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Preventing Accidents in Long-Haul Truckers

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Author Note: All six team members are seniors at Binghamton University studying Industrial and Systems Engineering. The team would like to give a special thank you to Professor McLeod and Professor Poliks for supplying us with the information needed to complete this project. We would not be where we are at this point in the design without their continued support and guidance.

Abstract: Driver fatigue causes thousands of accidents and fatal crashes per year. Fatigue is a leading cause in long-haul truck accidents, with 13% of trucking accidents being directly linked to a drowsy driver. Research has found that there is a direct relationship between blood circulation in the legs when sitting and attentiveness. Our project aims to construct a device, adapting the technology used in the Heart Partner by Sonostics, that will be utilized inside the cab of a truck. With ergonomic design, testing, and usability research, the team will create multiple mock-ups of the device to be reviewed and tested for effectiveness. Our team's device has the potential to save both thousands of dollars and, more importantly, lives.

Keywords: Ergonomics, Transportation, Trucking. Fatigue, Safety

1. Introduction

The Center for Disease Control and Prevention stated that driver fatigue causes thousands of serious collisions and around 6,000 fatalities a year. Truck drivers are far more likely to experience driver fatigue than the average person because of the strenuous hours and conditions they work under. Long-haul truck drivers experience constant physical exhaustion and are rarely able to attain the necessary 7-9 hours of sleep due to such demanding hours. The law states that truckers can drive up to 11 hours in a 24-hour period, however the nature of the job forces drivers to push beyond their limits to get deliveries done on time. Until now, we have found through surveys and face-to-face conversations with truck drivers that they have been turning towards caffeine, loud music, and even chewing gum to keep the fatigue at bay, which has only offered momentary relief. Our team has worked hard to develop a device that will change how truckers' function on the road. Our device is equipped with unique technology that will keep drivers more alert and prepared on the road and has long term benefits for both the drivers and trucking companies. The team's product stands to decrease the number of truck related accidents per year, resulting in millions of dollars saved in damages and safer roads for all vehicles.

2. Background

2.1 The Secondary Heart

The soleus muscle is commonly referred to as the secondary heart. This is because this muscle has the ability to pump blood throughout the body. Output from the heart relies on the veins ability to pump blood to the heart. When lying down, the flow of blood to the heart is not affected by gravitational influence. However, when sitting or standing upright, the flow of blood to the heart must go against the force of gravity. The amount of pressure required to ensure maximum blood flow to the heart while sitting or standing is unrealistic to obtain. This is when the body begins to rely on skeletal muscle pumping to return blood to the heart and brain. While seated, muscle pumping is created almost primarily through the activity of the soleus muscle. These muscles contain large venous sinuses that store blood, the blood is released when reflex responses activate contraction

of the muscle. Once the muscle contracts, there is enough pressure able to return the blood, as well as lymphatic fluid, back to the heart. If the soleus muscle is not able to contract, there will be inadequate fluid return to the heart, resulting in ineffective operation of the heart. Most importantly, poor fluid return to the heart causes lowered cardiac output and blood pressure. This directly results in conditions such as weight gain, chronic fatigue, and memory and attention deficits.

2.2 Current Technology

The current device, The HeartPartner by Sonostics, is a mechanical device that uses vibrations at a specific frequency applied to the bottom of the foot. Once these vibrations can reach the bottom of the foot, the Meissner's Corpuscles become stimulated and the soleus muscle contracts. The Meissner Corpuscles consists of nerve endings that are responsible for transmitting the sensations of vibration and touch. Also known as tactile corpuscles, they are found in the upper dermis, primarily in the glabrous skin on the fingertips and eyelids. As seen from figure 1, they are also scattered throughout the bottom of the foot. Meissner Corpuscles respond well to low-frequency vibrations and have the ability to send signals to surrounding muscles. The specific muscle that is targeted in this device is the soleus muscle, located in the calf. As shown in figure 2, the soleus muscle is a flat, broad muscle of the calf of the leg lying just beneath the gastrocnemius muscle. The specific frequency vibrations outputted through the device stimulates the Meissner Corpuscles, as a result the soleus muscle contracts due to a nervous system reflex. Nervous system reflexes occur when a nerve becomes stimulated by an outside source causing an immediate response of a muscle or gland.

