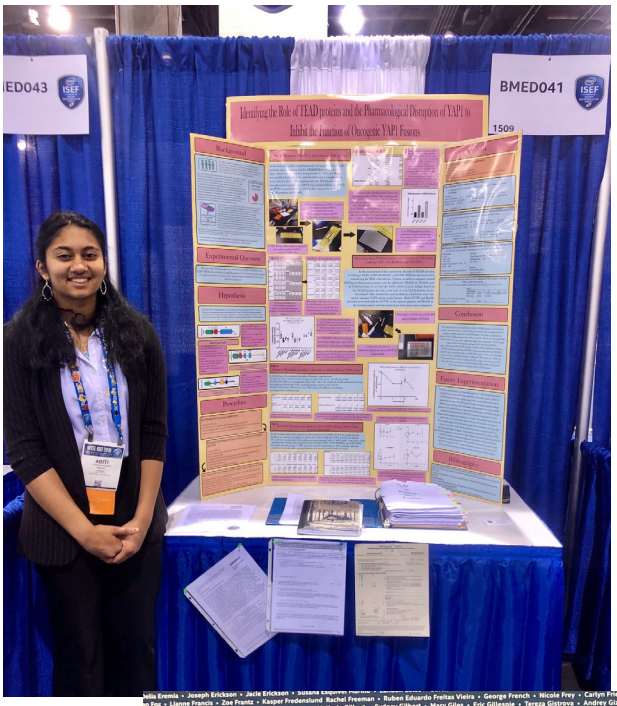
- 1st place in Behavioral and Social Sciences Category, Senior Division

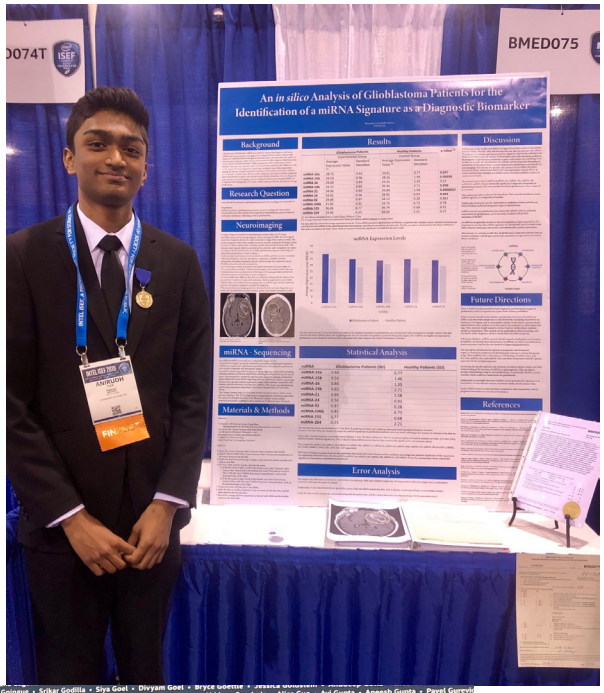
Varun Sridhar and Siddharth Shende, *"The Analysis of Environmental Factors Through the Implementation of a Machine Learning-Backed Aerial Drone For Increased Accuracy in Forest Fire Risk Assessment"*

- 1st place in Environmental Engineering category, Senior Division
- Normal E Borlaug Excellence in Sustainability Award, $100
- Wolfram Research, Inc. Mathematica Certificate of Achievement Award

Nikola Tesla STEM High School (Tesla STEM) has earned the first College Board AP® Computer Science Female Diversity Award for achieving high female representation in AP Computer Science A (CSA) and/or AP Computer Science Principles (CSP). Schools honored with the AP Computer Science Female Diversity Award have expanded girls' access in AP computer science courses. Out of more than 18,000 secondary schools worldwide that offer AP courses, only 685 have achieved this important result.

Nikola Tesla STEM High School female students are planting seeds for younger generations.
Lahari Nidadavolu, Supriya Baskar, Olivia Facq, Qing Hui Xie, and Minu Padhye are using an outreach program to promote engineering. It is called IM.A.G.IN.E, or *"I'm a girl in engineering."* I.M.A.G.IN.E started as an outreach program with a goal of encouraging more girls in core engineering fields through hands on activities.


BMED041
Identifying the Role of TEAD proteins and the Pharmacological Disruption of YAP1 to Inhibit the Function of Oncogenic YAP1 Fusions


