



Developing Drowsy Driving Mitigation Strategies in Himachal Pradesh

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Developing Drowsy Driving Mitigation
Strategies for Himachal Pradesh

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Abstract

The goal of our project was to develop and improve strategies to mitigate the risks associated with drowsy driving in Himachal Pradesh, India. Government data and anecdotal evidence suggest drowsy driving is a significant problem. To achieve our goal, we interviewed local bus and taxi drivers to identify drowsiness prevention strategies and understand ways to improve those strategies. Based on the data, we created four distinct prototypes to address drowsy driving: 1. A facial recognition device to detect drowsiness, 2. A blue-light system to reduce melatonin production in drivers, 3. Flavored taffies to keep drivers awake, 4. A portable and comfortable seat cover. We recommend further improvement to these prototypes, as well as policies to allow drivers to get more rest off duty.

Executive Summary

Drowsy driving is an issue that has been troubling various countries for years, and parts of India face compounded risks due to the country's geography and driving style. Driving while drowsy is especially dangerous when paired with poor road conditions in rural, mountainous areas, such as the areas encountered in Himachal Pradesh ("Consultancy Services," 2017). The Ministry of Road Transport and Highways in India reported in 2015 that 54% of total road accidents took place in rural areas, which led to 61% of the fatalities and 59% of the injuries in the country (Government of India Ministry of Road Transport & Highways Transport Research Wing, 2015). While there is a lack of data pertaining to accidents caused by drowsy driving within the country, studies by health organizations and universities in some low to middle income countries with driving conditions similar to India have detailed the prevalence of driver drowsiness. Data from these studies show that 75%, 44%, and 22% of commercial truck drivers have experienced drowsiness while driving in Thailand, Argentina, and Brazil respectively (Herman et al., 2014). In India, the only category drowsy behavior fits into is "fault of driver," which is split into two categories: speeding and intake of alcohol or drugs (HTRW, 2015).



Figure 1: An HRTC bus crash due to drowsy driving (Khan, 2017).

Drowsiness is classified as "Stage I" of sleep, or the transition between awake and asleep, and is the feeling of being sleepy for various reasons, which can cause a person to fall asleep at "inappropriate" times throughout the day (Sahayadhas, Sundaraj, & Murugappan, 2012). This sleep stage causes a decrease in brain activity and heart rate, which is largely associated with boredom, either in general or due to monotonous driving (US National Library of Medicine, 2017). As a result of the decreased brain activity, driver performance and awareness significantly decline (Lal & Craig, 2001).

The goal of our project was to develop and improve drowsiness mitigation strategies applicable in Himachal Pradesh. To assess the problem, we gathered information from bus drivers and taxi drivers about their experiences with drowsy driving. The results of our interviews with fifteen bus drivers and surveys with thirty taxi drivers indicated three key details of the experience of a fatigued driver:

1. There is significant pressure on drivers to continue on the road despite drowsiness, whether from their passengers or employers.
2. Many existing strategies to stay alert are known among drivers and can be improved even beyond their current level of effectiveness.
3. Most respondents are willing to purchase and use a technological device to help them stay awake on the road.

We researched drowsiness prevention strategies and evaluated how drivers used them. This research involved analyzing the effectiveness of certain detection and prevention strategies as



Figure 2: A team member being warned of drowsiness using our eye detection system on April 3, 2018.

well as using data from our interviews to understand how acceptable these strategies might be.

With these findings in mind, we developed four strategies to increase awareness of drowsiness and prevent drowsiness that we recommend drivers to use to stay awake on the road: a camera-based drowsiness detection system, two flavors of taffy, ambient blue lighting, and a portable seat cover.

Our technological solution was a camera-dependent drowsiness detection system consists of a raspberry pi computer, a night vision camera, a power supply, and software that analyzes facial features to detect drowsiness. It detects the closing of eyes and relays an alert that a driver may be drowsy. Currently, our prototype offers an eyelid closure detection method that is not calibrated to individual facial structures and uses a night vision camera. This strategy is recommended since it provides an unobtrusive way to detect driver drowsiness.

Inspired by a common driver strategy, we made a candy known as taffy. Both types of taffy started with a standard salt-water taffy recipe. The spicy taffy contained red chili powder for spice, while the sweet taffy contained black tea, orange marmalade, and soya flakes for caffeine and protein. This recommendation is based upon the taffy's ability to be used continuously as drivers can eat the taffies whenever they start feeling tired.



Figure 3: A few of the spicy taffies made on April 4, 2018

Considering a newly-introduced approach, we investigated the possibility of blue lights in the driver's compartment.