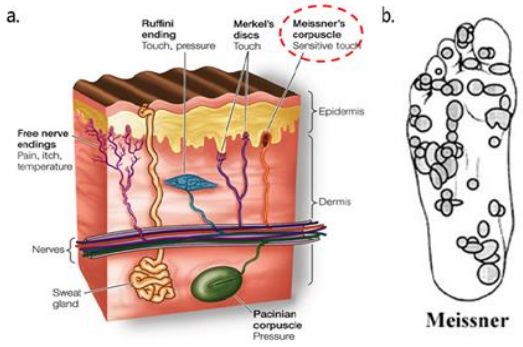

Figure 1. Meissner Corpuscles in the Foot

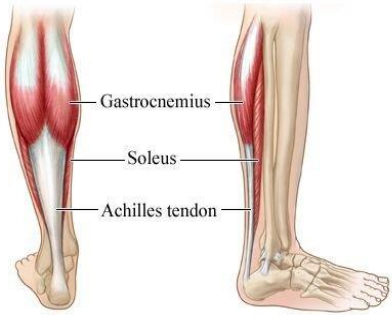

Figure 2. Location of Soleus Muscle

2.3 New Technology

The current device uses a mechanical signal to transmit vibrations through the foot of the user. The vibrations needed to successively stimulate the Meissner Corpuscles are at a frequency of 40 Hertz. Instead, our device will use an electromagnetic field to transmit vibrations through the foot of the user. This field will need to be strong enough to pass through the outer shell of the device and pass through the foot of the user. Additionally, the thickness of the truck driver's boot will need to be taken into consideration. From our survey, it was concluded that most truck drivers wear boots while on the job. The original device was not made to accommodate users with a thick sole boot; therefore, the device will need to output a much higher frequency. Due to this, these vibrations will need to be much stronger than the original frequency used. After conducting research on electromagnetic stimulation, the team determined that the frequency should be about 400 times stronger than 40 Hertz.

3. Methodology

3.1 Justification

In recent years, the amount of truck driving related incidents have become more and more frequent. From a study done in 2009 to 2018, there has been almost a 52% increase in the number of fatigue related accidents seen each year. Fatigue is a leading cause in truck accidents, as much as 13% of trucking accidents can be directly linked to a drowsy driver. Truck accidents are extremely dangerous because they can affect other passenger vehicles, 74% of all fatal passenger cases involve a large truck and 68% of all truck fatalities are passenger vehicle occupants. The average cost of a truck crash can cost up to half

a million dollars in damages and settlements, while a fatal crash can average at about three million dollars. Traffic accidents are estimated to cost the U.S. $871 billion a year.

Furthermore, truck drivers are far more likely to experience driver fatigue than the average person. Most fatigued drivers are tired before they get into a vehicle; however, truck drivers can experience constant fatigue and exhaustion from the demanding hours of their profession. By law, truck drivers are allowed to drive up to 11 hours in a 24-hour period. This is widely ignored by drivers, due to a variety of reasons such as pressure to meet deadlines or fear of losing their job. Drivers who are met with fatigue typically try to counteract these effects by drinking coffee, listening to loud music, taking a short break, and walking around, or smoke cigarettes. However, these options usually do not help for very long and can have negative side effects on the driver's heath. There needs to be a product that directly fights driver fatigue and helps the driver remain awake and alert. Our team aims to develop a product that will stand to combat driver fatigue and decrease the number of trucking accidents we see each year due to drowsy driving. This product could potentially save the lives of thousands of people a year and save trucking companies millions of dollars.