BMED075
An in silico Analysis of Glioblastoma Patients for the Identification of a miRNA Signature as a Diagnostic Biomarker
Background
Research Question
Neuroimaging
miRNA - Sequencing
Materials & Methods
Results
Statistical Analysis
Error Analysis
Discussion
Future Directions
References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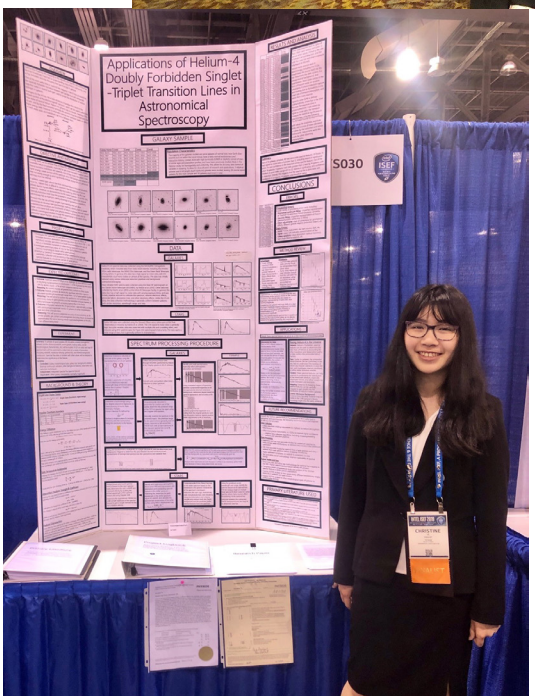
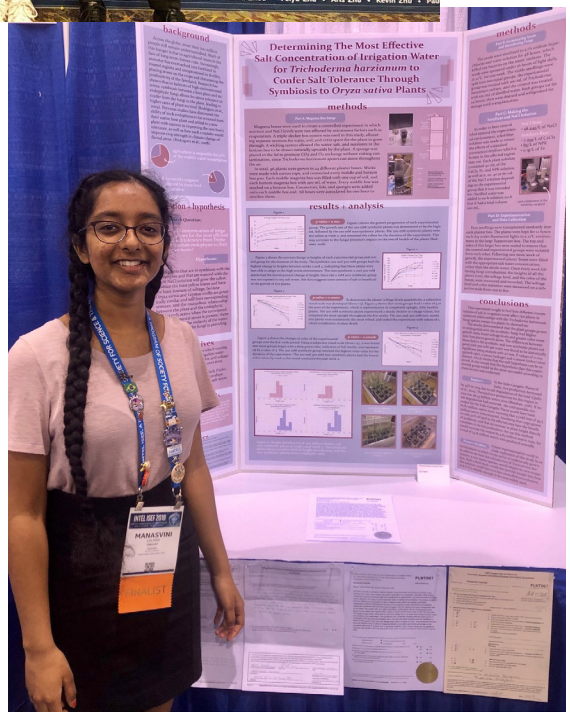
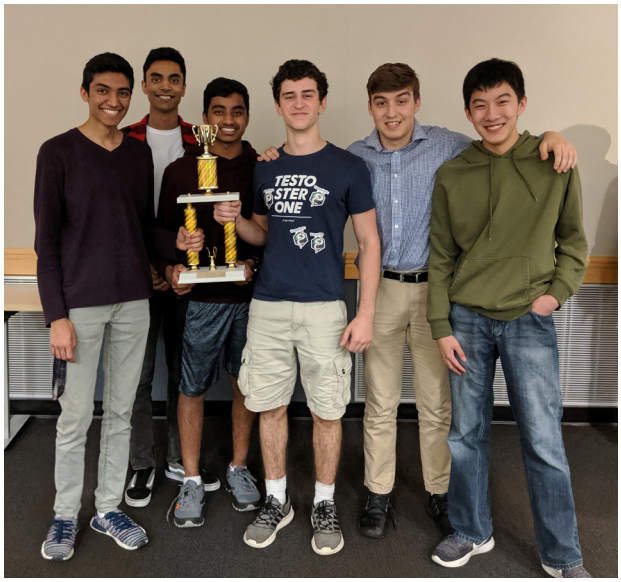
SOCIETY FOR SCIENCE & THE PUBLIC


Applications of Helium-4 Doubly Forbidden Singlet -Triplet Transition Lines in Astronomical Spectroscopy


Determining The Most Effective Salt Concentration of Irrigation Water for Trichoderma harzianum to Confer Salt Tolerance Through Symbiosis to Oryza sativa Plants
background
methods
results + analysis
conclusions

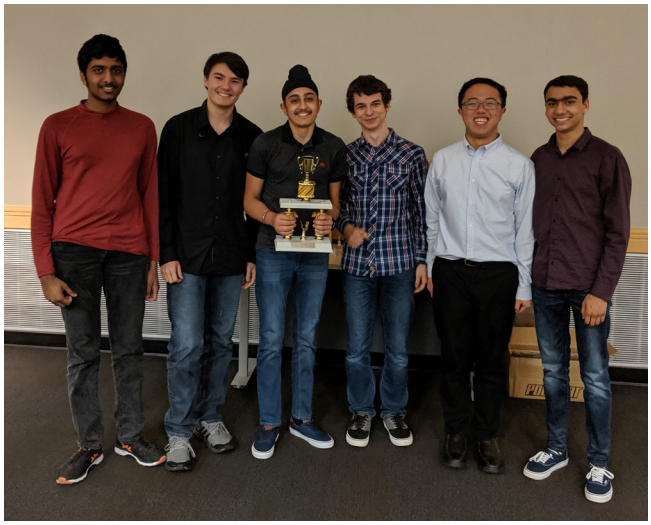


1st place, Implementation, "Faze Klans"

2019 Microsoft Hunt the Wumpus

2nd place, Innovation "Oh No!"

2nd Runner Up, "How To Train Your Viddy"



3rd Runner Up, "Artesian Code"

Student Choice, "Sytax Errors"

Nikola Tesla STEM Model UN

TSA State Conference Robotics - 1st Place

2nd Place Moving on to Nationals!

MATE ROV COMPETITION
Pacific Northwest

Science Bowl 3rd Place