Figure 4: Final blue light prototype

This light strategy consists of a set of blue LEDs intended to be placed on the dashboard of a car in an unobtrusive manner. Unfortunately, the blue light strategy suffered mainly in terms of the drivers' willingness to use it. The drivers were not aware of the scientific effects of blue lights on humans, which is the chemical delay of sleep by slowing the production of melatonin in the body. In addition, we could have more clearly conveyed that we would be using an ambient light rather than a bright, distracting light. As a result, we still recommend this strategy due to the research that

verifies how successful blue light is in keeping people awake.

Finally, we designed a foam-cushioned seat cover, which provides a more comfortable ride for the drivers by causing less physical strain on their bodies. In addition, it can be laid flat to double as a sleeping mat to give drivers more restful breaks off duty. Furthermore, this cushion was designed to have a pocket behind the headrest which can



Figure 5: Final seat cover

house our other devices, such as our camera-dependent drowsiness detection system. Our recommendation of this prototype stems from its portability, versatility, and comfort.

After fabricating our prototypes, we completed fifteen tests on a control group, taffy group, and blue light group of five participants each. We found that both the taffy and the blue light increased the participants' heart rate more than the control group, which had a negative trend line, correlating to a more alert and awake state. The taffy and the blue light group also had significant improvements from their first to second reaction time test. On average, the taffy group had a decrease of 22 milliseconds, the blue light had a decrease of 3.8 milliseconds, and the control had a gain of 17 milliseconds in their response times during their second test.

Drowsy driving is multifaceted and relatively complex, so no single strategy will permanently address the problem for every driver on the road. Even if our strategies are effective, the brain's functioning will still be significantly slower and less dependable than if the driver has gotten proper rest; extended wakefulness does not eliminate the potential for driver error due to impaired cognitive functionality. However, we believe that our set of recommendations and prototypes can address the issue of onset drowsiness during a single trip. Moving forward, our prototypes still have room for improvement. The blue light strategy can be refined and adjusted to address driver preferences, and the taffy production can be scaled up. With a bigger budget and more feedback on ergonomics, the seat can be designed to a higher quality standard to fit the drivers' need for better rest. Finally, the face detection software can be improved to be more easily calibrated to different drivers, and integrated to notice facial features such as yawning and head position. With all potential improvements in mind, our four prototypes and recommendations for policy change can serve as a strong foundation to future work and improvements in the field of driver safety.

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Authorship

Utkrisht Dhankar completed all of the Python programming for OpenCV required for the eye detection prototype. Alongside the other IIT members of the team, he conducted and translated a third of the bus driver interviews and taxi driver surveys.

Nico Fabbrini helped create the blue light LED circuit, conducted some of the prototype testing, and designed the first draft of the final presentation poster. Alongside his fellow WPI teammates, he did equal work writing and editing all sections of the report.

Archit Kumar implemented the eye detection software on the Raspberry Pi, helped complete the blue light LED circuit, developed a preliminary pulse sensor for drowsiness detection, and conducted some of the prototype testing. He also conducted and translated a third of the bus driver interviews and taxi driver surveys.

Glennndon McCormick co-designed the seat cover in Solidworks, assisted in the purchasing of the seat cover materials, conducted most of the prototype testing, and co-designed the final version of the final presentation poster. He also did an equal amount of writing and editing of the whole report with his fellow WPI teammates.

Sierra Palmer handled all of the taffy making, which included writing the recipes, acquiring the ingredients, and creating the taffies themselves. She also designed the final presentation pamphlet, put together the final presentation video, photographed our fieldwork, and contributed equally in the writing and editing of the entire report with her fellow WPI team members.

Rushil Singhal co-designed the seat cover, purchased the seat cover materials, conducted all of the prototype testing, and co-designed the final version of the final presentation poster. Additionally, he conducted and translated a third of the bus driver interviews and taxi driver surveys in conjunction with his other IIT teammates.

Table of Contents

Abstract	i
Executive Summary	ii
Acknowledgements	v
Authorship	vi
List of Figures	ix
List of Tables	x
Introduction	1
Background	2
Understanding the aspects of drowsy driving	2
Current drowsiness prevention strategies	3
Summary	5
Methodology: Developing and Improving Mitigation Strategies	6
Objective 1: Document and compare drivers' experiences with drowsy driving	6
Objective 2: Identify key aspects of existing strategies and technologies	7
Objective 3: Develop and test prototypes to mitigate drowsy driving	7
Results and Discussions	8
Objective 1: Driver's experiences with drowsy driving	8
Objective 2: Strategies drivers currently use to combat drowsiness	8
Objective 3: Prototypes to mitigate drowsy driving	9
Discussion	11
Project Outcomes	13
Recommendations for new strategies	13
Recommendations for policy making	14
Conclusion	15
References	16
Appendices	20
Appendix A - Bus Driver Group Interview Guide (English)	20
Appendix B - Bus Driver Group Interview Guide (Hindi)	22
Appendix C - Taxi Driver Survey Guide (English)	24