The team's device is specifically designed to prevent driver fatigue on the road. By stimulating a specific muscle in the calf, the device will increase blood circulation and help the driver stay alert on the road. For the user to experience the full effect of this product, they would need to use this device for at least an hour while driving. For this reasoning, the trucking industry is an ideal target market because of the lengthy amount of time drivers sit and drive each day. Since the 11-hour maximum ruling is not strictly followed, we see many fatigue related trucking accidents a year that cost companies millions of dollars in lost revenue, damages, and settlements. With this technology, life on the road will be changed forever. If successful, we should see a dramatic decrease in the number of trucks involved accidents per year. With less truck accidents, companies can expect to save millions that would've normally gone towards the collision and product replacement. This device will make the roads safer for not only truck drivers but for passenger vehicles as well.

3.2 Trucker Survey

The team created an online survey that was distributed to truck drivers, and gathered data that shows the age demographic, time spent on road and on breaks, average cruise control use, and willingness to try a non-invasive product to combat drowsiness. From the survey, 89 responses were recorded, as shown in Figure 3, all of whom were men with the major below the age of 50. Additionally, the survey showed that the overwhelming majority of truck drivers work for a company, rather than being an independent driver. Furthermore, when asked how many hours the driver drove each week, 58% responded with more than 50 hours and 35% responded with between 40 hours and 50 hours. Lastly, the survey asked if the driver would be willing to use a non-drug, non-invasive product that would decrease the chance of becoming drowsy while driving. To this question, about two thirds of the respondents said they would be willing to try using the device.

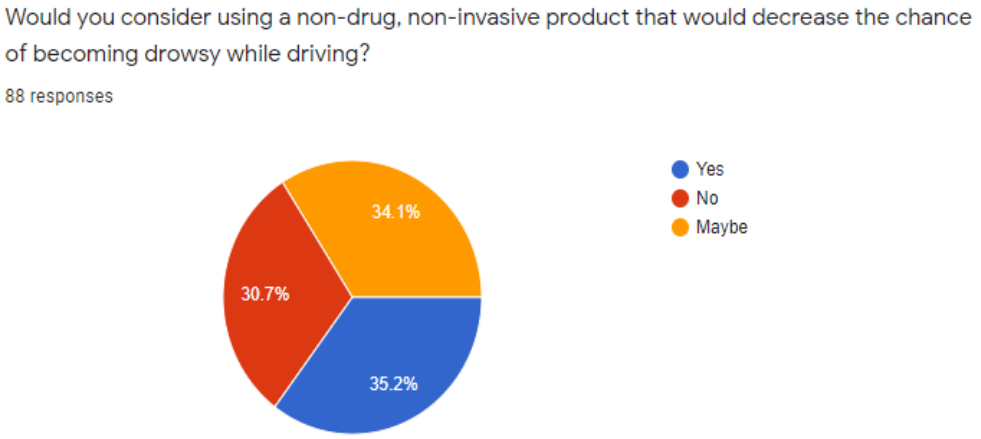

Figure 3. Example of a survey response

3.2.1 Company Contact

In addition to getting information from truck drivers, the team called trucking companies to gauge the level of interest in buying a product like this. In total, the team contacted twenty-five companies, which included companies like Werner

Enterprises, Swift Transportation, J.B. Hunt, and Schneider National. Many of the representatives either did not give sufficient feedback besides Werner Enterprises. This company gave the team insight into what the companies would want, attributes the device should have, and price ranges since the trucking companies would have to buy these in bulk for the fleet of trucks they use. This feedback helped the team realize the aspects of the designs that are essential to truck drivers. Our contact expressed interest in a product that could combat driver fatigue and potentially save their company money. They would need to see data on product effectiveness, cost, and scalability to see this as a viable product. The company contact had specified that currently they have their drivers rest, stop, and walk around or drink caffeine to fight drowsiness. Werner Enterprises runs about 3 million miles a day across the US and Canada where they see accidents in both equipment failure and driver error. In the case of an accident the company pays for the damages and restitution, upfront costs being about 80% and hidden costs around 20%. The expressed interest in a durable product and would pay around $2,000 per unit if this was an effective solution.

