SITFLOW (HOVR) EFFECT ON COGNITIVE PERFORMANCE

CAL POLY
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By

Carter Bergquist, Colette Lee, and Jared McMullen

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CHAPTER 1. INTRODUCTION AND BACKGROUND

As the workplace setting evolves around employees spending a majority of time sitting down, there has been an increased motivation in the furniture and accessories industry to provide an opportunity for exercise in these settings. It has been found that the constant sitting and lack of physical activity in these environments affects humans' long-term health, especially leading to obesity and high blood pressure. SitFlow is a start-up that aims to find a solution to this problem by giving users an opportunity to exercise and move while sitting and working. SitFlow's product is an under-desk apparatus that allows an individual to move with the potential to burn calories and increase circulation when the user is sitting; taking away the monotony and idleness of sitting while working.

SitFlow is NEAT (non-exercise activity thermogenesis) certified by Mayo Clinic, meaning that it has documentation that proves the SitFlow apparatus allows users to burn calories while doing normal, non-exercise activity (Koepp, 2012). Two additional studies have been conducted by the University of Illinois and Tokai University to examine the health benefits of SitFlow. From these studies, the apparatus has been successful in increasing circulation and calories burned by users while sitting. SitFlow has been proven to be successful in promoting energy expenditure and burning calories in not only sedentary work settings, but also in other sitting environments like gaming and schoolwork. However, this project will only focus on professional work settings such as corporate offices.

The purpose of this project is to conduct initial research, design and implement an experiment, and perform statistical analysis on the collected data to further examine the effects of SitFlow in sedentary work settings. While many of SitFlow's previous studies have focused on biological metrics like blood pressure and energy expenditure, this project's study will focus specifically on user work productivity and cognitive ability. Productivity in this case will be defined by user cognition which will be measured via the Criteria Cognitive Aptitude Test (CCAT) which measures aptitude, problem-solving abilities, skill learning capabilities, and critical thinking for pre-employment. The end goal is to find out if the SitFlow apparatus has an effect on user cognitive ability with emphasis on the apparatus' ability to provide simultaneous physical activity without reducing an individual's productivity in a work setting. The findings from this study will provide additional support of the benefits of SitFlow. The methods of data collection will stem from analyzing and comparing participants' scores on the CCAT standardized test as well as using data from participants' self-evaluation surveys, which will be discussed in further detail later in this report.

In terms of ethical considerations, the biggest factor affecting data collection will be the state of affairs in the context of the COVID-19 pandemic. As the pandemic has altered the overall way of life, the data must be collected in a way that adheres to social distancing and prevention guidelines set by the Centers for Disease Control and Prevention (CDC) and California Polytechnic State University, San Luis Obispo, (Cal Poly) to eliminate the risk of the participants, researchers, advisors, and anyone involved with the experiment being subjected to contaminated surfaces. When conducting the experiment and collecting the data that shall be used for analysis, materials and surfaces in the experiment setting shall be cleaned and decontaminated in order to create a safe and clean environment for those participating in the experiment. To ensure the ethical experimentation of human subjects, the research project was conditionally approved by the Cal Poly Institutional Review Board (IRB) on January 28, 2021. The IRB is responsible for evaluating research projects associated with Cal Poly ("Human

subjects research at Cal Poly", n.d.). There are ethical standards set by the IRB that need to be followed including, but not limited to, minimization of risk to subjects, benefits to participants as a result of any risks, equitable selection of participants, required documentation and consent from all participants, data collection security, participant confidentiality, protection of rights and welfare for individuals categorized as subjects in special classes, and accurately informing potential participants ("Human Subjects -- Procedures and Guidelines, n.d.").

The hope is that the data collected in this project's experiment will accurately reflect on SitFlow's relationship with individual cognitive performance. While the data pool is restricted to university students who are compliant with Cal Poly's COVID-19 testing program, the experimental environment will mimic that of a typical sedentary work setting. This report will further discuss literary review of supplementary materials, project structure and problem statement, design of experiment, the methods used for data collection and analysis, verification and validation, and impact analysis. The conclusion of this report will determine SitFlow's effect on work performance with an emphasis on cognitive performance and recommendations for further studies.

CHAPTER 2. PROBLEM DESCRIPTION

2.1 Problem Statement

SitFlow has been validated and certified in non-exercise activity thermogenesis (NEAT) by Mayo Clinic and has additional studies conducted by the University of Illinois and Tokai University that focus on energy expenditure. SitFlow wants to obtain more information to bridge the gap between these existing studies. The company wants to know how the SitFlow apparatus affects work productivity. For this project, work productivity will be defined in terms of the level of user cognitive abilities. Therefore, to study the relationship between the apparatus and work productivity, an experiment will be conducted to measure and compare levels of cognition via the Criteria Cognitive Aptitude Test (CCAT) while a participant uses the SitFlow apparatus and without. If the results from this study proves that the SitFlow apparatus has a positive effect on work productivity, the validation gained from this research project, in addition to the studies previously mentioned, will provide credibility to the product's ability to balance energy expenditure and work productivity which in turn will make SitFlow more competitive against similar products.

2.2 Project Objectives

As stated in the introduction, the purpose of this project is to conduct research and create an experiment to further examine the effects of SitFlow in sedentary work settings. By building upon SitFlow's previously conducting studies and researching competing products such as the under-desk elliptical and elliptical desks, the objective of this project is to further define the relationship between SitFlow and work productivity. Productivity is difficult to accurately describe so for the purpose of this project, productivity will be defined by an aptitude score measured by the Criteria Cognitive Aptitude Test (CCAT). At the conclusion of this project, the primary objective is to analyze the effects of using the SitFlow apparatus in a sedentary work environment based on cognitive ability. The findings of this study will be formally written and submitted for publication at a future date.

2.3 Current State

Table 1 breaks down exactly where SitFlow currently stands based on the true north metrics the team and their SitFlow sponsors decided on. SitFlow currently has three main studies from Mayo Clinic, University of Chicago, and Tokai University. During the Mayo Clinic experiment, SiFlow was compared against sitting and standing. The clinic identified a potential to increase energy expenditure by approximately 20% when using SitFlow. The University of Chicago compared three workstations: seated, standing, and swinging. The University determined using SitFlow elevated metabolic rate by just over 17% without impacting cognition. Cognition in this study was measured by the Stroop word-color test. And finally, at Tokai University, SitFlow was identified to produce increased heat production by 18% to 20%, greatly improving blood circulation.

Currently these three studies are the main three sources to validate SitFlow's ability to increase a user's energy expenditure. This research project will focus on SitFlow's other main element of not decreasing work productivity while using the apparatus. Beyond the experiment

completed at the California Polytechnic State University, San Luis Obispo, SitFlow plans to run experiments at two other universities: San Jose State University and University of California, Berkeley. Both experiments from these universities will aim at further researching the effects of user work productivity by measuring cognitive ability while using SitFlow.

True North Category and Metrics	Current State	Target State
Productivity	N/A - research intended to quantify, assess	Define, quantify, and measure
Ease of Use	Short learning curve	Maintain short learning curve
Energy Expenditure	Increased by approximately 20% after using the product (Mayo Clinic); blood circulation improved after 10 minutes (University of Tokai)	To maintain/increase statistics
NEAT	Validated and certified by the University of Illinois and Mayo Clinic	Continue to encourage NEAT and obtain more validation
Accessible for all ages	Mainly geared for older adults/elderly people	Increase exposure to a younger audience
Range of motion	20 Degrees of motion from relative balance beam position	Maintain current state
Range of ages involved in research	K-12 schools and eldery homes are using the product	Provide accessibility of the product to more schools and elderly homes
Fun	Product is enjoyable to use	Maintain current state

Table 1: Current State of SitFlow

CHAPTER 3. LITERATURE REVIEW

3.1 Introduction

In preparation for the literature review and future of the SitFlow project, the team's first step was to research the gaps in existing knowledge obtained from our sponsors. For the first stage of research, each team member chose a topic to further develop. Our first stage topics included existing SitFlow studies, similar experiments to our project, and product application. After combining our research, the team created a fishbone diagram shown in Figure 1:

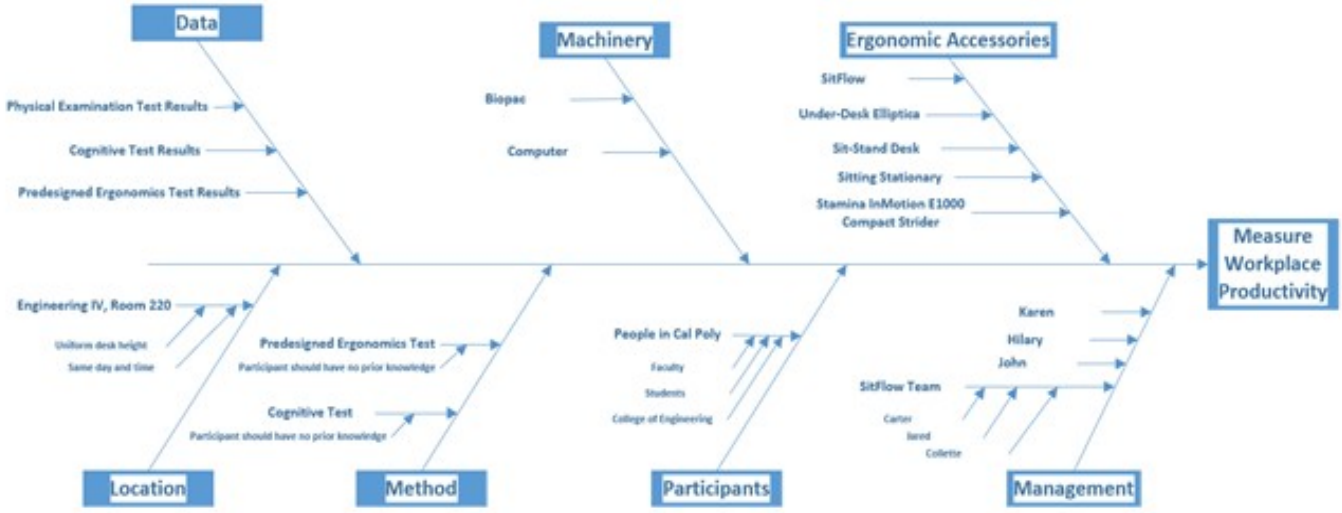


Figure 1: Fishbone Diagram

The fishbone diagram shows how we expanded the initial individual research topics to pinpoint critical gaps in our information. Two significant gaps discovered were in the data and method sections. These gaps questioned how we would quantitatively and qualitatively define productivity and how we would select the cognitive test that will be utilized in our experiment.

To resolve these issues, the team used different resources to compare the authors' solutions and opinions. Since defining productivity and having a reliable cognitive test are key factors of the SitFlow project, these elements became the basis of the project's literature review. By the latter part of the first quarter, the team synthesized their research based on relativity in the following seven categories: product background, product application, competing or similar products, existing studies, relevant studies, and cognition tests.

3.2 Product Background

SitFlow, originally named "HOVR," derived from the idea of providing a non-distracting mechanism that promotes natural movement while sitting. The SitFlow product strives to eliminate the guilt of sitting for long periods of time which seems inevitable in the modern era.

According to Daniel E. Lieberman's article, "Is Exercise Really Medicine? An Evolutionary Perspective" (Lieberman, 2015), humans, now more than ever, seek a greater amount of activities to optimize their health. The reasoning behind this is evolution lacking a trend in sedentary lifestyles - a person is equally as likely to be active and inactive. Lieberman continues to note that exercise is not meant to be a medicine nor a solution to prevent underlying health issues that come from long periods of sedentariness. Instead, exercising should become a permanent requirement by adjusting daily routines and finding entertaining outlets to promote more activity in all environments, namely in offices, schools, and homes.

The reality is, despite the recommended stretch or walk breaks throughout the workday, most individuals do not take these opportunities. By skipping these brief breaks, a person may develop long term health issues such as obesity, type 2 diabetes, cardiovascular disease, cancer, and, notably the most common, musculoskeletal pain (Ojo, 2018). Musculoskeletal pain refers to intense, chronic pain that can be felt anywhere in the body. Due to the increase of sedentary behaviors, cases of these types of pains are drastically increasing and affect the patient's physical and mental state (Hanna, 2019). Thus, work productivity in employees with musculoskeletal pain - or any underlying disease resulting from sedentary behaviors - tend to exponentially decrease. On the other hand, if the person did take a stretch or walk break, it will take a significant amount of time to regain focus; with some tasks taking more time than others. For instance, if a computer programmer were to take a ten-minute exercise break after an hour of working, it will take approximately fifteen to twenty minutes to regain the amount of focus previously obtained (Mark et al., 2005). By reducing or eliminating the time taken to refocus, the programmer has the ability to work for a longer period of time, ultimately saving the company money and obstacles that come with employee accommodations.

SitFlow is an easier decision for corporations because of the potential to reduce health insurance costs by better accommodating employees' needs. Offices are currently SitFlow's largest market but the product is easily applicable to schools, homes, and even video gaming environments. In fact, the product has already been converted into a video game controller. SitFlow was awarded the "Best Office Accessory" at NeoCon and "Second Prize in VR" at MIT hackathon. One of SitFlow's greatest achievements was receiving accreditation for non-exercise activity thermogenesis (NEAT) by Mayo Clinic. NEAT is an important concept in describing SitFlow and became a key term in the project. NEAT refers to any activity, other than sleeping, eating, and sports, that exerts energy. This includes mundane tasks such as yardwork, cleaning, typing, etc. Products that are qualified for NEAT certification successfully increases energy expenditure when an individual sits by more than ten percent ("Here's a Few Reasons Why Your Standing Desk probably isn't NEAT Certified, n.d.). Thus, with NEAT validation and all these achievements in hand, there is no doubt that SitFlow has accomplished natural, subconscious movement that can be implemented into sedentary behaviors. The next step for the product's development and accreditation is to conduct an experiment to test if the product positively, negatively, or does not affect work productivity.

SitFlow is marketed as an office accessory which is an industry with room for improvement. Furniture designs are leaning towards developing their technology, but they lack key ergonomic aspects which is the backbone of the industry. Ergonomics help in understanding the relationship between humans and other surrounding elements. By utilizing ergonomics into

furniture and accessory designs, human safety and health are taken into account (Rozlina, 2012). Another concept that is not well-used is biohacking. Designs that utilize "biohacking" uses technology in some way to improve the body. Rather than solely focusing on technology that seems to be on trend, biohacking products prioritize potential health benefits in their designs. SitFlow is a biohacking product with a distinct feature of non-disrupting the user while promoting subconscious movement.

3.3 Product Application

SitFlow has a large target population ranging from schools, offices, seniors, and gaming environments. In general, SitFlow aims to market their product to people who sit for long periods of time and have strong sedentary behaviors. Thus, the team found it necessary to research product background and application separately to highlight and accommodate the product's many uses. Rather than discussing the straightforward reason why SitFlow can be used in different environments, it was decided by the team that it is more beneficial to discuss how SitFlow can be effective for a specific user's unique needs.

In addition to the environments listed, SitFlow also helps individuals with ADD/ADHD who are constantly fidgeting (SitFlow, 2017). Rather than forcing the individual to stop fidgeting, SitFlow provides an alternative way for the fidgeting to occur while remaining non-distracting. Therefore, SitFlow can make a significant impact by providing an easy way to fidget with a possibility to increase work productivity in an subconscious manner. As stated in the introduction of our literature review, one of the obstacles the team faced was defining productivity. While researching product application, the team had the initial idea to quantify productivity as the comparison between the output to input (DXC.technology, 2019). However, this definition was vague and difficult to model around the SitFlow experiment so the team decided to find another solution direction.

3.4 Reflecting on the Current State of SitFlow

In 2020, civilian workers spent an average of 42.7 percent of the workday sitting (U.S. Bureau of Labor, 2020). If the workday is ten hours, this means that civilian workers spend more than four hours of their day sitting at their desk. Since 2016, there has been a 3.7 percent increase in the average amount of time a civilian worker is sitting (U.S. Bureau of Labor, 2016). With sedentary behaviors increasing, there has been a growing opportunity in providing a form of exercise in these settings. Sedentary behaviors include any activities that require low levels of energy expenditure including, but not limited to, computer use and watching TV. The lack of energy expenditure or physical activity in workplace settings leads to the development of numerous chronic diseases such as obesity and high blood pressure as well as increased risk of morality (Katzmarzyk et al., 2009). Despite what was previously stated, it is crucial to note that excessive sitting has not been linked directly to health consequences; therefore, sitting for long durations of time does not necessarily equate to lack of exercise (Owen et al., 2010). There are multiple reasons, in addition to excessive sitting, that result in the development of chronic diseases such as personal lifestyle and diet. Regardless, excessive sitting may affect an

individual's overall workplace productivity and performance which, in turn, can affect the individual's health.