Appendix D - Taxi Driver Survey Guide (Hindi)	26
Appendix E - Map of taxi survey locations in Mandi	28
Appendix F - Experiment design	29
Appendix G - Post Experiment Survey	32
Appendix H - Graphs of taxi driver responses' to survey questions	42
Appendix I - Testing results from prototype experiments	43
Appendix J - PVT Testing Results	44
Appendix K - Bill of Materials	44
Appendix L - Taffy recipes	45
Appendix M - CAD models of seat cover	47
Appendix N - OpenCV face recognition code	48
Appendix O - Project logo for handouts	54
Appendix P - Information pamphlet for open house	55
Appendix Q - WPI poster	57

List of Figures

Cover Photo: Taxis driving through Mcleod Ganj

Figure 1: An HRTC bus crash due to drowsy driving	ii
Figure 2: A team member being warned of drowsiness using our eye detection system	iii
Figure 3: A few of the spicy taffies made	iii
Figure 4: Final blue light prototype	iii
Figure 5: Final seat cushion	iii
Figure 6: Construction on the road in Kamand	1
Figure 7: Distribution of accidents vs. time	3
Figure 8: Example of Border Roads Organisation Sign	4
Figure 9: Example of blue LEDs	4
Figure 10: Methodology process	6
Figure 11: Two team members performing fieldwork at the taxi stand in Mandi	7
Figure 12: Setup for testing with a control group participant	7
Figure 13: Passenger pressures	8
Figure 14: Passenger rest	8
Figure 15: Effective and comfortable solutions	9
Figure 16: A few of the spicy taffies made	9
Figure 17: CAD design of our seat cover prototype	10
Figure 18: Pulse vs. method of testing	10
Figure 19: A team member being warned of drowsiness using our eye detection system	13
Figure 20: A team member pulling taffy	13

List of Tables

Table 1: Prototype pros and cons

11

Introduction

Drowsy driving is an issue that has been troubling various countries for years, and parts of India face compounded risks due to the country's geography and driving style. Driving while drowsy is especially dangerous when paired with poor road conditions in rural, mountainous areas, such as the areas encountered in Himachal Pradesh ("Consultancy Services," 2017). The Ministry of Road Transport and Highways in India reported in 2015 that 54% of total road accidents took place in rural areas, which led to 61% of the fatalities and 59% of the injuries in



Figure 6: Construction on the road in Kamand on March 27, 2018.

the country (Government of India Ministry of Road Transport & Highways Transport Research Wing, 2015). While there is a lack of data pertaining to accidents caused by drowsy driving, studies in some low to middle income countries with driving conditions similar to India have detailed the prevalence of driver drowsiness. Data from these studies show that 75%, 44%, and 22% of commercial truck drivers have experienced drowsiness while driving in Thailand, Argentina, and Brazil respectively (Herman et al., 2014). In India, the only category drowsy behavior could fit into is

“fault of driver,” which is split into two categories: speeding and intake of alcohol or drugs (HTRW, 2015).

Multiple strategies have been developed to keep drivers alert. The most common of these strategies for drivers in Himachal Pradesh are to use tea stops or pay attention to cautionary road signs that are placed in higher road elevations by the Border Roads Organisation, a government entity that controls road infrastructure in north and northeastern India (Border Roads Organisation, 2016). Some technological strategies include mobile phone applications that detect the closing of eyes and play loud alarms and GPS systems that recognize when a driver starts veering out of their lane due to inattentiveness (You et al., 2013; Bergasa, Almeria, Almazan, Yebes, & Arroyo, 2014). More compliance with these strategies needs to be mandated, however, as exemplified by three drowsiness-related accidents that took place in Himachal Pradesh within 24 hours of each other. These accidents led to the deaths of 41 people when three buses fell into gorges (Express News Service, 2016).

The goal of our project was to develop and improve drowsiness mitigation strategies applicable in Himachal Pradesh. First, we gathered information from bus drivers and taxi drivers about their experiences with drowsy driving. Second, we researched drowsiness prevention strategies and evaluated how drivers used them. This research involved analyzing the effectiveness of certain detection and prevention strategies, as well as using data from our interviews to understand how acceptable these strategies might be. Finally, we developed different prototypes to assist the reduction of drowsy driving. Utilizing these three objectives, we developed long term strategies to aid in mitigating driver drowsiness in Himachal Pradesh.