4. Design Phase

4.1 Ergonomics

According to the American Heritage Dictionary of the English Language, ergonomics can be defined as “biological science applied to study the relation between workers and their environments" (Houghton, 2016). Our workers are truck drivers, and the environment they work in is the trucking cab. Our team wanted to maximize their productivity by reducing operator discomfort, making sure we did not make the task of driving harder than it already is. We started by collecting the thoughts and opinions of real truck drivers on how often they used cruise control, their foot positioning when driving, and the amount of space in their trucks. Measurements were collected on the amount of available floor space at the foot of each driver, to help build a design that will fit in most, if not all trucks and will not impede the driver’s performance. We executed this by going to a local Travel Centers of America truck stop, where we briefly talked to drivers and asked to measure the floors of their trucks as they stopped to rest and refuel. By combining the data we collected, our team was able to develop some guidelines as to what characteristics we believed our device should have and the problems it would solve. Safety considerations we made when designing our devices were that it should only stimulate the top half of the foot, it shouldn’t impede driving, getting in and out of the vehicle, or distract the driver. We addressed these challenges by focusing on driver comfortability. Additionally, each design is built to restrict electromagnetic pulses from reaching the heel, due to the lack of testing on the HeartPartner technology with stimulation of this area of the foot.

4.2 Creating the Designs

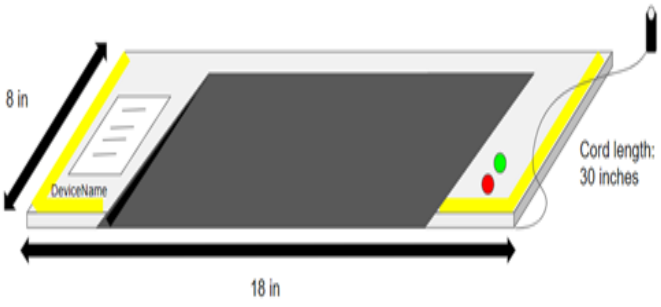

Figure 4. Inclined Mat Design

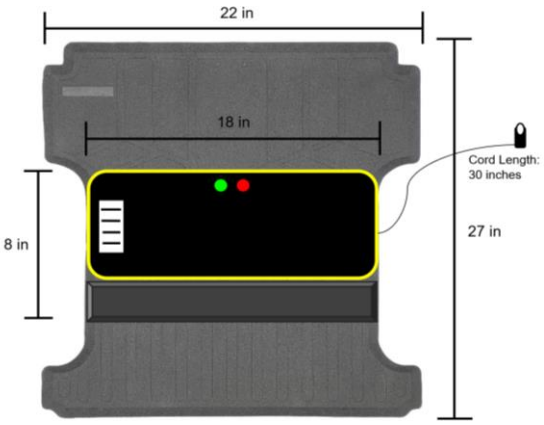

Figure 5. Raised-Heel Mat Design

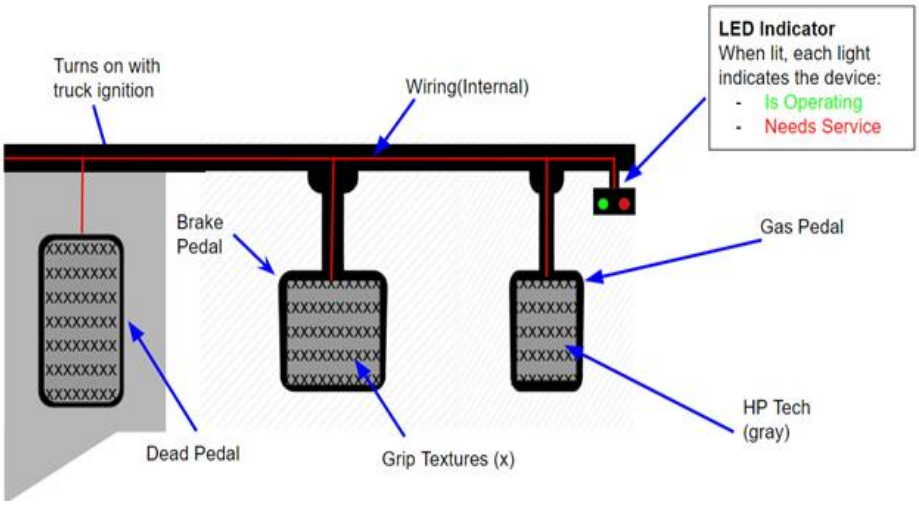

Figure 6. Pedal Design

Above are the final three designs we decided on. They include the *Inclined Mat Design* (Figure 4), the *Raised-Heel Mat Design* (Figure 5), and the *Pedal Design* (Figure 6). The first design, the Incline Mat, features a car mat-like shape that includes a cutaway area in the middle of the mat which guides the feet onto the HeartPartner (HP) tech. This would allow for the driver to rest their feet on the mat while using cruise control, keeping their blood flowing. The second design, the Raised-Heel, is similar in concept to the first design but instead of having an incline for the feet, this design has a raised pad for the heels to rest on top of, placing the front of the foot directly on the HP tech. This design would likely be placed closer to the base of the driver's seat, as this is a more comfortable location for the driver's feet if their heels are to be raised. The final design, the Pedal, provides a different approach to utilizing the HP technology. The amount of time drivers spends using cruise control is determined by the landscape they are driving on, so we decided to install the coils right onto the pedals for those who may not use cruise control often while driving. This design also features a "dead pedal" that has HP tech installed, designed to let the left footrest off to the side as the right foot is used to drive.