Employers in more sedentary workplaces are more at risk of an increase of healthcare costs if their employees develop health issues or experience decreases in work productivity. A primary concern companies should have when selecting a more active alternative to standard desks is the consequence of interrupting an employee's workflow. As stated previously, after an employee takes a break, it takes a significant amount of time to refocus and heavily reduces productivity; with some tasks taking longer than others (Mark et al., 2005). Additionally, the more interruptions an employee experiences, there is a higher chance that errors will occur. By reducing or eliminating the time taken to refocus, the worker has the ability to work for a longer period of time, ultimately saving the company money and avoiding obstacles that come with employee accommodations. In order to compensate or resolve the issue of employee interruption, companies are searching for efficient, reliable resources to allow employees to have a choice to sit, stand, or be more active while increasing productivity. Three popular resources used in modern workplace settings include adjustable sit-standing desks, under-desk ellipticals, and treadmill or bike desks. All these resources share the same goal of balancing energy expenditure and productivity. However, none of them succeeded perfectly; employees still showed a decrease of work productivity or lack of energy expenditure which will be explored in the following section.

3.5 Competing or Similar Products

It is important to research competing or similar office accessories to provide insight on SitFlow's target audience and compare product performance. Additionally, information collected from these products can assist in designing the SitFlow experiment.

Stamina InMotion E1000 Compact Strider Elliptical is an elliptical that allows the user to stand or sit with adjustable resistance. SitFlow is designed to be used only while sitting so the E1000 Compact Strider Elliptical has more variability. However, according to reviews, most users prefer to use the E1000 Compact Strider Elliptical while sitting because support is needed when standing in addition to a 250-pound weight limit ("Stamina InMotion E1000 Compact Strider Elliptical Trainer Review"). An appealing feature of the E1000 Compact Strider Elliptical is the electronic display which tracks user performance in time used, calories burned, and strides per minute. SitFlow has the potential to collect and display similar data in a future application. The team decided to research the E1000 Compact Strider Elliptical primarily because of the similarity in textured pedals to SitFlow's and variability in targeting different muscles based on different motions (moving forward and backward). The key takeaway from researching the Stamina InMotion E1000 Compact Strider Elliptical is that potential customers prefer to have a portable and budget-friendly product. From this, we can assume the customers are transporting the product to different places such as offices, homes, and schools. Although it is a big assumption, it gives the team insight into who is using the product and why.

Cubii is an under-desk elliptical and one of SitFlow's top competitors. To support their claim that Cubii may have positive effects when used in the workplace, a study is being conducted to evaluate the work performance while using the product and influences made based on the quality of pedaling (Rovniak, 2020). Since the study is ongoing, results have not been released but the information provided can influence the future of the SitFlow experiment. The

sample size of the Cubii study is sixty with the primary criteria of participants being overweight or obese. A randomized trial with a treatment structure of a two (healthy gift card or Amazon gift card) by three (immediate incentive, partial immediate incentive, or delayed incentive based on pedaling quality) factorial design was utilized. Data is collected by the Cubii application which is connected to the product via Bluetooth. The measurements collected included: employee ratings of work performance, supervisor ratings of employee work performance, elliptical pedaling volume, gift card receipts, total non-pedaling activity, satisfaction from the participant, social environment, and participant demographic and health. If the results return positive, it can provide insight on better promoting active office environments. From the current state of the Cubii experiment, the research team can take away the data methods used in a proposed questionnaire, utilize giving participants incentives after completing the experiment, and arrange a reasonable duration of time for data collection due to participant scheduling. At the initial stages of the experimental design, the team needed an idea of the number of participants needed to sample in the SitFlow experiment. The team noted the sample size of sixty and data collection process that is planned in the Cubii application. However, due to the COVID-19 pandemic, the team designed the experiment with additional safety precautions. Having a sample size of sixty would account for more variation in our target population but is not feasible during the pandemic.To solve this, the research team has conducted statistical analysis to better create a sample size range using the G*Power software described in the Design and Evaluation of Potential Solutions section.

Another competing product is a treadmill desk. Unlike under-desk ellipticals, treadmill desks allow the user to stand and walk at a slow pace while working at a stationary desk. In the journal Obesity, a study was conducted to test the impacts of using a treadmill desk for one year (Koepp, 2012). The study was performed to track how treadmill desks affected time spent sitting down and the potential health benefits associated with the product. The sample size was thirty-six (twenty-fix females, eleven males) with sedentary jobs. The study found that physical activity increased after using treadmill desks for a year and weight loss occurred in obese test subjects. From the Obesity study, the team gained more understanding of SitFlow's target audience or people who would find the product appealing. The Obesity study also added onto the foundation, providing ideas for how the team can formulate our data collection. Again, the strict criterion of the study's participants will be difficult during the pandemic but having thirty-six participants is more realistic. Since the team does not have an abundant amount of time and resources, the experiment will have to be condensed and the learning curve has to be taken into account. After researching product background and application and similar and competing products, the team went on to the next stage of researching existing studies which have similar outcomes to our goal.

3.6 Existing Studies

SitFlow has been certified in non-exercise activity thermogenesis (NEAT) by Mayo Clinic. NEAT refers to any activity other than sleeping, eating, and sports that requires energy. In today's workforce, individuals who do manual labor have a higher NEAT than individuals who do stationary or business labor (Levine, 2002). There are simple ways to increase an individual's NEAT score. For instance, taking the stairs instead of the elevator. In addition to the Mayo Clinic study, SitFlow has two medically supervised studies conducted by the University of Illinois in Chicago and Tokai University located in Japan.

The Mayo Clinic study was one of the initial tests to examine SitFlow's effects on user health and cognition (Koepp, 2017). By using heart rate and energy expenditure, the study also demonstrated how SitFlow plays a role in providing observable health effects. There were twenty-six participants (twelve males, fourteen females) sampled using a Steelcase standard office chair as its control chair, treadmill, and SitFlow. The study concluded that SitFlow increased energy expenditure by approximately twenty percent in twenty-five participants making it more effective than sitting or walking. This study became our base in designing our experiment. Since Mayo Clinic's study tests SitFlow to a control (chair) and a competing product, our goal is to take the next step in designing an experiment to test SitFlow's effects on work productivity. In other words, the team's goal is to build on the results of this study to further validate SitFlow's positive effects. If the effects do not align with Mayo Clinic's, the team will analyze the results to see if there are any causes for the negative or lack of correlation.

The Tokai University conducted by Dr. Taro Takahara is in Japanese, so one of our sponsors, John Harada (personal communication, October 6, 2020), gave the team a summary on the study. With the use of MRI and thermography, the Tokai University study proved that using SitFlow for ten minutes increased blood circulation. This can benefit users that suffer from cold feet and legs while sitting for a long duration of time. The study also found that heat production was increased by eighteen to twenty percent. Similar to the Mayo Clinic study, the team hopes to build upon Tokai University's work in efforts to see if there is a positive, negative, or no correlation between SitFlow and work productivity.

Craig Horswill conducted a study for SitFlow under the University of Illinois in Chicago (Horswill, n.d.). The purpose of his study was to test and compare metabolic rates when using SitFlow versus sitting and standing. There were sixteen participants (three males, thirteen females) who performed all three tests (sitting, standing, and SitFlow). Horswill concluded that compared to sitting, SitFlow increased metabolic rate by just over seventeen percent and seven percent compared to standing. Horswill has provided a lot of information to SitFlow so the team read his study with every detail in mind. However, because we do not want to create an identical study, we decided to focus our attention on other studies not conducted by SitFlow to design our experiment. These studies can be found in the "Relevant Studies and Tests" section of our literature review.

3.7 Relevant Studies

The first experiment we looked at tested the musculoskeletal and cognitive effects of under-desk cycling compared to sitting for office workers (Baker, 2019). The goal of the experiment was to answer whether a change in working position can decrease the development in health risks. The procedure of this experiment is similar to SitFlow's Mayo Clinic study (Koepp, 2012). The team found this experiment to be insightful because it was based on similar experiments involving testing furniture accessories to a control group and improved their methods. Additionally, the experiment included elements they would like to improve or add to make the experiment more thorough if conducted again. First, the experiment did not evaluate user discomfort and feasibility. This can be included in our future experiment by including a questionnaire after each test is run. Second, the study took measurements every thirty minutes.

This is a feasible amount of time considering each session took two hours. However, since the team wanted to optimize the experiment's outcomes, a company called Biopac was contacted to utilize their eye tracking software. By using their software, the team will be able to measure and interpret physiological elements (Biopac, n.d.) including, but not limited to, where the participant is focusing their attention to better visualize the participant's cognitive state. Due to unforeseen circumstances, the Biopac eye tracking software was not implemented into the final design of the experiment which is covered in the Design and Evaluation of Potential Solutions section.

A second experiment we looked at analyzed cognitive performance when compared to an active workstation (Ojo, 2018). This experiment occurred during a twelve to fifty-two week period which is significantly greater than the time given to the SitFlow experiment of approximately ten to fifteen weeks. The participants involved office workers who were presented with five different cognitive tests: attention, memory, reasoning and reaction time, work-related performance, and productivity after prolonged use of active workstations. The study concluded that the sit-stand workstations did not have a negative effect on productivity. In this experiment, the participants seem to fit a very broad range of simply being office workers so this fits the resources the team has. Rather than focusing on a group of people with a strict criterion, we will have our participants be within the Cal Poly community. Additionally, the tests used can be applied to our experiment so that we can cover as many aspects as possible.

3.8 Cognitive Tests

In order to start designing our experiment, we researched studies that have conclusions similar to our objective. To start, the team was introduced to the term "flow" coined by Mihaly Csikszentmihalyi (Csikszentmihalyi, 2008). A person is in a state of flow when they are heavily involved in activity so that nothing else seems to matter. When the flow state occurs, self-consciousness disappears and concentration on the task at hand is so intense that it seems like there is no attention left to think about anything else. In terms of SitFlow, the act of using the product is subconscious so it does not take away any attention from the task. In other words, SitFlow is non-distracting and does not disrupt cognition. There are two main factors to be in the flow state: challenge and skill. A task must not be too challenging nor require too much skill. If a task is too challenging, the individual conducting the task will feel anxious. On the other hand, if the task requires too much skill, for instance, a geometry test, the individual will feel bored. Flow applies to our experimental design because to obtain optimal results, we have to choose a task that falls in between being too challenging and requiring too much skill.

With flow in mind, the team started researching more relevant studies and experiments. At first, the team was unclear whether energy expenditure was a contributing factor to the project but determined that our experiment should be primarily based on cognition. From our prior research stages, we noticed that most, if not all, of the studies had some form of standardized cognitive test. Therefore, we focused on researching different types of cognitive tests. The test of variables of attention (T.O.V.A.) was introduced to the team by one of our sponsors. It was difficult to find an experiment describing the procedure, but the team was able to find one experiment using T.O.V.A. to measure attention and impulse control in children (Greenberg, 1993). In this experiment, T.O.V.A. was a visual Continuous Performance Test that lasted

twenty-three minutes. The Continuous Performance Test has several different variations but are all based on the original application of measuring inattention and impulsivity. Participants would be shown several visuals and instructed to respond to a target. For the purposes of our experiment, T.O.V.A. seemed like a good option. Though, it did not prove to be credible enough. Credibility became a leading factor when selecting the cognitive test for the future of the SitFlow product. The team looked into how cognitive tests develop normative data and possible limitations (Thomas, 2016). When selecting a cognitive test, the team will be aware of the intentions of the test (what it was designed for), the measurements taken, and range of participants (who was the test designed for).

Somewhat similar to the Continuous Performance Test, the Stroop Color and Word Test shows the participant a word referring to a color with the word being a different color. For instance, "RED" would be shown on the screen but the word is in blue. The participant would have to say what color the word is rather than reading the word. The Stroop Test does not require a lot of skill and is not highly difficult, leading it to fit the criteria extremely well. It has been widely used in a plethora of experiments; including SitFlow's study conducted by the University of Chicago in Illinois. The only negative of using the Stroop Test for our experiment is the lack of variability and short time duration. Despite this, the team decided to use the Stroop Test while training the participants to use the SitFlow product. This way, we can record their learning curve when adjusting.

Since the search for an ideal cognitive test became a huge task, a team member was assigned to solely dedicate his research to different cognitive tests and their origins and purpose. The team's initial criteria for the cognitive test were credibility, flow, and time. (These criteria are further developed in the "Initial Designs" section.)

The Wonderlic Test assesses problem-solving abilities and capacity to perform when the clock is ticking. It features fifty questions in a span of twelve minutes. The test includes four categories: general knowledge, verbal reasoning, abstract reasoning, and numerical reasoning. The benefit of the Wonderlic Test is that it does not require any prior knowledge to take the test but it is challenging. When taking the test, it is common for people to not be able to complete the fifty questions. For this reason, the team decided to look at other tests.

The Professional Learning Indicator (PLI) is identical to the Wonderlic Test lasting twelve minutes with fifty questions. The purpose of PLI is to assess potential hires to test for skills outside of a resume by measuring cognitive ability and capacity to learn and adapt. The PLI can be adjusted to certain situations but may be unhelpful for SitFlow because its purpose does not align with our experiment.

The Montreal Cognitive Assessment (MoCA) test takes ten to fifteen minutes where the participant memorizes a short list of words, identifies a picture of an animal, and copies a drawing of a shape or object. The test is aimed for individuals with mental illnesses, easy to administer and interpret, and commonly used amongst neurologists and psychologists. The MoCA test seems to be a fitting test for our experiment but it is rather basic compared to other tests we looked at.

Lastly, the Criteria Cognitive Aptitude Test (CCAT) is used for pre-employment and measures aptitude, problem-solving abilities, skill learning capabilities, and critical thinking. The CCAT is fifteen minutes long with fifty questions. Like the previous tests, most people do not finish the test. However, this is embedded in the CCAT design. The questions are mixed and increase in difficulty as the participant progresses so that the participant can take the test multiple times if needed. The team concluded with a multicriteria decision analysis that CCAT is ideal for our experiment because it includes: problem solving and attention to detail, can be taken multiple times by a participant, credible, timely, and within a reasonable budget.

CHAPTER 4. DESIGN AND EVALUATION OF POTENTIAL SOLUTIONS

4.1 Cognitive Test Analysis And Decision

The center point of this SitFlow experiment relied on choosing a validated cognitive test to administer to our participants during our experiment. It was very important to the sponsors that the cognitive test be more mentally stimulating than a common typing test but less than, say a sample SAT test. Another constraint was finding a test that didn't require any prior knowledge base, to ensure any participants could take the test. The experiment began by analyzing five initial cognitive tests. The tests consisted of: Wonderlic Test, Montreal Cognitive Assessment, Criteria Cognitive Aptitude Test, Predictive Learning Index Test, and the Stroop Test. All five tests found had been narrowed down from tests researched in the literature review. This ensured any test analyzed could be used to conduct the experiment. A Many Criteria To Consider (MCDA) decision analysis was performed to quantify choosing a test to use for the experiment. The analysis consisted of eight thought out criteria, each with a respective weight attached. To avoid bias, each team member listed out how each criteria should be weighted in a table. The final weight was created from an average of each team member's individual rank.

Weight:	10	6	3	9	6	8	10	8
Criteria:	Effectively measures cognitive ability	Reasonable time limit (1 being not reasonable)	Affordable Test (1 being not afforadable)	Doesn't require prior knowledge base	Measures a wide variety of abilities within cognitive scope	Test was designed for cognitive testing purpose for tasks similar to ones in our experiement	Has solid backing within academia	Easily can be performed while using SitFlow

Table 2: MCDA Weighted Decision Analysis Criteria

Each criterion from Table 2, was well researched by each team member and discussed as a collective group. The first and most important criteria was based on the cognitive test effectively measuring our participant's cognitive ability. With a rank of 10, this criterion was focused on the college student demographic, and how well the test would target that group. Having a reasonable time limit, was to ensure two tests could be completed in a reasonable time limit. Meaning, the total time it would take to complete the test would not hurt the ability to get participants to take the test. Finding an affordable test was a factor, but due to having students project funding available, lowered the overall weight. Like discussed before, having no prior knowledge base ensures any participant can take the test. Measuring a wide variety of abilities within the cognitive scope includes reasoning skills, logical analysis, and spatial reasoning skills. The team ranked this a high eight, as the more abilities, the more comprehensive the test is. Having a solid backing within academia held the highest weight of ten, as in order for the test to be credible, other case studies and experiments had to be performed prior. This was the sponsor's most important request when picking a test, as it ensures SitFlow does what our results say, and there are other tests to prove this. Our other 10 criteria were the test's ability to effectively measure a user's cognitive ability. The team saw this as the most fundamental important criteria, as a high score was needed to even be considered in the decision analysis. Lastly, it was important that the SitFlow product can be used simultaneously with the test being taken. This meant little to know movement while taking the test, to ensure one's balance was not constantly being disrupted. Due to the team not budgeting in the ability to buy and evaluate each cognitive test, the evaluations were based on individual team member's own research.