Background

Himachal Pradesh has approximately 33,000 km of public roads, with rural roads accounting for 75% of the total road network (“Consultancy Services,” 2017). In one study, 55% of the main users (truck drivers, taxi drivers, and private car owners) reported feeling unsafe while commuting on Himachali roads (“Consultancy Services,” 2017). The three most common reasons cited for feeling unsafe were high traffic speeds, blind turns, and bad or narrow roads (“Consultancy Services,” 2017). Combining the 625,154 licensed drivers on Himachali roads with poor driving conditions greatly exacerbates the inherent risks of drowsy driving (Himachal Pradesh Department of Transportation, 2017).

Commercial transportation companies can require their drivers to remain awake on the road for long periods of time. Many popular trips for commercial passenger drivers include routes from Manali to Delhi, which can take up to 13 or 14 hours. Once they arrive at the desired location, they often have to turn around and immediately drive back to their start location with little to no rest in between. Long hours of driving considerably increases the risk of drowsiness and emotional or mental stress (Ghuman, n.d.). In the US, certain regulations limit the amount of legal driving time to a maximum of 11 continuous hours, based on time off-duty and whether the driver is carrying property or passengers (Federal Motor Carrier Safety Administration, 2017). Such laws are not in place for drivers in India.

Understanding the aspects of drowsy driving

Occupational pressures such as long working hours create conditions that can induce driver drowsiness. Drowsiness is classified as “Stage I” of sleep, or the transition between awake and asleep, and is the feeling of being sleepy for various reasons, which can cause a person to fall asleep at “inappropriate” times throughout the day (Sahayadhas, Sundaraj, & Murugappan, 2012). This sleep stage causes a decrease in brain activity, which is largely associated with boredom, either in general or due to monotonous driving (US National Library of Medicine, 2017). As a result of the decreased brain activity, driver performance and awareness significantly decline (Lal & Craig, 2001). Worsened driving performance can be observed as slower response time on turns, eye closure for multiple seconds on long, straight roads, weaving between lanes, and sudden accelerations if the driver has been startled after dozing (Seen, Tamrin, & Meng, 2010).

Furthermore, prolonged drowsiness is considered chronic partial sleep deprivation, which is classified as insufficient sleep for multiple consecutive nights. Sleep deprivation significantly reduces cognitive functions, including attention, memory, vigilance, and decision-making. The effects of sleep deprivation are commonly tested in psychomotor vigilance tests (PVT), which measures the participants’ response times to a timer popping up on a screen (Ahola & Polo-Kantola, 2007). In a study, participants that were restricted to five hours of sleep for a week still had reduced PVT scores even after a ten hour rest (Dinges et al., 1997). A similar sleep restriction study concluded that in common cases of chronic partial sleep deprivation, individuals functionally adapt to their depleted condition, but remain at a significantly lower performance level (Belenky et al., 2003). In a driving context, the adverse effects of sleep deprivation on the brain’s performance can cause road accidents even if the driver doesn’t fall asleep, and these effects increase in severity with prolonged sleep deprivation.

To emphasize the danger of drowsy driving, the Centers for Disease Control and Prevention compares drowsy driving to drunk driving. If a driver has been awake for eighteen hours, their

mental state is the same as driving with a blood alcohol content (BAC) of 0.05%. Additionally, being awake for twenty-four hours straight can be the equivalent of having a BAC of 0.1%. Considering that the legal BAC limit in India is 0.03%, this driving behavior is absolutely dangerous (Ministry of Law and Justice, 1988).

There are some noticeable symptoms of drowsiness that could serve as indicators to a driver. These indicators can include difficulties when focusing, eyelid heaviness, consistent yawning, and restlessness or irritability (National Sleep Foundation Drowsy Driving Prevention Week, 2018). As a person becomes more sleep deprived, the electrical activity in their brain and their heart rate slow down, which causes slower response times (Johnson et al., 2011). Using these symptoms, there are many options in determining how to identify drowsy drivers. However, it is important to note that for a mitigation strategy to be successful a drowsy driver must be made aware of their drowsiness, which entails an alerting strategy.

Daily schedules of these drivers also influence drowsiness. Circadian rhythms are the cycles in which a person’s body operates throughout the day, and influence the release of certain hormones such as melatonin, which notifies the body that it needs to sleep. (National Institute of General Medical Sciences, 2017). In India, the highest percentage of road accidents in 2015 took place between 15:00-18:00 hours and 18:00-21:00 hours, as illustrated below in Figure 7 (GIMRT & HTRW, 2015, p 25). These times take place at the end of the work day and during traditional tea time, and then again around dinner time or post-dinner time when the sun has gone down.