4.3 Mock-ups of Designs

The team created mock-ups of three final designs, each design had a different feature that we desired to test and gauge how well it would work. The Inclined Mat design has a heightened heel to protect from over-stimulation, this mock-up is being fabricated out of foam insulation with labels for electronics. The Raised-Heel design is a pad for the floor, this mock-up is made of insulation foam with labels for electronics. The Pedal design is a pad to attach to the brake and gas pedal, the mock-up we have decided to go with is attached to a prefabricated pedal with a pad we plan, representing the device, built out of wood. The materials for the mock-ups are rudimentary and are different from the materials that will be used in the final device that will be used by truck drivers.

4.4 Testing, Feedback, and Redesign

The three mock-ups will be tested to see the fit of the designs in a semi-truck cab. The physical design of this device is the main part of the testing since the technology has already been proven effective. The team created a survey including demographic data and questions with scaled answers to determine the effectiveness of each design and allows the testing subject to choose their top design. The questions are answered with either a scale of one to five, yes or no, or a specific design related answer choice (i.e. for the pedal design, the survey asks the subject to choose the optimal angle they prefer the pedal to be at, 35 degrees or 55 degrees). This process was tested by the team and is expected to take approximately 10 minutes to complete per truck driver which includes a background of the team's objectives and device's intended use. These questions are geared towards gathering feedback for creating a final mock-up by analyzing the feedback, choosing the top of the three designs, and adapting any aspect from the other designs that are deemed useful.

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5. Analysis of the Methodology: Conclusion

To conclude, our application of the HeartPartner technology is going to provide a safer and more attentive driving experience for users. Feedback from trucker drivers and a trucking company was retrieved, allowing the team to better understand the scope of the project. Next, the team began formulating different potential design ideas. Each of the designs accomplish the task of increasing driver attentiveness; however, the designs differ in foot placement, while using the device. The three aforementioned designs will be evaluated, in trucks, and from the feedback a final design will be chosen. The finished product aims to decrease the frequency of fatigue related trucking accidents, saving trucking companies capital and saving human lives.

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