4.2 Solution Alternatives

	Weights:	10	6	3	9	6	8	10	8	Total (Score*Weight)
	Wonderlic Test	7.7	8.7	8.7	6.7	7.0	6.0	9.0	9.0	**463.6**
3	MoCA	7.3	8.3	8.0	8.7	8.0	4.7	9.0	9.3	**471.3**
1	CCAT	9.0	7.7	8.3	8.7	8.0	7.0	8.3	9.0	**495.0**
	PLI	7.7	8.7	7.0	7.3	7.3	6.7	7.3	8.3	**450.4**
2	Stroop Test	7.3	9.0	8.0	8.3	7.0	7.3	8.3	8.3	**474.0**

Table 3: MCDA Cognitive Test Score Breakdown

Out of the five tests first analyzed, three tests were selected and ranked from highest scoring to lowest scoring shown in Table 3. The Criteria Cognitive Aptitude Test, or the CCAT, was the highest yielding cognitive test. This 15 minute test includes 50 questions addressing cognitive areas such as: vocabulary, logic, mathematics, and spatial reasoning. This was the perfect breakdown for our experiment as it addressed a wide variety of cognitive functions. While it aligned with testing the favored functions, it also had been used in a handful of prior case studies. Technology companies such as Vertafore, Crossover, and Vista Equity Partners have used CCAT as a predictive tool to identify successful workers. Due to the success of these case studies, it reassured us the MCDA had concluded on the optimal test. While it was clear that the CCAT was the favored test, the two other ranked tests were close runners. The second place option, The Stroop Test, appealed to the team due to its abundant backing within academia. It has been involved in studies by Child Neuropsychology, The Spanish Journal of Psychology, Journal of Sport and Health Science, and hundreds more. While it carried a solid foundation, it had previously been used in a SitFlow experiment to compare participants' cognitive abilities. And with a goal of adding on to prior experiments and not repeating, this turned the team away from the test. The last option of the Montreal Cognitive Assessment also carried strong backing within academia, but focused on assessing cognitive impairment, mainly with elderly participants. This led the team to believe they had made the right decision with choosing the Criteria Cognitive Aptitude Test. Below is the breakdown of the Criteria Cognitive Aptitude Test question categories:

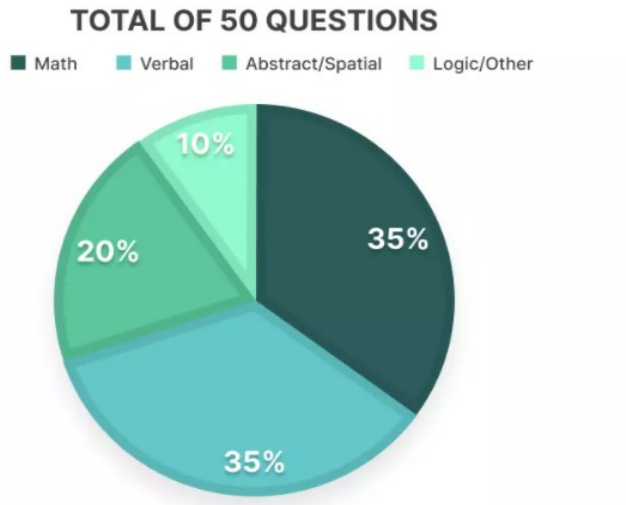


Figure 2: Criteria Cognitive Aptitude Test question breakdown decided by Criteria Corp.

4.3 Design of Experiment

The following subsections will describe the process of designing the SitFlow experiment. Each subsection represents a major milestone in the project. The first phase of designing the experiment includes the preliminary research conducted by the team and the base plan of the experimental design completed in the first quarter. The second phase of designing the experiment involves overcoming a major delay caused by the COVID-19 pandemic by looking at the initial design in a new, more structured, perspective in the second quarter. Finally, the third phase of designing the experiment took place in the third quarter and includes the first three experimental runs and fourth experimental run with a slight modification to examine user familiarity.

4.3.1 First Phase of Designing the Experiment

In the first phase of experimental design, there were a galore of constraints that come with running an experiment during a global pandemic. For instance, as the plan was to perform the experiment in Engineering IV, the team had to ensure the experiment aligns with COVID-19 regulations. Additionally, making sure a meaningful sample size was attained while upholding the ethical standards set by the Cal Poly Institutional Review Board (IRB). The IRB is responsible for the protection of human participants in research by reviewing compliance with ethical standards in research projects (“Human subjects research at Cal Poly”, n.d.). The team planned to conduct the experiment using two groups: a non-SitFlow sitting group, and a SitFlow sitting group. Each participant will participate in both groups, meaning they will take multiple versions of the CCAT. The order in which group the participant performs the experiment in will be randomized to measure the effectiveness of the intervention or, in this study, the SitFlow apparatus (Hariton, 2018). Before both groups begin the test, they will see an instructional video on how to use SitFlow, followed by a short adjustment period, where they can move around and get familiar with the product. Participants will complete both tests in under 35 minutes. This is accounting for both tests taking 15 minutes long, and having a five minute break in between

tests. Lastly, all participants will take a short survey to gauge their experience of the SitFlow product. The design will look similar to the figures below:

Figure 3: SitFlow group: CCAT Test 1, Biopac eye tracking (webcam), SitFlow tutorial, SitFlow product, and survey.

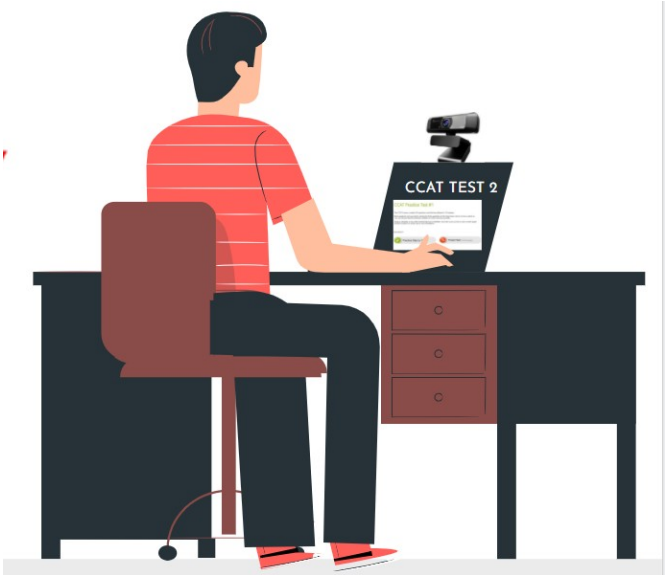


Figure 4: Non-SitFlow group: CCAT Test 2, Biopac eye tracking (webcam), and survey.

Once the data is collected through excel, a paired t-test will be run to compare the participant's mean cognitive scores within their respective group. From here, the team can determine if SitFlow improves, impairs, or does not affect cognitive ability.

4.4.2 Second Phase of Designing the Experiment

The experiment will be conducted in one of California Polytechnic State University, San Luis Obispo's classrooms within Building 192 (Engineering IV). For the completion of the experiment, all participants are required to take two Criteria Cognitive Aptitude Tests (CCAT): one while using the SitFlow apparatus and one while sitting stationary. Due to the complexity of the COVID-19 pandemic, the experimental design was modified to meet the safety, health, and university protocols set by Cal Poly in the second quarter. The first major modification was the cancelation of the Biopac eye tracking device. The research team faced a long delay in the project's second quarter and since the device was lent for a strict duration of time, the new experimentation schedule did not align with the availability of the device. Fortunately, the loss of the Biopac eye tracking device did not require the research team to pivot from their original design since it only introduced additional data to the study.

The second modification was the movement from computer-based test taking, to printed sheet with scantron testing. Since the cancellation of Biopac, which required the test be administered via computer, this transition can be made. With the help of a smartphone application that can grade a test in a second, this will ensure the test is graded accurately.

The third modification that needed to be made was focusing on the testing venue. The research team was required to submit a research expansion plan document before the experiment could be conducted. Within the research expansion plan, the team had to restate what was defined in the Institutional Review Board (IRB) documents in addition to the testing venue floor plan. The plan can be seen in Figure 5 and defines where each person would be located when the experiment was being conducted.

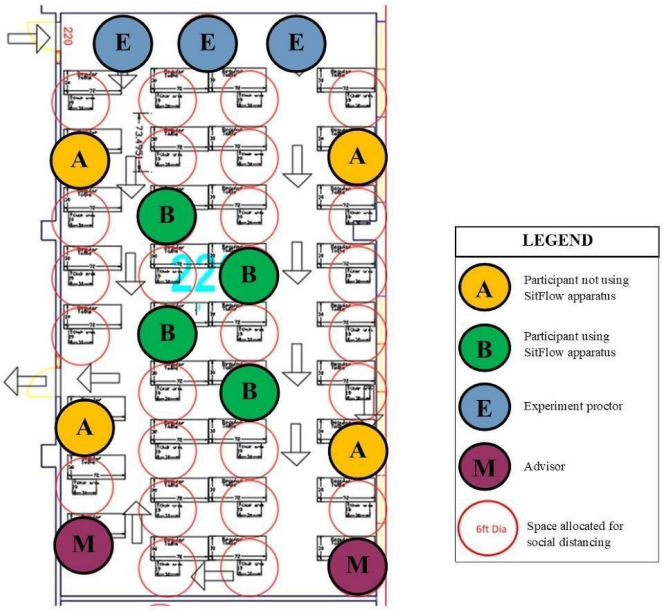


Figure 5: Testing Venue

All individuals in the defined space will be a minimum of six feet apart. Individuals who are proctoring the experiment were located at positions "E." Advisors (labeled "M") were required to be onsite due to policies set by the university. The advisors had no role in the experiment other than monitoring the safety of the students.

The number of participants was calculated using a statistical power analysis tool called G*Power (G*Power, n.d.). A screenshot of the main window is shown in Figure 6. While the sample size aimed to be 34 participants, this did not need to be the sample size used in the experiment. Depending on how the data is analyzed will determine if G*Power's sample size is necessary.

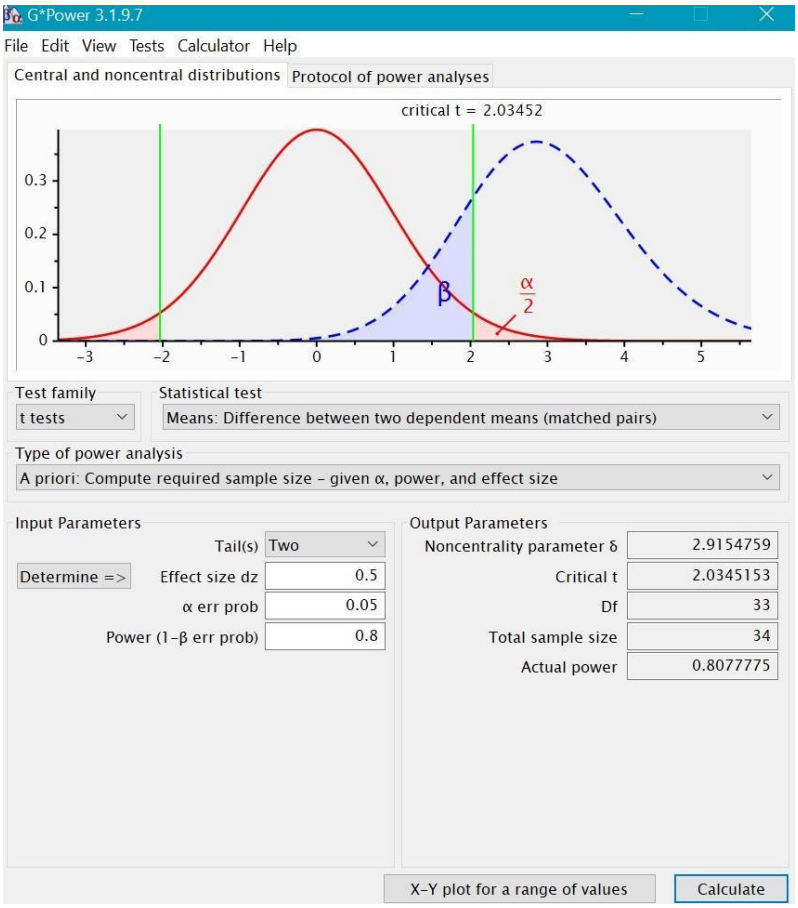


Figure 6: G*Power Statistical Power Analysis for Experimental Sample Size

A breakdown of the experimental schedule can be seen in Table 4. In each session, four participants were randomly assigned to take a cognitive test with or without the SitFlow apparatus. Students who are assigned to use the SitFlow apparatus were asked to sit in a spot labeled "B" and students who were not assigned to use the SitFlow apparatus were asked to sit in a spot labeled "A."

Start Time	End Time	Activity
3:00	3:10	Advisors/PIs Arrive
3:10	3:15	Participants Arrive, Check-in
3:15	3:20	Demonstrate Wow to Use SitFlow
3:20	3:35	First Iteration of CCAT
3:35	3:40	Rest Break
3:40	3:55	Second Iteration of CCAT
3:55	4:00	Participants Depart, Tests Collected
4:00	4:10	PIs Clean Workspaces
4:10	4:15	Participants Arrive, Check-in
4:15	4:20	Demonstrate How to Use SitFlow
4:20	4:35	First Iteration of CCAT
4:35	4:40	Rest Break
4:40	4:55	Second Iteration of CCAT
4:55	5:00	Participants Depart, Tests Collected
5:00	5:10	PIs Clean Workspaces
5:10	5:15	Participants Arrive, Check-in
5:15	5:20	Demonstrate Wow to Use SitFlow
5:20	5:35	First Iteration of CCAT
5:35	5:40	Rest Break
5:40	5:55	Second Iteration of CCAT
5:55	6:00	Participants Depart, Tests Collected

Table 3: Experiment Schedule

For data collection, an industrial engineering skill set was well utilized in this experiment due to students' in-depth understanding of both engineering test design and analysis as well as human factors and ergonomics concepts. In setting up the experiment itself, the coordinators of the experiment and data collection have demonstrated understanding of proper ways to set up, conduct, and collect and analyze data to determine relationships between variables in evaluating significance through prior coursework. The experiment and data collection will account for human factors and ergonomics, as this will largely stem from the self-evaluation survey done by participants and the results from the cognitive test.

A post-experiment questionnaire will ask participants about their physical and comfort levels prior and during the experiment. Some metrics that will be addressed in the questionnaire include comfortability, range of motion, influence of prior injuries, posture examination, attention span and enjoyment. These will all help SitFlow obtain a mix of quantitative and qualitative responses to expand upon future experiments. Before the participant takes the post-experiment survey, they have the option to opt out completely or opt out of any questions they do not wish to answer. Additionally, participants are ensured that their responses will remain anonymous in a written statement that can be seen in Figure 7.