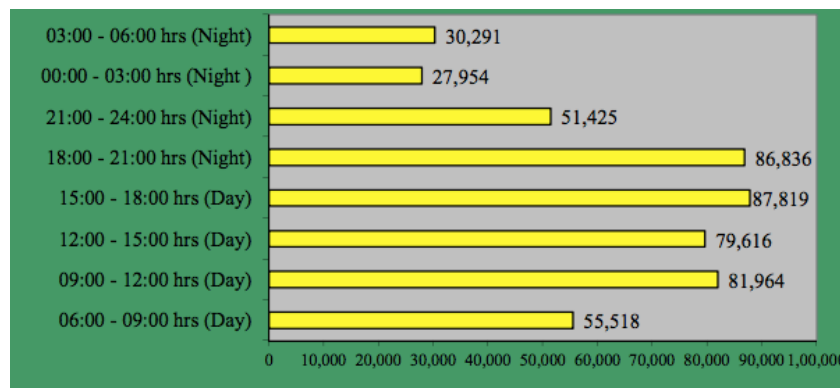


Figure 7: Distribution of accidents vs. time (GIMRT & HTRW 2015, p 25)

Current drowsiness prevention strategies

Current strategies for drowsy driving prevention in the Himachal region mostly consist of tea breaks, cautionary road signs, and playing music (Team-BHP, 2018). In the future, technology-based strategies may provide a better way of detecting drowsiness through quantitative metrics.

Simple driver strategies

Clever signs are one of the most popular ways that the Border Road Organisation has used to mitigate drowsy driving (Border Roads Organisation, 2016). Their signs have fun sayings on them intended to catch drivers’ attention, but also warn of the dangers that the roads can present (Figure 8). Alongside the use of road signs, some popular strategies on an Indian driving forum, Team-BHP, include splitting up long trips, using a co-driver, and only driving during daylight

hours. To stay alert while driving, the same forum recommends keeping fresh air circulating through the air conditioner, keeping the windows rolled up, and listening to fast-paced music (Team-BHP, 2018). Although these strategies are used and recommended by this forum's drivers, there have been no official studies to prove the effectiveness of these strategies.

Facial Recognition Applications

Facial recognition applications are on the forefront of drowsy driving detection technology. Typically, these are smartphone applications that require a front-facing camera to scan the driver's face for signs of drowsiness. For example, CarSafe uses facial orientation and blinking rates of the driver to detect drowsiness and distraction (You et al., 2013). The application recognizes prolonged blinking as an indication of "microsleep," which is defined as three to fifteen seconds of sudden, unintentional stints of sleep (Tirunahari, Zaidi, Sharma, Skurnick, & Ashtyani, 2003). Metrics such as PERCLOS (PERcent CLOSure of the eyes) have been developed to detect the onset of this phenomenon; these measurements are derived from tests involving the proportion of eye closure to eye openness during a one-minute period. The measurements allow the program to determine how long someone has been blinking and alert the driver to wake up if their eyes have been closed for a certain amount of time. The use of this metric positively correlates to improved driver performance (Vaca, 2005).



Figure 8: Example of Border Roads Organisation Sign (Bhatia, 2017).

Vibrations and alerts

Multiple studies have explored the use of vibrations or alarms to alert drivers of their drowsiness. One particular study of 25 participants was conducted using a prototype steering wheel with vibration capability and a loud buzzer. When a driver displayed signs of drowsiness, the wheel would vibrate and the buzzer would sound, alerting the driver of their drowsy behavior. In general, subjects reported that the buzzer was more effective but significantly more annoying compared to the vibrations (Tan et al., 2013). The study was based on a relatively small sample and produced mostly qualitative data, so the study is relatively incomplete if used on its own to propose a broader solution to drowsy driving. Despite the small sample, the study shows potential options for alert systems.



Figure 9: Example of blue LEDs (fotographos, N.D.)

Blue light

With the introduction of blue light, the body becomes more alert because the light suppresses the creation of melatonin and shifts circadian rhythms as much as three hours with the right amount of exposure. (Harvard Health Letter, 2012). In a study, the introduction of a constant blue light with a wavelength of 468 nm led to a decrease in the amount of times the driver crossed

the centerline while driving by around 45%, as compared to the placebo given to participants (Taillard et al., 2012). However, having too much blue light introduced into an environment can also have negative consequences on the body. Not only does blue light cut back on the amount of sleep a person could get, but it also can worsen the quality of sleep by causing the person to wake up more frequently in the night. It is recommended to remove any blue light from a person's environment one to two hours before they sleep to ensure more quality sleep (Breus, 2017).

Summary

A review of the literature led us to three key points that guided our work in India. First, we learned that drowsy driving can be comparable to the dangers of drunk driving due to the depletion of cognitive functions, and normal brain functionality cannot be restored until consistent healthy sleep is practiced. Second, strategies for drowsy driving already exist in the form of cautionary road signs and tea stops, but may not significantly prevent accidents. Third, alerting devices or stimuli can greatly improve the chances of a drowsy driver from entering microsleep phases. With this prior research, we were able to establish our approach to introducing new drowsiness prevention strategies in Himachal Pradesh with regards to our stakeholders' driving conditions.

Methodology: Developing and Improving Mitigation Strategies

Given the need for a more consistent and effective way to prevent drowsiness on Himachali roads, the goal of this project was to develop and improve drowsiness mitigation strategies applicable in Himachal Pradesh. To accomplish this goal, we completed three objectives:

1. Document and compare drivers' experiences with drowsy driving
2. Identify key aspects of existing strategies to prevent drowsy driving
3. Develop and test prototypes to mitigate drowsy driving

These objectives and our strategies to collect data are outlined in Figure 10 below.

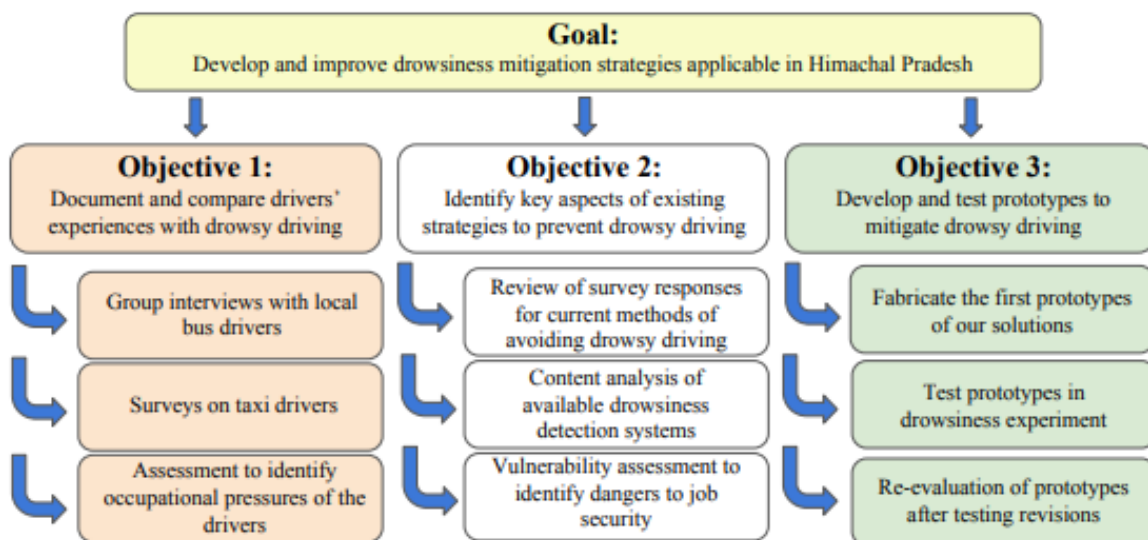


Figure 10: Methodology process

Objective 1: Document and compare drivers' experiences with drowsy driving

Based on the implications of drowsy driving on passenger safety, we determined that our main stakeholders consisted of bus drivers and taxi drivers, and we conducted a group interview with 15 local bus drivers. We asked the bus drivers 23 questions about their current drowsy driving prevention strategies, pressures and motivations, personal experiences with drowsy driving, and comfort levels with potentially intrusive aspects of prototypes. Subsequently, we created a survey of questions similar to those from the group interview for 30 taxi drivers, using a sample of convenience. From the survey responses, we conducted a baseline assessment of the driver's occupational pressures and working conditions to gauge whether the drivers believed occupational policy change was necessary.

Objective 2: Identify key aspects of existing strategies and technologies



Figure 11: Two team members performing fieldwork at the taxi stand in Mandi on March 26, 2018

From the surveys, we determined the respondents' preferences for certain anti-drowsiness strategies. We realized that multiple strategies needed to be developed to meet the most needs of the stakeholders. Using these preferences, we assessed both the drivers' drowsiness prevention strategies and previously researched technologies based on criteria such as ease of use and intrusiveness. Then, we examined available strategies, such as eyelid detection and vibration, to evaluate the applicability and cost effectiveness of potential prototypes.