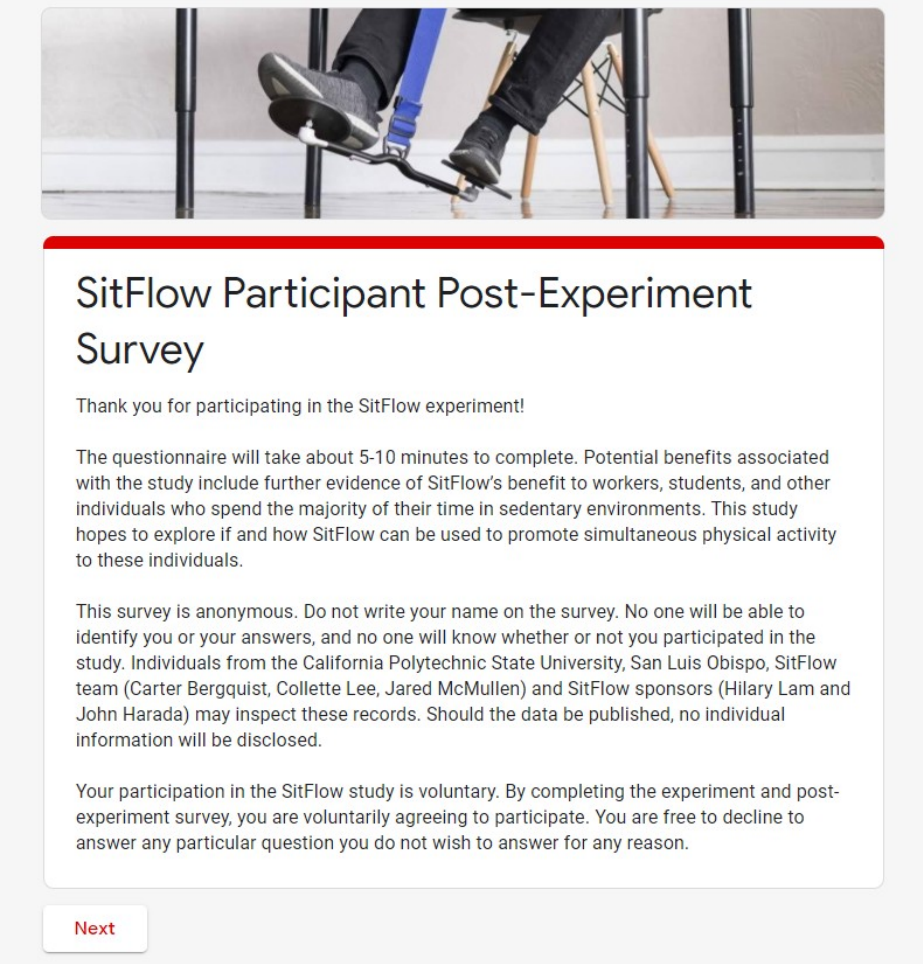


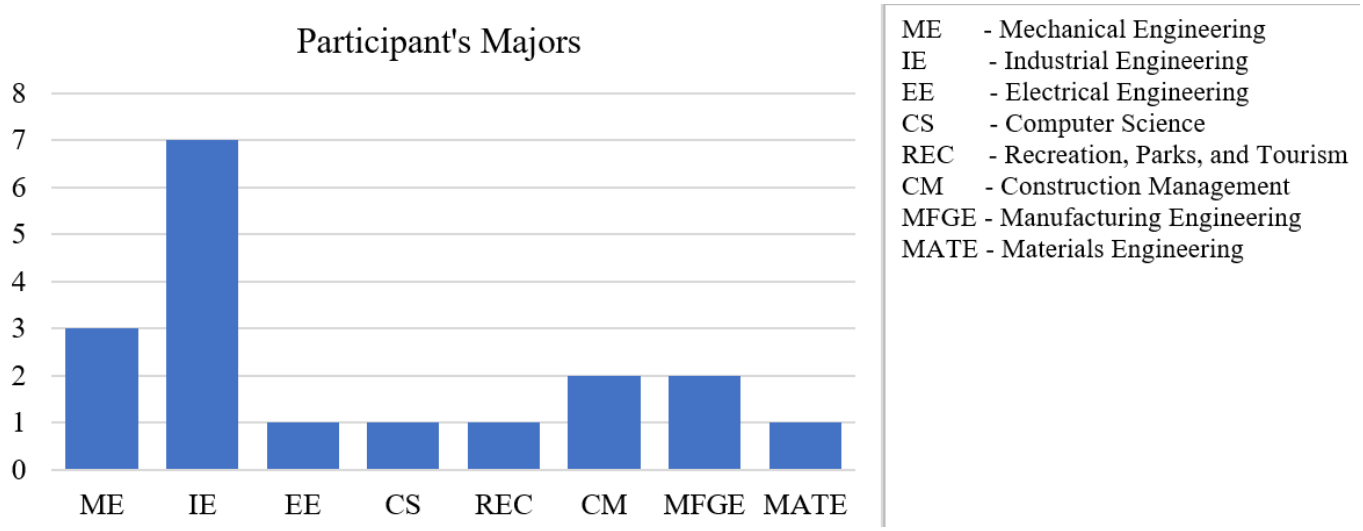
Figure 7: Post-Experiment Survey Participation Agreement

At the conclusion of each session, the stations will be sanitized, and each participant will receive a ten-dollar Starbucks gift card compensation for their time. A Starbucks gift card was selected due to the IRB guidelines; incentives cannot be from a location that sells alcohol or drugs. Ten dollars was the selected amount because it will take the participants fifty minutes to complete the experiment. The Starbucks gift card was sent to each participant's Cal Poly email once they have completed the survey or requested to opt out.

4.4.3 Third Phase of Designing the Experiment

Eighteen Cal Poly students voluntarily participated in the first three testing sessions. The bar chart in Figure 8 shows the distribution of majors. The experimental procedures are outlined in the second phase of designing the experiment.

The SitFlow sponsor voiced concern regarding the familiarization period. Since the participants only had a few minutes to adapt to the SitFlow apparatus as outlined in the second phase of designing the experiment, the sponsor was not confident that this was enough time for familiarizing oneself with the product. Thus, there needed to be a slight modification in the



experiment: invite at least half of the eighteen participants who have already completed the experiment to do another experimental run. The purpose of calling back these participants was to test if there was significance between the first time they used the SitFlow apparatus and the second. Each testing session (first and second experimental run) per participant were separated by a minimum of two weeks. One issue that the SitFlow research team faced was only having the Engineering IV lab reserved for four weeks. It was critical for the team to make the proposed modification work to not only fulfill the needs of the sponsor company but to obtain data points for the second experimental analysis.

The research team immediately contacted the eighteen participants asking if anyone would be interested. Similar to their first experimental run, each participant would receive a $10 Starbucks gift card as an incentive. Out of the eighteen participants, nine participants returned during the fourth week for the final round of testing. These nine individuals returned to allow the group to properly assess how an increased learning period affected user ability with SitFlow. In further discussions with the sponsors at SitFlow, there was concern over how only a five-minute long preparation familiarity period might not be sufficient to allow participants to be fully familiarized with SitFlow, and this concern was accounted for in allowing these nine individuals to return for another testing day with increased familiarity. The experimental protocols and procedures were exactly the same as the first three weeks of experiments; again, outlined in the second phase of designing the experiment.

4.5 Final Experiment Design (User Guide)

The following subsections will summarize in detail how to replicate the experiment in this report to obtain similar, if not identical, data points.

4.5.1 Participants

To determine the minimum sample size for sufficient statistical power (0.8), the researchers used G*Power software which resulted in this number to be 34. A screenshot of the

software can be seen in Figure 6. However, due to constrictions that arose from the COVID-19 pandemic, the study was conducted with a sample of 18 voluntary college students (11 males and 7 females) from the California Polytechnic State University, San Luis Obispo, (Cal Poly) population. Participants who have learning disabilities (ADD, ADHD, etc.) were excluded from the study to create a controlled environment. While the introduction of SitFlow in school and work setting environments can prove to be helpful to students with learning disabilities, previous and ongoing studies have made learning disabilities as the focal point of their research. This study focuses on the effects on user productivity and cognitive ability. Due to the COVID-19 pandemic, participants were limited to students who have been attending in-person and on-campus laboratories. Additionally, individuals are prohibited to participate if they have had any exposure to COVID-19 positive individuals, if they exhibit any symptoms of the virus, or if they have been in an environment that goes against San Luis Obispo social distancing or gathering orders in place. Therefore, inclusion criteria were at least 18 years old, attending an in-person and on-campus laboratory, abidance to the San Luis Obispo and Cal Poly COVID-19 regulations, and not diagnosed with a learning disability. The study was approved by the Cal Poly Institutional Review Board. Participants signed an informed consent form and were presented with a $10 gift card compensation at the completion of the experiment.

4.5.2 Experimental Conditions

The testing venue can be referenced in Figure 5. The experiment was conducted in nine fifty-minute sessions, three sessions per week. In each session, four participants are randomly assigned to take a cognitive test with or without the SitFlow apparatus using an online random generator (Random.org, n.d.). An example screenshot can be seen in Figures 9 and 10 where each participant is represented by a letter (A, B, C, D, E, F, G, and H). Since there are only two treatments in the experiment (SitFlow and stationary sitting), it is important for the randomization process not to be a simple 1:1 or 50% ratio. This is critical in examining the true effect of the intervention treatment.

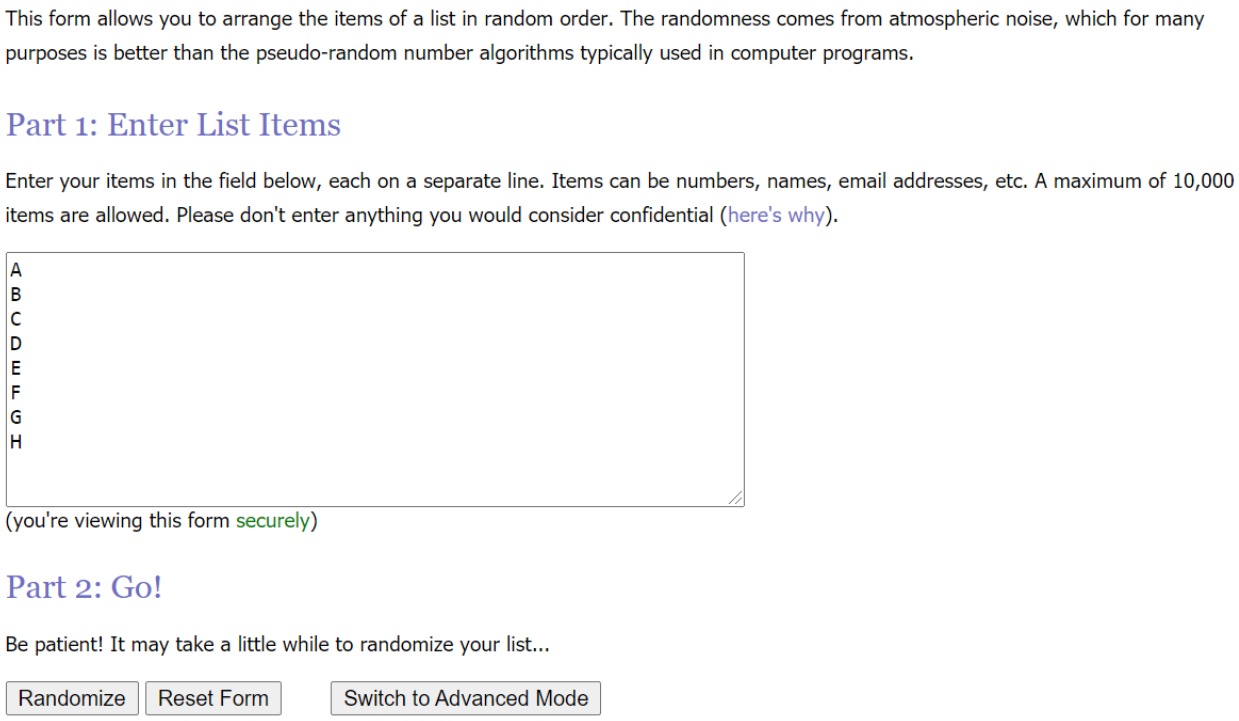


Figure 9: Random Distribution Listing Participants

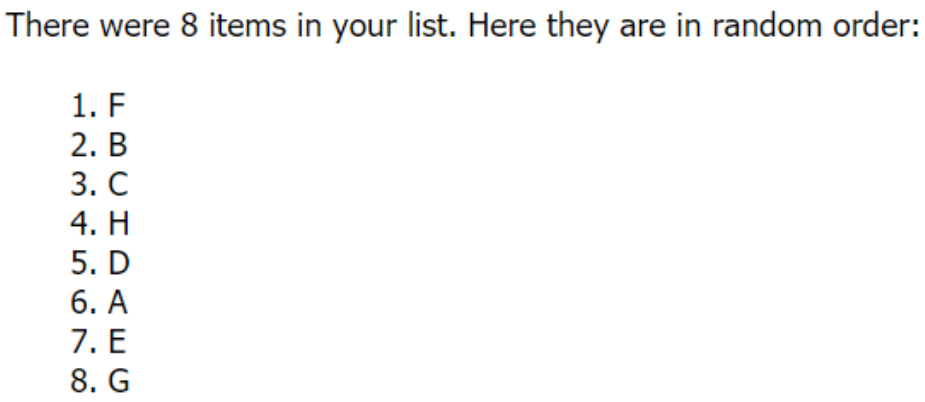


Figure 10: Randomly Distributed Groups

Students are assigned to use the SitFlow apparatus if they were represented by an odd number in the randomizer and were asked to sit in a spot labeled “B” (Figure 5). Students who were not assigned to use the SitFlow apparatus were represented by an even number in the randomizer and were asked to sit in a spot labeled “A.”

4.5.3 Study Design and Procedure

Cal Poly students were recruited by members of the research team via email to groups of students enrolled in the university's testing program, as these were the only students who were permitted to be on campus at the time of testing. The participants were directed to a classroom on the Cal Poly campus to participate in a fifty-minute-long testing session. There were four three-hour sessions, split into three fifty-minute-long testing sessions, each separated by a week. All participants were required to take two versions of the Criteria Cognitive Aptitude Test (CCAT): one while using the SitFlow apparatus and one sitting stationary at a desk without the apparatus, the latter being used to gather baseline data on participants' performance on the CCAT.

Prior to arrival to the experiment location, participants were randomly assigned to use the SitFlow apparatus first or second using a random number generator before arrival to the experimental location. After the first CCAT, the participant switches to the alternative option (with the SitFlow apparatus or sitting stationary). When the participant is assigned to take the CCAT using the SitFlow apparatus, a brief video is shown to demonstrate how to use the product. At the completion of the two CCAT tests, participants took a survey to measure qualitative data referring to the individual's comfort levels when using the SitFlow apparatus, confidence score, and history of discomfort.

The final three-hour session involved nine participants from the original eighteen participants returning for another round of testing in order to properly account for an adjustment period for the SitFlow apparatus. In the first round of CCAT testing, participants had a five-minute period to get accustomed to the apparatus and how it moves. By adding this second round of testing, participants were more adjusted to the SitFlow after using it for roughly twenty minutes during the first round of testing; allowing the participants to be more accustomed to the device. With increased familiarity, the researchers ran the same testing procedure as before, this time looking to compare SitFlow versus stationary sitting CCAT scores with users being more adjusted to the device and also comparing scores from the first rounds of testing with the second round.

4.5.4 Data Analysis

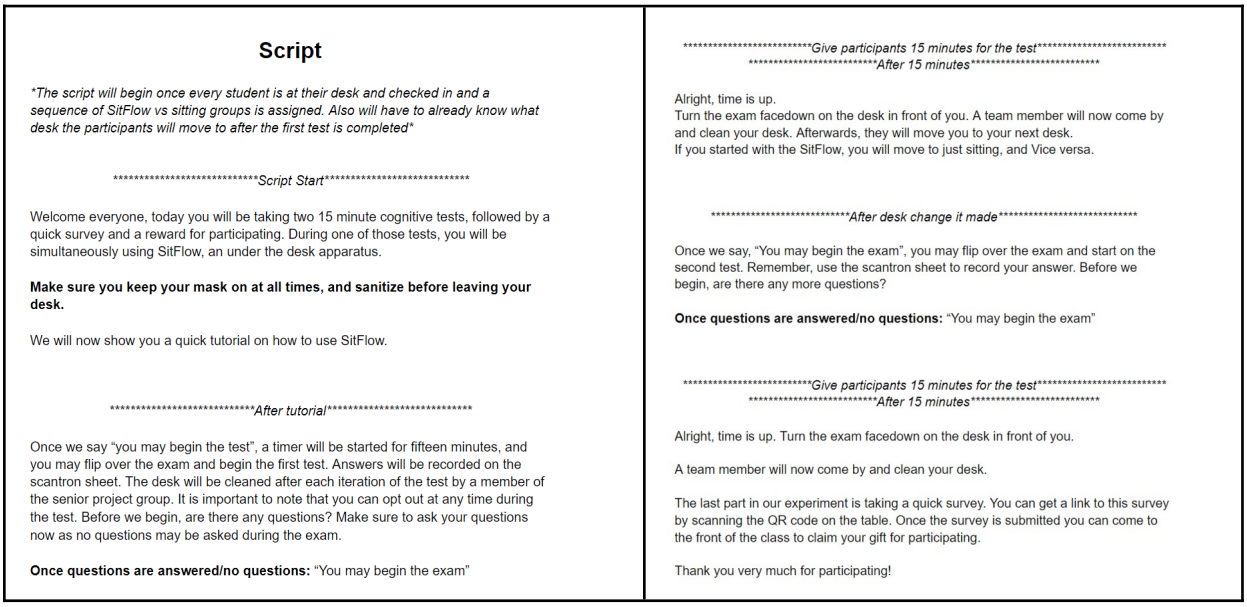
The data analysis can be found in section 8.4 Experimental Results.

CHAPTER 5. VERIFICATION AND VALIDATION OF PROPOSED SOLUTIONS

In order to verify and validate the experiment would be run successfully on a larger scale, the team had an initial trial run with members of the team's personal pod. This is referring to individuals that the team member is exposed to on a daily basis, to minimize the spread of COVID-19. The intended purpose of this trial run was to ensure the cognitive tests used in the real experiment would yield accurate data, and the experimental set up would work ensuring no issues. As there were only a few weeks in which the experiment could be performed, every minute of testing was important to the success of the project.

5.1 The Trial Run Setup

The trial run was conducted using the SitFlow desk mount. A short detailed video on how to use SitFlow was played for the participant (SitFlow, 2019). A script, viewed in Figure 7, was followed during the whole process to get a better estimate of the time it would take to complete one cycle. Once the users finished the video, instructions on how to take the test, and how long the experiment would take were explained. Once the team member said "you may begin", the participant began the test on the packet of paper, circling their answer with a number two pencil. Once the fifteen minute allotted time was up, the user flipped over the test and a break of five minutes was given. After the break, the second cognitive test was performed, this time using SitFlow. Once the fifteen minute allotted time was up, the user flipped over the second test indicating they were finished, and continued to the individual completion of the survey. Since this was a trial run, no incentive for participating was given.



Script

The script will begin once every student is at their desk and checked in and a sequence of SitFlow vs sitting groups is assigned. Also will have to already know what desk the participants will move to after the first test is completed

**********Script Start**********

Welcome everyone, today you will be taking two 15 minute cognitive tests, followed by a quick survey and a reward for participating. During one of those tests, you will be simultaneously using SitFlow, an under the desk apparatus.

Make sure you keep your mask on at all times, and sanitize before leaving your desk.

We will now show you a quick tutorial on how to use SitFlow.

**********After tutorial**********

Once we say "you may begin the test", a timer will be started for fifteen minutes, and you may flip over the exam and begin the first test. Answers will be recorded on the scantron sheet. The desk will be cleaned after each iteration of the test by a member of the senior project group. It is important to note that you can opt out at any time during the test. Before we begin, are there any questions? Make sure to ask your questions now as no questions may be asked during the exam.

Once questions are answered/no questions: "You may begin the exam"

**********Give participants 15 minutes for the test**********
**********After 15 minutes**********

Alright, time is up.
Turn the exam facedown on the desk in front of you. A team member will now come by and clean your desk. Afterwards, they will move you to your next desk.
If you started with the SitFlow, you will move to just sitting, and Vice versa.

**********After desk change it made**********

Once we say, "You may begin the exam", you may flip over the exam and start on the second test. Remember, use the scantron sheet to record your answer. Before we begin, are there any more questions?

Once questions are answered/no questions: "You may begin the exam"

**********Give participants 15 minutes for the test**********
**********After 15 minutes**********

Alright, time is up. Turn the exam facedown on the desk in front of you.

A team member will now come by and clean your desk.

The last part in our experiment is taking a quick survey. You can get a link to this survey by scanning the QR code on the table. Once the survey is submitted you can come to the front of the class to claim your gift for participating.

Thank you very much for participating!

Figure 11: Script

5.2 Trial Run Results

The results in Table 4 show the average values between participants involved in the test experiments. From the qualitative data collected from the post-experiment survey, most participants believed the SitFlow was comfortable and non-distracting. They also believed the time breakdown gave them enough recovery time, and that there is no need to extend the break period between the two CCAT tests. According to Test-Guide.com (Test-Guide, 2021), a score between 18 to 42 is commonly seen for various roles. A higher score can be seen by positions such as lawyers or attorneys. Given the test scores were in this range, the team has confidence the cognitive test would work on a larger scale for our experiment .

Time taken	Sitting Group score	SitFlow group score	Score Discrepancy
55 minutes	35	38	8.2%

Table 4: Results of Test Experiments

The trial run was crucial to gauge how our data collection period would run. Through receiving normal scores on both CCAT tests, and having no issues with the questions, we can validate that the cognitive test will work in our experiment. We can also further validate that the experiment can be successfully run under one hour, allowing for three groups of four to be tested in a three hour lab on a weekly basis.

CHAPTER 6. IMPACT ANALYSIS OF PROPOSED SOLUTIONS

The impact that the proposed solution will have on different aspects of the surrounding environment was heavily considered in the designing of the experiment. An analysis of more specific aspects of the surrounding environment are listed below.

6.1 Public Health

With many individuals spending long periods of time in sedentary environments (workplace, school, etc.), prevalence of health issues stemming from long periods of sitting, such as soreness and circulatory issues, has increased in these individuals. According to 2020 data on workers' comp statistics from Insurtech, soreness and pain was the second-highest reported workplace injury with 15.9 incidences per 10,000 workers. With employees in these environments lacking exercise and physical activity, the addition of SitFlow into these settings can improve the overall health of employees and promote a healthier workplace culture.

6.2 Safety and Welfare

- Every participant can opt out of the experiment at any point.
- Participants reserve the right to not answer any questions on the post-participation survey; they also have the option to opt out of the survey entirely.
- Results will be collected and stored without using participants names, as each participant will be given a participant ID upon arrival to ensure anonymity.
    - Upon completion of data analysis, all raw data will be destroyed for the sake of the participants.
- Participants will be assured that there are no risks associated with using the SitFlow apparatus.
- Participants, PIs, and advisors will adhere to the following guidelines to eliminate risk of COVID-19.
    - Daily self-monitoring will be checked upon arrival at the testing room.
    - Surfaces and SitFlow will be sanitized after each use.
    - Hand sanitizer will be available and used frequently even when hands are not visibly dirty.
    - No more than 9 total people will be in the room at any given time.
        - For reference: max occupancy of 192-220 with COVID protocol is 35.
    - Face coverings will be used at all times by all people in the room.
    - 6 ft distance will be maintained by all individuals in the room.
    - Each workspace will be disinfected after each CCAT iteration with soap water + spray bottle and EPA certified disinfectant.
    - Disposable gloves and eye protection will be used when disinfecting.
    - All contact surfaces and equipment will be cleaned with soap and water first, and then disinfected according to CDC guidelines after each testing session.

6.3 Cultural

Within sedentary workplaces, executives within the company can create healthier workplaces cultures by promoting employees to use SitFlow while they work. As mentioned, workplaces with employees who spend significant chunks of time sitting often experience high rates of health problems that result from the sitting. If executives allowed simultaneous exercise for their employees, morale and physical health can be improved, thus promoting healthier workplace cultures.

6.4 Economic Factors

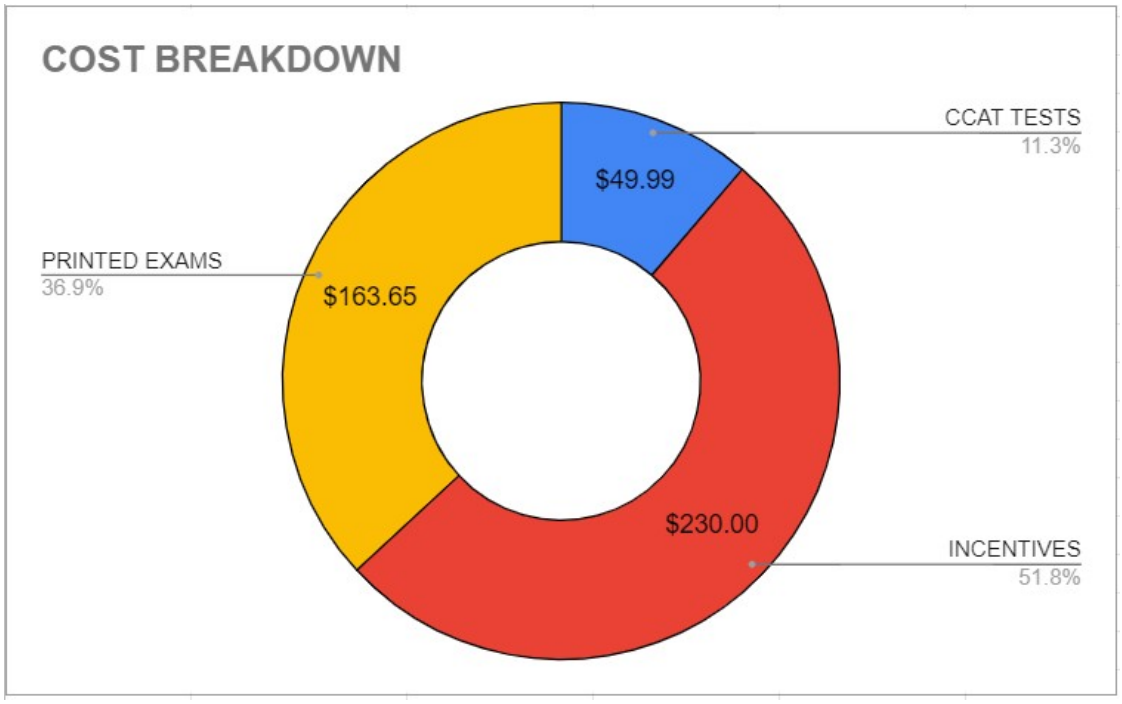


Figure 12: Economic Cost Breakdown

The economic factors shown in Figure 12 include the price of each cognitive test, the incentives given to participants for partaking in the experiment, and the cost to print 72 copies of the exam. The total amount totaled $443.64, an amount that is well in the senior project budget. The two CCAT tests were taken from AptitudeTests.org. We found their rate of $24.99 per test to be a fair price amongst other credible test providers. As for the $10 amount given to participants, this amount represents roughly minimum wage for an hour of work in the United States. To comply with school regulations, the incentives will be given out in the form of Starbucks gift cards. Lastly, due to the over 1400 pages being printed for the experiment, we went to a local store and used an industrial printer.

As the figure above shows the group's cost breakdown for orchestrating the in-person testing experiment, the economic impact of SitFlow can also be seen on a larger scale.

Referencing the 2020 data from Insurtech, insurance companies paid slightly over $888,000 worth of workers' comp during the year. If SitFlow were implemented to reduce these costs by even a mere 5%, this would decrease the payments issued by more than $44,000 in the future.

CHAPTER 7. IMPLEMENTATION PLAN

7.1 Plan Steps

The team focused its effort towards the end of quarter three on finding meaningful conclusions from the experimental data and presenting these conclusions to SitFlow. Due to the wide variety of methods in which the data can be analyzed, this process can take quite some time. Below is the implementation plan for our project. It takes place in four components:

1. Completing the data analysis - This entails reviewing all statistical methods for analyzing the quantitative data as well as examining the qualitative results received from the survey.
2. Providing SitFlow with our findings - This portion of the plan requires summarizing our findings and presenting this in a way that SitFlow can understand with minimal questions. This not only includes our sponsor, but anyone else involved in the SitFlow company.
3. SitFlow sending the findings to a journal for publishing - This step in the plan involves SitFlow independently submitting the findings from the project to a publisher. While this submitting process is independent from Cal Poly, the team has also worked on a separate report that can be used by them to submit.
   SitFlow is able to improve marketing efforts - In this last stage of the plan, it is important to realize that SitFlow is a startup company. While it has only been involved in a handful of experiments, the project's findings will aim to boost marketing efforts and help them scale the company.

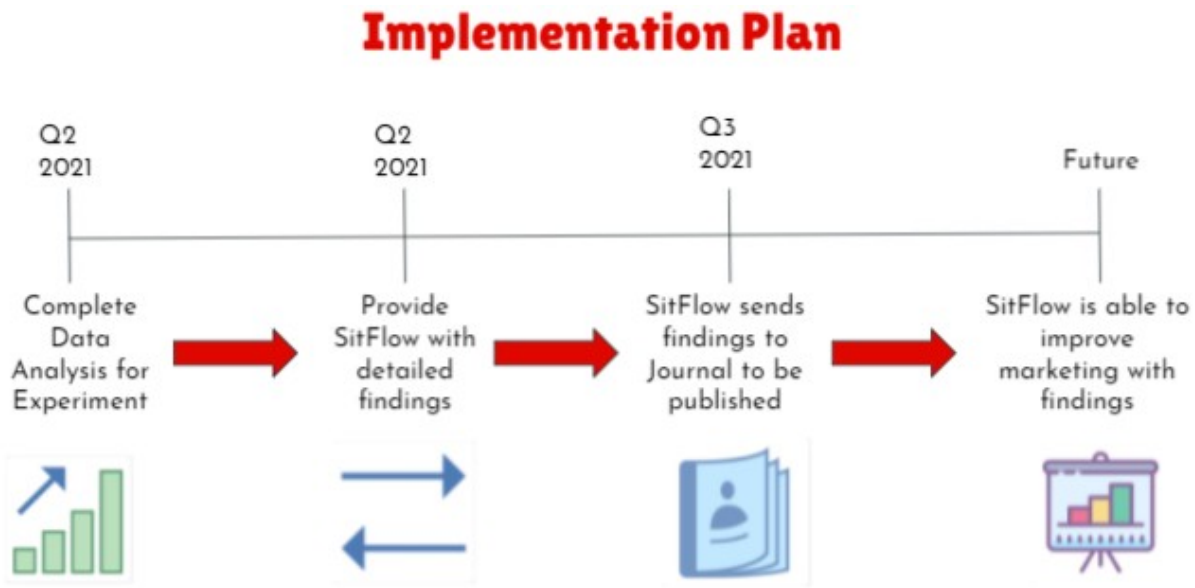


Figure 13: Experimental Implementation Plan

In the image above, an overview of the implementation plan's steps are listed as well as a timeline. The timeline is broken up into quarters of a typical year, not a school year. While the team is able to complete the first half of the plan, as this will be completed by the end of the school year, the second part is dependent on SitFlow's internal schedule.

And while this will help with marketing efforts, the culmination of proceeding experiments at additional schools will add onto our work, thus leaving the timeline open to the “future”.

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Overview

The team faced a long delay in the second quarter of the SitFlow senior project but have viewed the experience as educational and beneficial for the final design and implementation of the experiment. Without this delay, the team believed that the experiment would not have been as concrete as it was developed to be at the end of the second quarter due to the Institutional Review Board (IRB) document revisions. This chapter is organized to talk about the importance of communication, experimental design, experimental results, and future recommendations.

8.2 Communication

8.2.1 Second Quarter

The second quarter of the SitFlow senior project required the team to communicate with several different people from various departments. The team's main advisor, Karen Bangs, and SitFlow sponsor, Hilary Lam, were our main points of contact throughout the project. At the conclusion of the first quarter and beginning of the second quarter, the team contacted Trish Brock to complete the Institutional Review Board (IRB). It is mandatory to complete the IRB before experimentation. The document evaluates the elements of the projects to ensure the safety of the participants, experimenters, and any other individuals involved. Although it was a lengthy process, the team was able to complete and gain conditional approval from the IRB after three iterations in the midst of the second quarter. The team was then directed to contact the senior project manager, Tali Freed, to gain further approval for on-campus experimentation. Tali informed the team that a research expansion plan will have to be submitted in order to gain full approval. The research expansion plan was submitted but was immediately denied by the Engineering Dean. After conversing with the Dean, Daniel Waldorf, the Industrial and Manufacturing Engineering Department's Faculty and Department Chair, announced that the experiment cannot be conducted on or off campus due to COVID-19 regulations.