Alongside the preliminary ideation of these strategies, we considered the potential risk to job security that detecting driver drowsiness might entail, such as having video stored of drivers sleeping on the job. To address potential pitfalls, we discussed drivers' preferences with respect to video caching, and brainstormed methods to store data without risking the drivers' employment standings.

Objective 3: Develop and test prototypes to mitigate drowsy driving

From an evaluation of driver preferences, manufacturability, and cost effectiveness, we gathered the necessary materials to create our anti-drowsiness solutions. We created prototypes using SolidWorks, OpenCV, various light-sensitive cameras, a raspberry Pi, and taffy recipes. Upon the completion of our first prototypes, we orchestrated a drowsiness experiment with 15 participants to test the effectiveness and ease of use of our prototypes. The experiment consisted of splitting the participants into three groups: control, blue light, and taffy. The control group took a PVT, read a monotonous text titled "Scientific American Supplement No. 841" for ten minutes, and then took a second PVT (Various, 1892). The blue light group and taffy group underwent the same procedure, but also used the prototype during the reading to keep themselves awake while reading. Immediately after testing, participants were given a feedback survey to collect their opinions on our solutions. Using the gathered feedback, our prototypes were then re-evaluated and modified to address the concerns from the testing phase.



Figure 12: Setup for testing with a control group participant on April 18, 2018

Results and Discussions

The results of our interviews with fifteen bus drivers and surveys with thirty taxi drivers indicated three key details of the experience of a fatigued driver:

1. There is significant pressure on drivers to continue on the road despite drowsiness, whether from their passengers or employers.
2. Many existing strategies to stay alert are known among drivers and can be improved even beyond their current level of effectiveness.
3. Most respondents are willing to use a technological device to help them stay awake on the road.

Objective 1: Driver's experiences with drowsy driving

We asked 30 taxi drivers working at the bus stand and taxi stand in Mandi about their experiences with drowsy driving, their strategies for avoiding driving drowsy, and their preferences on strategies we were willing to develop. Of the 30 taxi drivers, 43% claim to be pressured by their passengers to continue driving, even as they become drowsy (Figure 13), while 57% reported being asked by their passengers to pull over and rest (Figure 14).

In the group interview, we learned that bus drivers must adhere to strict schedules, as some passengers need to catch a plane or a train at the end of the drive. These bus drivers all discussed driving long hours with little to no rest, making it difficult to find time to accomplish small tasks each day, such as showering or getting sufficient sleep. Moreover, the bus drivers do not get quality rest at their bus stops because the stops are uncomfortable and noisy. Another common response among these bus drivers was that sometimes they had to drive faster than they preferred to reach their scheduled destination on time to satisfy their passengers.

Do passengers pressure you to drive while tired?



Figure 13: Passenger pressures

Do passengers ask you to pull over because they can tell you are tired?

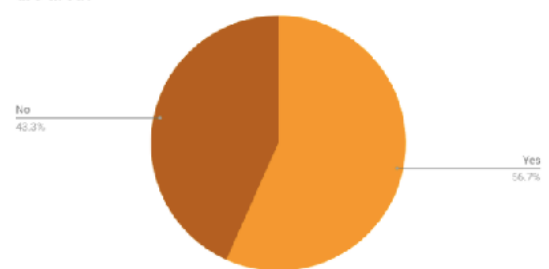


Figure 14: Passenger rest

Objective 2: Strategies drivers currently use to combat drowsiness

The most popular current strategies among respondents were drinking tea, stopping to rest, and washing their face (Figure 15). Using their answers on strategies that were effective and comfortable, we identified blue lights and alarms as viable prototype options.

Moreover, considering the possible need for a technological strategy, our research indicated the advantages of a camera monitoring system. Ninety-three percent of drivers responded positively to having an unobtrusive camera monitoring them for drowsiness detection. Although

previous studies such as CarSafe had used cell phone cameras, our interviews with bus drivers revealed that the use of cell phones while driving is prohibited (You et al., 2013). Thus, a separate device would be necessary.

We asked drivers if they would rather have video data from the camera saved or deleted due to potential risks to job security. Notably, 67% of drivers responded that they preferred the video be saved so that it can be recalled in the event of an accident or altercation where the driver was not at fault. Therefore, the drivers typically considered saving the video data as a benefit to job security as opposed to a detriment.