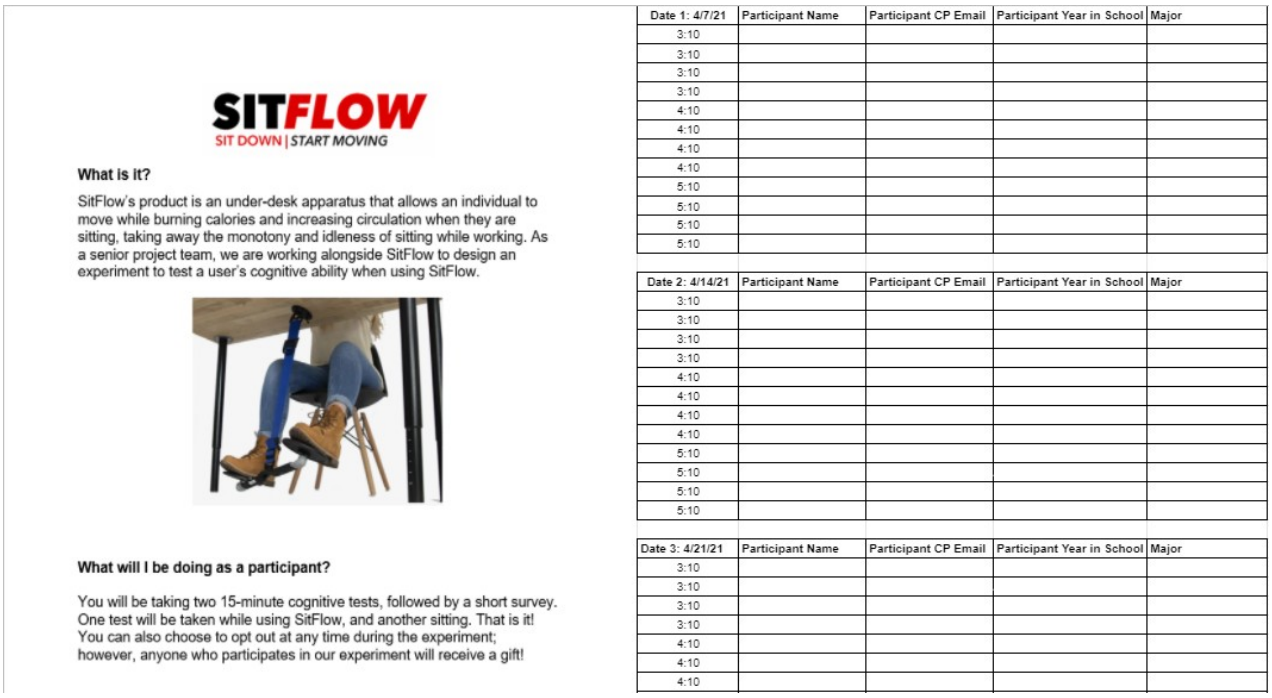
Dan's announcement led to a stagnant stage in the team's advancement but with guidance from Karen and Tali, the team was able to provide an alternative solution: instead of experimenting on-campus or with individuals we never contacted, the team will experiment within our pods or housemates. Dan approved the alternative solution; however, there were still doubts within the team and SitFlow sponsor. Since the experimental analysis will be published to an ergonomic journal, strict guidelines pertaining to data accuracy will have to be met. Thus, the main obstacle the team would face if the experiment were to be done within our respective living situations would be the amount of variability introduced to the data. If one team member were to conduct the experiment in his household with his housemates, there is a large probability that his results would be significantly different than another team member's regardless if strict protocols were followed. The variation in setup and environment would be too large to make the data creditable; therefore, making the experimental results and analysis inadequate for publication.

During the process of getting approval to conduct the experiment, the team kept in close contact with the SitFlow sponsor. Weekly meetings were held every Monday, 3:00PM to 4:00PM PST, and updates were posted or sent via Trello or email. During the seventh week of

the quarter, during a weekly meeting, the team was notified that the experiment cannot be conducted in the second quarter due to the lab section listed as virtual. According to university policies, students are not allowed on campus if the class is not labeled as face-to-face. This was not made apparent to the team, advisors, or SitFlow sponsor so the team had no choice but to postpone the experiment to the third, and final, quarter of the project. However, this opened up an opportunity for the research team to recruit participants who are enrolled in face-to-face classes including, but not limited to, other senior project class sections and introductory labs.

8.2.2 Third Quarter

The experiment was implemented for four consecutive weeks in the third quarter during the designated senior project lab timeslot (Wednesday, 3:10PM to 6:00PM). The research team recruited participants from their individual pods or points of contact and emails sent out to in-person lab and senior project instructors. Within each recruitment email, a sign up sheet in the form of a Google Sheet was linked. An image of the sign up sheet can be seen in Figure 14. The participants' names and information has been removed for animosity.



SITFLOW
SIT DOWN | START MOVING

What is it?

SitFlow's product is an under-desk apparatus that allows an individual to move while burning calories and increasing circulation when they are sitting, taking away the monotony and idleness of sitting while working. As a senior project team, we are working alongside SitFlow to design an experiment to test a user's cognitive ability when using SitFlow.

What will I be doing as a participant?

You will be taking two 15-minute cognitive tests, followed by a short survey. One test will be taken while using SitFlow, and another sitting. That is it! You can also choose to opt out at any time during the experiment; however, anyone who participates in our experiment will receive a gift!

Date 1: 4/7/21	Participant Name	Participant CP Email	Participant Year in School	Major
3:10				
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3:10				
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Date 2: 4/14/21	Participant Name	Participant CP Email	Participant Year in School	Major
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Date 3: 4/21/21	Participant Name	Participant CP Email	Participant Year in School	Major
3:10				
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Figure 14: Experiment Sign Up Sheet

The sign up sheet had a short description of the SitFlow apparatus and experimental procedures. Students who are interested in participating entered their name, Cal Poly email, year (1st, 2nd, 3rd, 4th, etc.), and major in a date and time slot that best works for them. A few days before an experimental session, the participants who signed up for that respective date are

contacted via email. Within each email, a note of gratitude was stated as well as a reminder to the date and time the participant signed up for, the location, protocols to follow in guidance with Cal Poly's COVID-19 regulations, layout of the experimental environment, and breakdown were attached.

Communication during the third quarter heavily involved emailing the senior project and lab instructors, participants, the team advisor (Karen), and the SitFlow sponsor (Hilary). The team had to work together to recruit as many participants as possible to fill in each time slot and collect data. Weekly meetings held with the SitFlow sponsor were held every Tuesday 11:00AM to 12:00PM. There were no major delays in the third quarter; however, the data analysis was affected by a slight modification in the experimental design which is described in section 4.4.1 Second Phase of the Experiment.

8.3 Experimental Design

A bulk of the experimental design process took place in the first quarter. An outline of the procedures, materials, and participants was created. The team did not anticipate to get rejection from the IRB and received detailed feedback regarding the gaps in our experimental design including, but not limited to, who is excluded from our experiment, what is the layout of the experimental environment, what will the participants gain from participating in our experiment, and what materials are we using in our experiment. The feedback allowed the team to further develop the experiment and make the design more concrete which provided an aid in the submission of the research development plan and discussion with the Engineering Dean.

Having the data collection phase of the project delayed by a quarter was not ideal but it ultimately made the experiment flow better. The team was able to fill in all the gaps identified by the IRB and heavily modified the experiment by excluding Biopac. Biopac was a great resource of data collection to find exactly how long a participant is focused on a target. However, Biopac was lent to the SitFlow team and was determined to not be feasible to use due to the heavy delay in the team's schedule. By eliminating Biopac from the experiment, the team can focus on the quantitative results from the cognition test (CCAT) and qualitative responses from the post-experimental survey.

A modification in the experiment also affected how the data was analyzed. The initial design of the experiment involved having each participant run the experiment once. In other words, each participant would only participate in one experimental run. The modification had half of the participants return to do the experiment again so that the research team could determine whether familiarity with the SitFlow apparatus is significant or not. It is important to note that the experiment did not change with this modification. Instead, the returning participant who has experience with the SitFlow from their first experiment run will return after a few weeks to see if their scores change between the first experimental run and the second experimental run.

This modification was requested by the sponsor due to a concern in the short familiarization period which will be further discussed in the next section.

8.4 Experimental Results

There were two forms of data collected in the study: quantitative and qualitative. The quantitative data stems from the CCAT test scores while the qualitative data is from the post-experiment survey. There are two parts to the overall experiment. Part one includes the eighteen participants from the first three experimental runs. Part two of the experiment involves the returning nine participants in the fourth experimental run.

8.4.1 Quantitative Results Overview

The software used for the statistical analysis is Minitab 19.2020.1. The research team conducted four statistical tests on the data collected from the experiment. In part one of the experiment, three tests were analyzed. First, a two-way analysis of variance (ANOVA) was used to examine the order effect. Then, a t-test was conducted to focus on the first intervention type (SitFlow or stationary sitting) of each participant. After proof of insignificance in the prior two tests, a final examination of effect size took place in conclusion of part one of the experiment. For the second part of the experiment, two paired t-tests were used to look at experimental time.

8.4.1.1 Quantitative Results Part I

For the first part of the experiment (without the modification), the team ran an analysis of variance (ANOVA) test. This test analyzed the scores from eighteen unique participants and compared their CCAT test scores when they used the SitFlow apparatus while taking the test and when they took the test sitting. The two independent variables that were taken into consideration were the intervention type and intervention sequence as well as their interaction effect. Intervention type simply refers to whether the participant took the CCAT test while sitting or using the SitFlow apparatus. Intervention sequence refers to when the participant used the SitFlow apparatus during the first CCAT or second CCAT. The ANOVA table can be seen in Table 5.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Intervention Sequence	1	300.31	300.31	9.16	0.005
Intervention Type	1	10.51	10.51	0.32	0.575
Intervention Sequence*Intervention Type	1	65.40	65.40	1.99	0.168
Error	32	1049.68	32.80		
Total	35	1432.75			

Table 5: ANOVA table for intervention sequence and intervention type for the first three experimental runs

The probability values (P-values) are highlighted. P-values evaluate how well the sampled data supports the null hypothesis ("How to correctly interpret p values", 2014). The null hypothesis in this case states that the means are equal. The null hypothesis is rejected if the P-value is less than the level of significance (0.05). If the P-value is greater than the level of significance, the null hypothesis is failed to be rejected and no concrete analysis can be derived from the test. For instance, looking at the interaction effect (Intervention Sequence*Intervention Type) on Table 5, the P-value is 0.168 which is greater than the level of significance (0.05). The null hypothesis failed to be rejected, meaning that there is not enough significance to derive a conclusion from the interaction effect. Now looking at the factor of intervention sequence, the P-value is 0.005 which is less than the level of significance, 0.05. Thus, the null hypothesis is rejected and there is evidence that there is a significant effect in intervention sequence. Following the same rule, the factor of intervention type is not significant (P-value=0.575 > level of significance=0.05).

As seen in Figure 15, a boxplot was created to further visualize the data from the ANOVA test comparing the intervention type and intervention sequence factors. From the boxplot, it is interesting to see that participants who used the SitFlow apparatus first did better than the participants who used the SitFlow apparatus second. From this statement, it is questionable if SitFlow has a lasting effect on the user or if the participant is more comfortable with the experimental or testing procedures in the second CCAT test taken. Although this could not be confirmed due to insignificance, a further study was designed in the second part of the experiment to focus on the effects of familiarization which is discussed in the Future Recommendations section of this report.

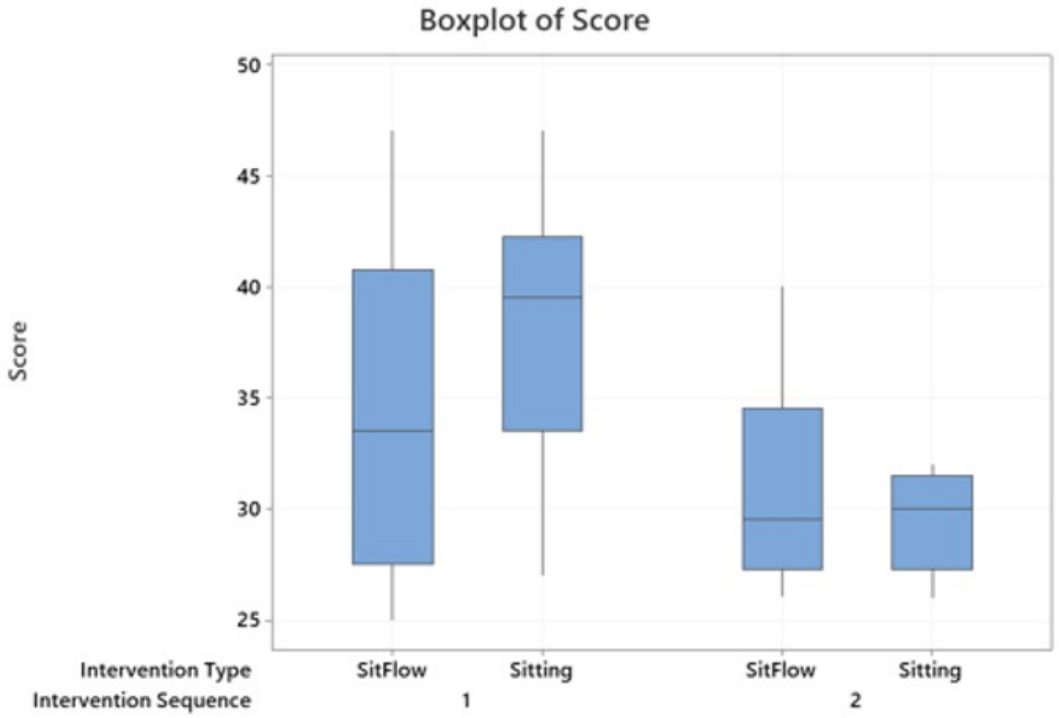

Figure 15: Boxplot for the intervention type and intervention sequence

Since the intervention sequence was the only significant factor from the ANOVA analysis, the team conducted an independent t-test on the same scores from eighteen participants. By eliminating the second CCAT score for each participant, the order effect is no longer taken into account. When creating any statistical test, in this case a t-test, it is crucial to understand that the test design may inadvertently create significance; meaning that the test has potential to be biased. The t-test used in this portion of this study has been validated by a prior study which examined clinical trials utilizing the two-period change-over design (Grizzle, 1965). From this study's t-test, the P-value was determined to be 0.088 which is slightly greater than the significance value of 0.05. Although there is no longer significance between the SitFlow and sitting groups, an argument could be made that the sample size was too small to detect a significant difference by looking at the small difference between the P-value and significant value. This argument is further discussed in the Discussion section of this report.

For the final analysis in part one of the experiment, Cohen's d effect size was evaluated. Cohen's d effect size examines the difference between two group means divided by standard deviation. The standard deviation can be from either group because Cohen's d assumes that the standard deviations and sample sizes are similar, if not the same for both groups. Effect size is a measurement of the experimental effect. Cohen's d effect size equation for this study is written out below:

$$Effect\ Size = \frac{\mu_{SitFlow} - \mu_{Sitting}}{Pooled\ Standard\ Deviation}$$

$$where\ Pooled\ Standard\ Deviation = \sqrt{\frac{(n_1 - 1)s_2^1 + (n_2 - 1)s_2^1}{(n_1 + n_2 - 2)}}$$

Equation 1: Cohen's d effect size

Cohen's d effect size can be interpreted with the following values: d=0.2 signifies a 'small' effect, d=0.5 signifies a 'medium' effect, and d=0.8 signifies a 'large' effect (Becker, 2000). Effect sizes can be related to the average percentile standing of the experimental unit to control unit. For example, an effect size of 0 means that the experimental group (with treatment) is at the 50th percentile of the control (untreated) group. On the other hand, an effect size of 0.8 means that the experimental group (with treatment) is at the 79th percentile of the control (untreated) group. The calculated Cohen's d effect size is 0.2153 which can be interpreted as a small effect or the difference between the two groups is negligible.

Cohen's d effect size works best for larger samples (N>50). Since the sample size in this experimental analysis is 18, Cohen's d may give a larger correlation value. In order to reduce the effect size and prevent over-inflation, a correlation factor is available and multiplied to the prior equation as seen below:

$$Effect\ Size = \frac{\mu_{SitFlow} - \mu_{Sitting}}{Pooled\ Standard\ Deviation} \times \left(\frac{N - 3}{N - 2.25}\right) \times \sqrt{\frac{N - 2}{N}}$$

$$where\ Pooled\ Standard\ Deviation = \sqrt{\frac{(n_1 - 1)s_2^1 + (n_2 - 1)s_2^1}{(n_1 + n_2 - 2)}}$$

Equation 2: Cohen's d effect size with correlation term

The calculated Cohen's d effect size with the correlation factor is 0.1933 which is still interpreted as a small effect or the difference between the two groups is negligible.

8.4.1.2 Quantitative Results Part II

For the second part of the experiment, the data from the modification was analyzed. The purpose of the modification was to study the effects of using the SitFlow apparatus after a period of familiarization. Since the research team had limited time scheduled to run the overall

experiment, the first experimental run each returning participant underwent was considered the initial familiarization period with a few weeks of rest, and the second experimental run was the follow up period of further data collection when the participant was more familiar with the SitFlow apparatus. For this phase of the experiment, the research team conducted two paired t-tests.

The paired t-tests consisted of the test scores from the nine returning participants' test scores from their first and second experimental run. A paired t-test compares the means of two sampled populations where the samples in those populations can be paired with one another. The goal of the paired t-tests was to see if there was significance between the participants' first experimental run and second experimental run to examine if there was an ultimate familiarity effect. There were two separate paired t-tests for when the participant was using the SitFlow apparatus and sitting. Both paired t-tests showed significance with the P-values being 0.035 when the participant took the CCAT with the SitFlow apparatus and 0.003 when the participant took the CCAT while sitting stationary. The significant value validated that there was an effect based on experimentation time; thus, there is a familiarity effect. This implies that the test scores are affected by how familiar or experienced the user is with the SitFlow apparatus. Additionally, as seen in Table 6, the mean CCAT test scores taken while using the SitFlow apparatus increased by 8 points from the first experimental run to the second experimental run while the mean CCAT scores while sitting stationary increased by approximately 6 points. Recall that the CCAT test has a maximum score of 50 points so an 8 point increase would result in scoring 16% higher during the second experimental run and a 6 point increase would be 12% higher. In respect to the United States' standard letter grading scale where A (90-100%) is passing and F (<=59%) is failing, a 16% fluctuation could severely influence a student's grade; in other words, this percentage is highly significant.

	First Experimental Run	**Second Experimental Run**
SitFlow	32	40
Sitting	34.67	40.89

Table 6: Mean CCAT test score comparison between the first and second experimental run

It is important to consider that the participants took the same two CCAT versions in the first and second experimental run. Although the experimental runs were separated by a minimum of two weeks, there is a possibility that participants may be able to recall their answers to a few questions. For the purposes of the timeframe of this study, there will be an assumption that this is rare and will not affect the overall test scores.

8.4.2 Qualitative Results Overview

In addition to the quantitative data analysis discussed above, the team was able to collect a sizable amount of qualitative data as well. Due to the survey administered to all of the participants at the end of each testing period, we were able to collect 27 responses. While 18 of these responses were from part one of the experiment, 9 of these responses were from the participants that were invited back for the second part of the experiment (part two). In this overview, the qualitative data will be split into two sections: qualitative data in part one, and qualitative data in part two. It is important to note that the survey taken by participants in part two included additional questions to gauge their experience using SitFlow for a second testing period.

8.4.2.1 Qualitative Data Part I

Upon completion of every testing time slot, participants in the first part of the experiment were given 18 questions mostly focusing on how they felt using the SitFlow product. These questions included the user's attention span, freedom of movement, comfort, focus, test taking abilities, alertness, and enjoyment during the testing slot. There were additional questions thrown in the survey to gauge traits particular to the participant, including: their posture at work, their ability to work under pressure, and how fast they commonly work through tasks. To begin the analysis of the qualitative data for part one, we can first analyze the focus experienced among the participants.

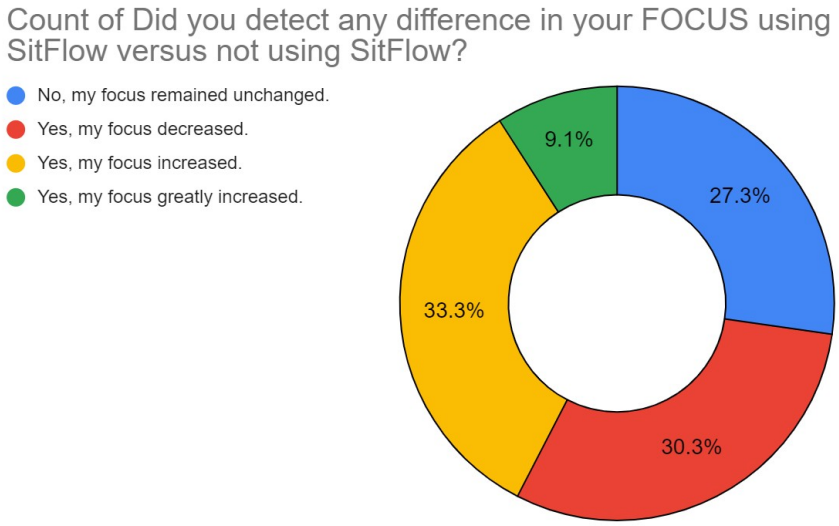

Figure 16: Focus using SitFlow

This pie chart depicts that just under 70 percent of the participants in part one saw their focus remain the same, increase, or greatly increase. While just over 30 percent exhibited a decrease in focus. Having this high of a percentage of participants having an unchanged or boosted focus score is promising that this will be the case in a work setting. Next, participants reported their comfort using the SitFlow:

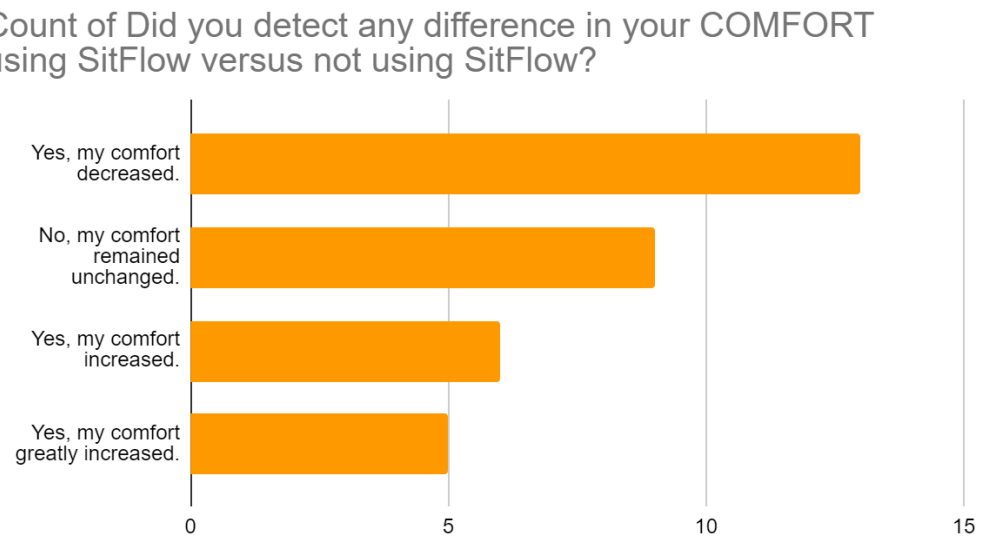

Figure 17: Comfort using SitFlow

Having a lower spread of scores for comfort is predicted in the test design. Since this was the part one of the experimental process, none of the participants had used SitFlow before. While a five minute video was shown at the beginning to familiarize everyone with the SitFlow, everyone is unique and some take longer to become comfortable than others. In the following figure, participants reported if there test taking abilities changed while using SitFlow:

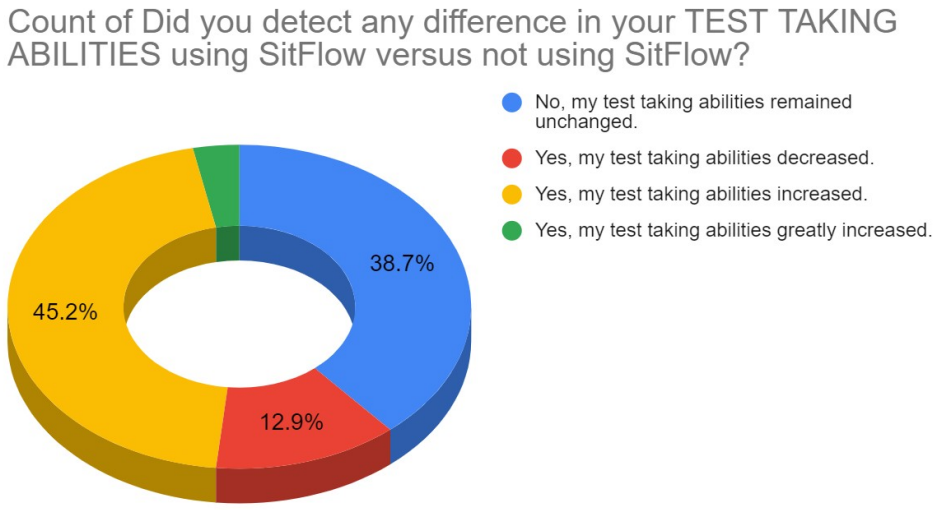

Figure 18: SitFlow Test Taking Abilities

Depicted above, almost half of the participants in the experiment felt an increase in their test taking abilities when using SitFlow. Additionally, only about 13 percent felt a decrease in test taking abilities when using SitFlow. Next, shown below is how participants felt about their freedom of movement:

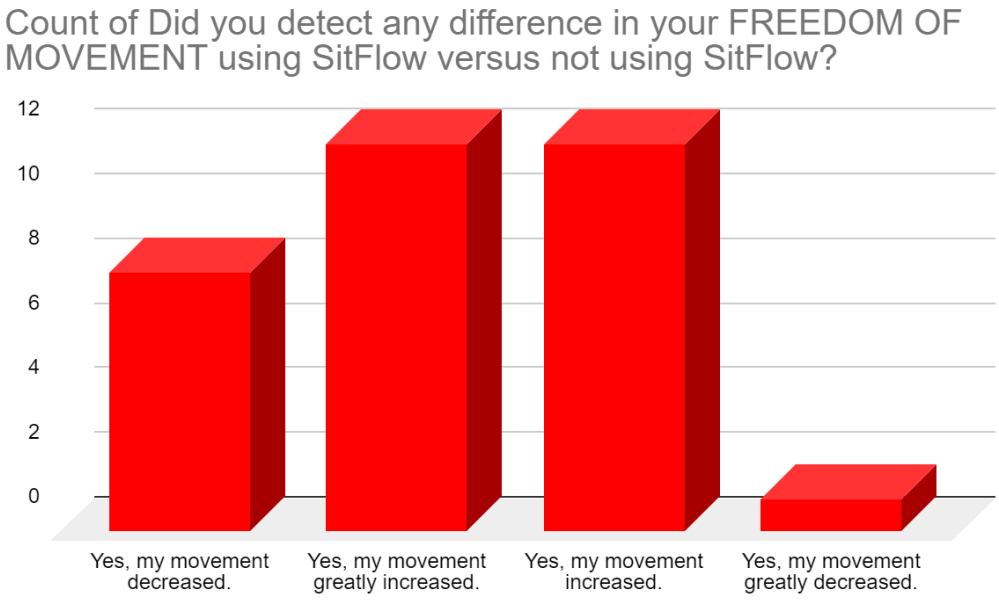

Figure 19: SitFlow Freedom of Movement

Looking at the bar chart, it is clear that most participants felt that they had an increased freedom to move while using the SitFlow device. This indicates that most participants did not feel confined in their movement by the device. While a smaller amount of participants felt that their movement decreased, this could be due to the confines of the desk used in the experiment or other external factors. Next, we looked at attention span when using the Flow device:

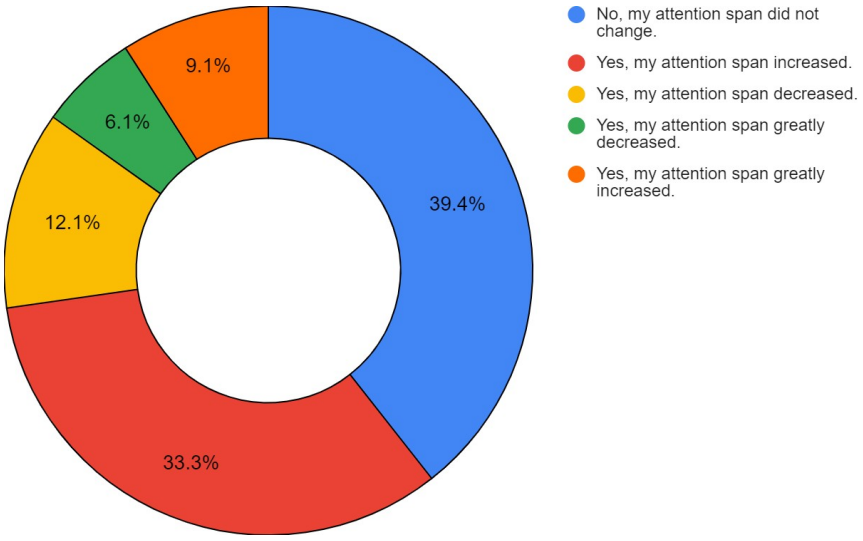

Figure 20: SitFlow Attention Span

Depicted in the bar chart is the percentage of participants that felt that their attention span increased, decreased, or remained the same, with varying degrees. Roughly 73 percent of participants exhibited either no charge or an increase in their attention span while using the SitFlow device. This is especially important when taking a cognitive test, when every second of attention is needed to complete a large amount of questions in a short time window. This also translates to the workplace, where long spans of attention are needed to complete assigned work. This further validates that the SitFlow device would perform well in a work environment. Moving on, we the pie chart below depicts alertness while using SitFlow:

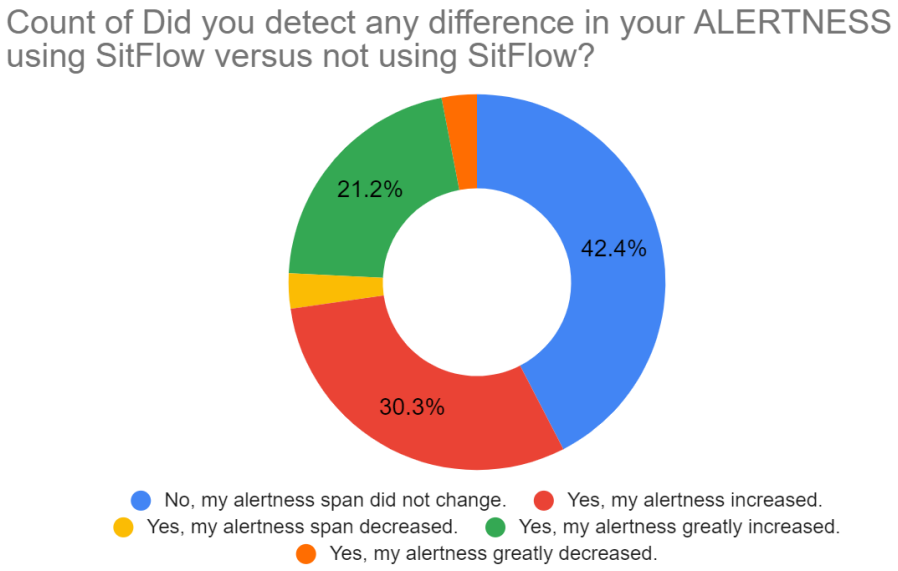

Figure 21: SitFlow Alertness

The information collected above presents a whopping 94 percent of participants experienced no change, a slight increase, or a great increase when using the SitFlow device. Alertness is closely tied to exercise, and since energy is being expended when participants use SitFlow, this aligns with the higher percentage of alertness increases.

In addition to the questions surrounding the participant's experience while using the SitFlow versus sitting, the team also asked a variety of questions related to work habits. These questions were derived and modified from the Nordic Musculoskeletal Questionnaire (NMQ). The NMQ is a standardized test aimed to study musculoskeletal problems in the workplace (Crawford, 2007). The research team decided to include questions from the NMQ because the main objective of the post-experiment survey was to collect qualitative information from the participants including, but not limited to, their initial reaction to the SitFlow apparatus. Due to each participant having their own work ethics, it is impossible to truly standardize or measure the amount of discomfort prior to the experiment. The participants' levels of discomfort may be an important factor to consider in the analysis of the data because there may be a significant correlation to the ease of using the SitFlow apparatus and prior comfort level. Thus, the NMQ test was designed to be administered as part of a periodic health inspection for employees in the form of a self-administered questionnaire, self-administered survey, or as an interview (Kuorinka, 1987). The NMQ test has been proven to be credible and reliable for qualitative analysis especially if symptom severity is included on a numerical scale (Descatha, 2007). Symptom severity is included heavily in the second part of the post-experimental survey; the first part of the post-experimental survey focuses on the participants' work ethics. The term work ethics in this case refers to the participant's normal workday. One participant could be in one

position for several hours (deskwork) or they could be constantly on their feet. By asking modified questions from the NMQ, the research team could get a better understanding on the levels of discomfort profiles.

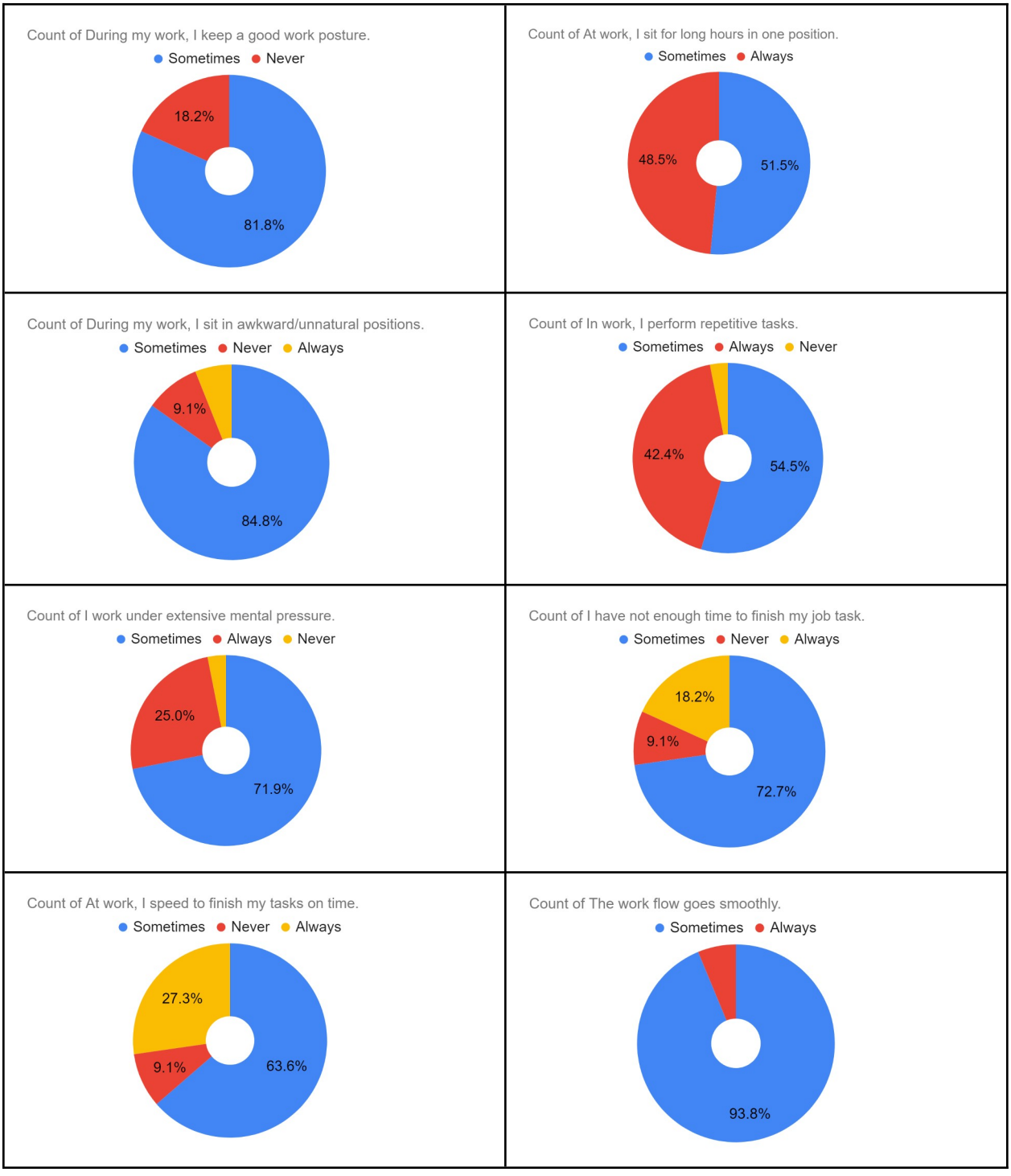

Table 7: Participants Work Habits

The breakdown of these responses surrounding work habits can be seen on the table above. Each chart was created using a "count", simply alluding to the breakdown being a comparison of the number of responses in each category. Throughout the table we can see that participants almost always respond with "sometimes" or "always" indicating that this could in fact be a correlation to participants' ease of use of the SitFlow device.

8.4.2.2 Qualitative Data Part II

Once the data collection process was completed for part one, the nine participants were invited back, and once again took a survey at the end of the testing block. This time, the survey was modified to gauge how participants felt using SitFlow in part one versus part two. This tied into the quantitative analysis, where ANOVA was used to compare scores in part one versus part two. The first question two questions asked were to compare focus and comfort between the two parts:

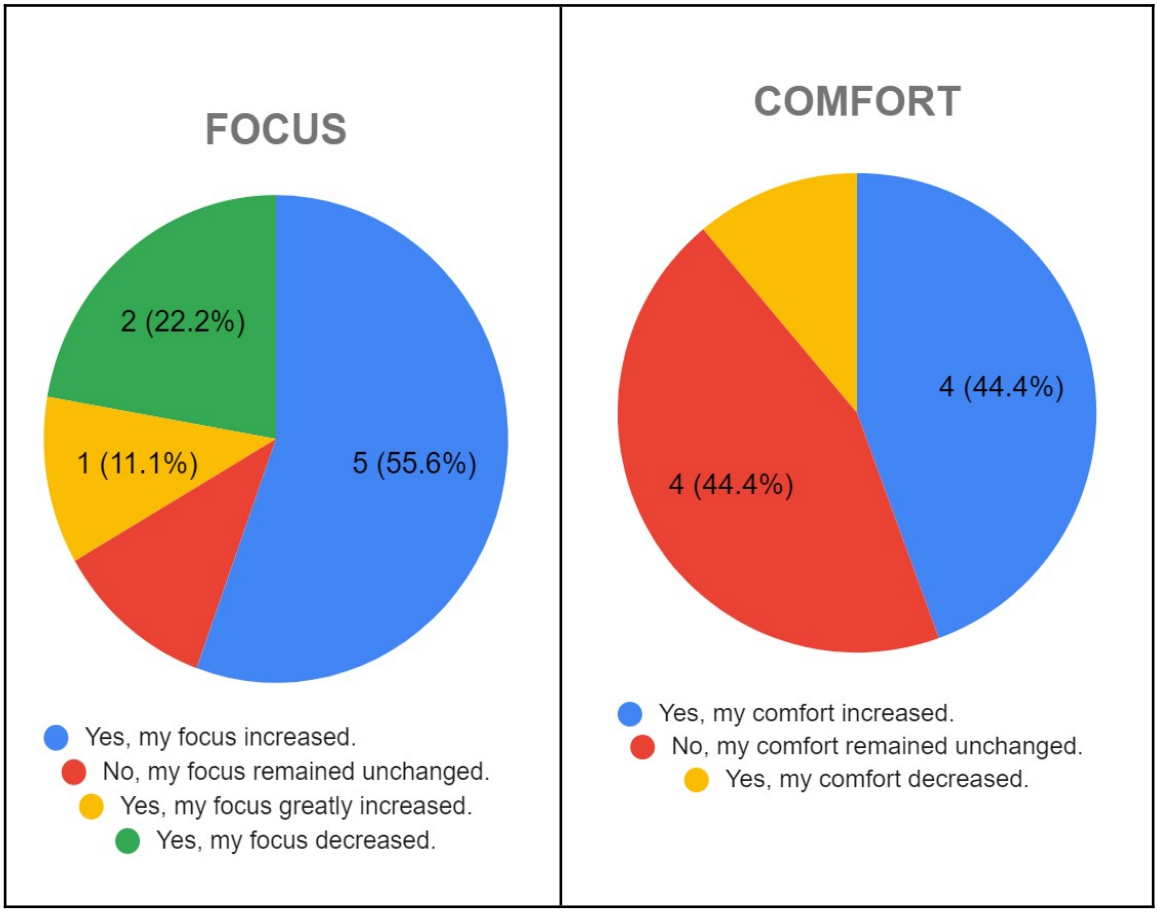

Table 8: Focus and comfort during second part of experiment

First, looking at the focus chart on the left, it is evident that six of the nine participants in part two experienced an increase in their focus. We followed up and asked why participants felt that their focus had increased and common responses were “I was more used to the SitFlow” or “I had more practice”. This leads us to believe that even a relatively short period of practice will significantly impact a participant's perceived focus while using the SitFlow. There were two participants that felt their focus decreased. Seen on the follow up response, those participants experienced a decrease in focus due to external factors such as “creaking of the desk”. On the comfort chart on the right, over 50 percent of participants experienced no change or a slight decrease in comfort. Participants explained that this was mainly due to the “table height being weird”, and less to do with the SitFlow. In the next two questions were regarding test taking ability and movement:

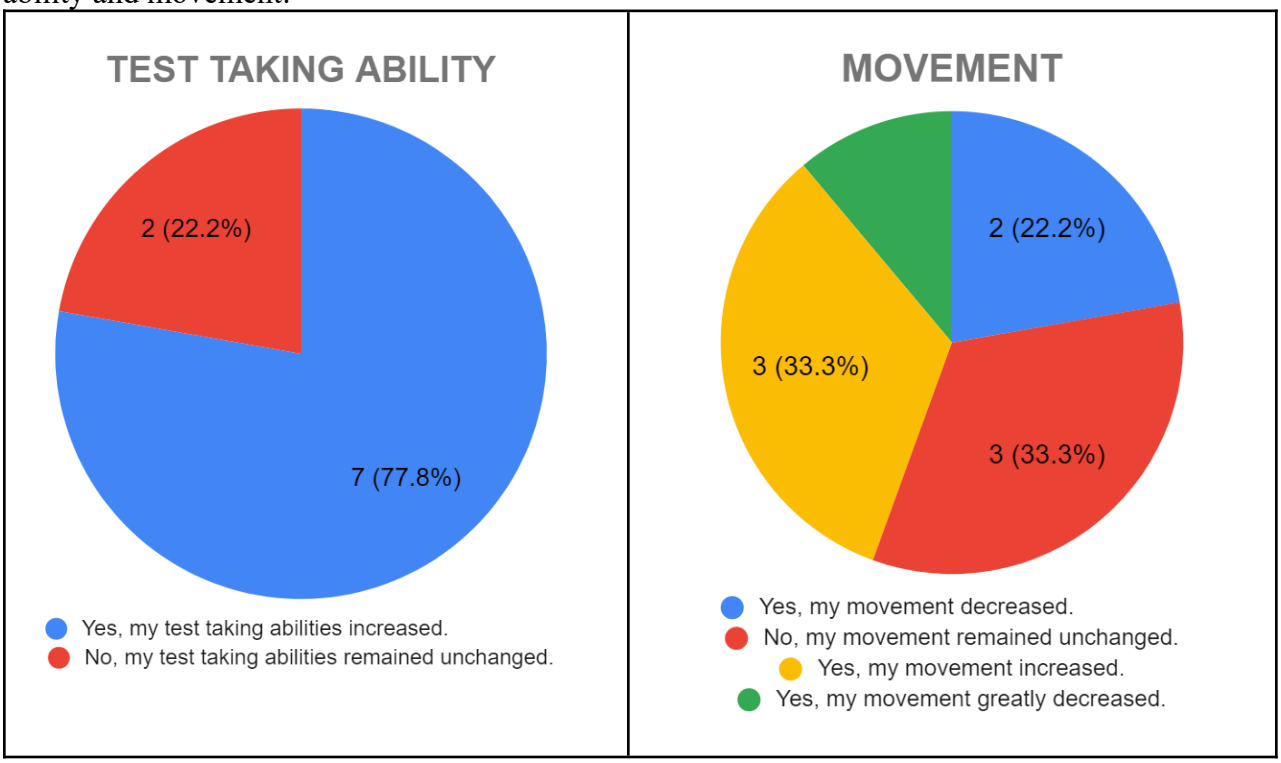

Table 9: Test taking ability and movement in second part of experiment

Taking a look at the test taking ability graphic on the left, an astonishing seven participants felt their abilities increase, two perceived no change, and no one felt a test taking decrease. This qualitative data aligns with the quantitative data, as scores generally increased. Participants suggested this was also due to more familiarity with the SitFlow device. In regards to the graphic on the right, results were more mixed. We can attribute this to the nature of our experimental set up. We experienced a handful of comments directed towards the table height restricting motion, and few comments directed towards the movement of the SitFlow itself. Lastly, the final two questions were regarding attention span and alertness:

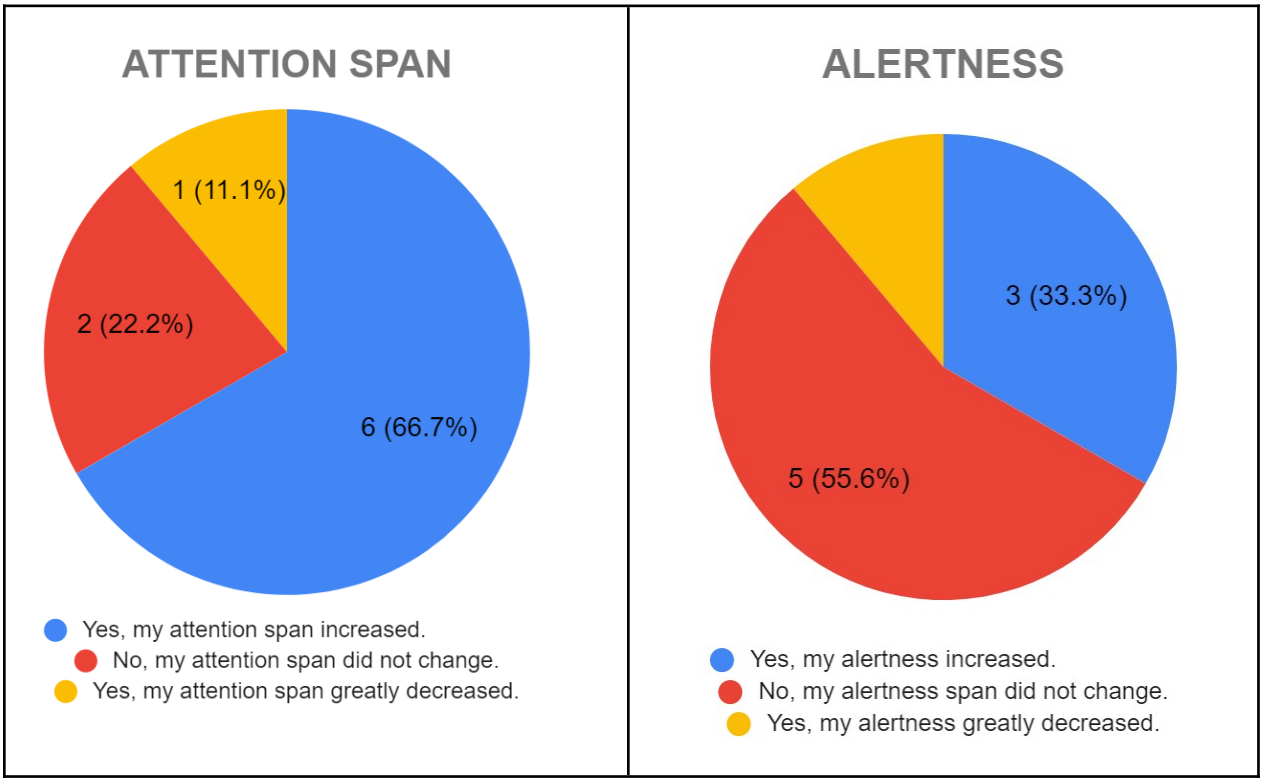

Table 10: Attention span and alertness in part two of the experiment

Finally, looking on the pie chart on the left of the table, we can see that participants generally experienced the ability to concentrate mentally on the CCAT for a longer time period. This would align with our previous finding as the more familiar with the SitFlow device, the less time you will have to think about using it. And lastly, participants' ability to be in a state of high sensory awareness, or alertness, was mixed. Most participants encountered little to no change in alertness. This specific attribute can be influenced by many factors such as perceived energy levels including the amount of sleep experienced by that person (Shahid, 2014).

8.5 Future Recommendations

8.5.1 Participant Compliance

Due to the COVID-19 pandemic, the research team had a restricted target sample population. All participants must be compliant with the Cal Poly testing program in addition to being enrolled in a minimum of one in-person class. During the four weeks of experimentation, Cal Poly required students to be tested at least twice a week, three days apart. If a student does not follow this protocol, they are restricted to only the testing site on campus ("Student testing," 2021). This was an obstacle the team faced because some participants were noncompliant the day of their respective experimental run and were unable to participate. A future suggestion to

combat any compliance related issues is to send a separate reminder to participants to complete any requirements needed beforehand. Sending a separate email reduces the amount of tasks to do on a single email, preventing any stress to develop on the participant. Additionally, since the participant has to be compliant for two entities (Cal Poly University and the SitFlow research team), having two emails provides more organization and less clutter.

8.5.2 Field Experiment

Another future recommendation is to have a field experiment rather than a simulation. The experiment in this report was a simulation of an office environment. Since there was a strict time slot to conduct the experiment, the research team was unable to lengthen the familiarization period when using the SitFlow. If a field experiment was conducted, the participants could be recruited from a single office location or various office locations. An idea of the experimental schedule following standard work hours can be seen in Table 10.

Time	Experiment Description
8:30AM-11:45AM	Familiarization Period
11:45AM-12:00PM	First CCAT Test
12:00PM-1:00PM	Break
1:00PM-1:15PM	Second CCAT Test

Table 11: Suggestion for future experimentation schedule

For the field experiment example, the goal will be exactly the same as the initial goal of this report to further define the relationship between SitFlow and work productivity in the form of a cognition test (in this case, CCAT). Since there was significance that using SitFlow for the first CCAT test had a higher score on the second test, the field experiment example will not be randomized if the participants take the first test with the SitFlow apparatus or sitting (Grizzle, 1965). Instead, the test versions will be randomized and since the CCAT tests are assumed to be of equal weight or difficulty, the order of which they are taken should not be a significant factor.

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