Effective Solutions & Current Methods to Mitigate Drowsiness

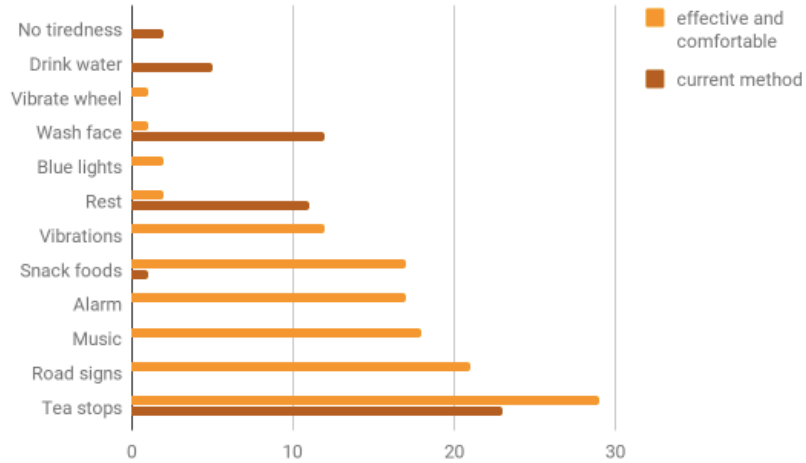


Figure 15: Effective and comfortable solutions

Objective 3: Prototypes to mitigate drowsy driving

We decided to consider both technological and non-technological approaches in our prototype design. The first technological strategies we explored involved a “drowsiness detection” component to recognize driver fatigue, and an “action” component to alert the driver. We chose this two stage strategy since all existing technological strategies follow this model. For the detection aspect, we focused on using an OpenCV camera for facial detection. Using a raspberry Pi, which is a small computer common for prototyping, and its compatible camera, we wrote code in Python that utilized OpenCV to recognize eye closure for the facial recognition software. If the driver’s eyes were closed for 48 frames, or the equivalent of one second, the computer triggers the aforementioned “action” component of the device. We knew that facial recognition would be a useful strategy to work with from all our survey data and literature review.

The action component of our technological device was designed to alert the driver when drowsiness was detected. Considering the potential for distraction, we used only an alarm to alert the driver of their drowsiness. Respondents’ also positively reacted to these ideas, with 56% agreeing to alarms, which is further supported by previous studies (Tan et al., 2013).

Alongside the “detection-action” strategies considered, we also developed three strategies designed to make the drowsiness mitigation less intrusive. First, we developed a candy for drivers to eat whenever they felt drowsy, since 56% of drivers indicated they eat when drowsy. To satisfy the respondents’ tastes, we developed two taffies:



Figure 16: A few of the spicy taffies made on April 4, 2018

one containing red chili for spiciness, as 33% of respondents preferred spicy snacks, and the other containing black tea, orange, and soya flakes for sweetness, as 43% of respondents preferred sweet snacks. The latter flavor also contained caffeine from the tea, protein from the soya, and most B vitamins and other macronutrients needed in order to help keep a person awake for an extended period of time (Palmer, 2018).

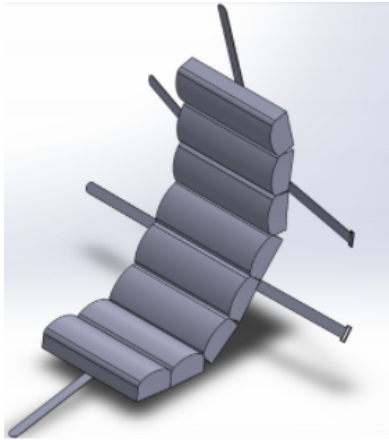


Figure 17: CAD design of our seat cover prototype

A second strategy we conceived was a cushioned seat cover that could house any of the technological prototypes that we have designed, such as the blue light system or the raspberry pi. We created the seat cover in response to the common complaint during our bus driver interviews and taxi driver surveys for a more comfortable driver’s seat. The drivers typically rest in their seats when off duty, and 93% of respondents mentioned that they were comfortable with a seat cover to hold additional devices. Furthermore, since many bus drivers resort to sleeping in the aisles of their buses, we designed the seat cover to function as a portable sleeping mat. The mat gives the drivers the opportunity to have more restful breaks, reducing their overall fatigue and their chances of driving drowsy.

Third, we prototyped a small set of blue LEDs. We prototyped the blue light system, despite only garnering two positive responses out of thirty total, because the LEDs were relatively simple to implement and required that the drivers test it for themselves to understand its potential effectiveness. This was also due to the recent research done in the field of blue lights and its association with driving (Taillard et al., 2012). The lights were designed to diffuse enough blue light to reach the driver’s eyes to reduce the production of melatonin, but not to mimic something like headlights that could pull the driver’s attention away from the road.

After fabricating our prototypes, we completed fifteen tests on a control group, taffy group, and blue light group of five participants each. We found that both the taffy and the blue light increased the participants’ heart rate more than the control group, which had a negative trend line (Figure 18). The taffy and the blue light group also had significant improvements from their first to second PVTs. On average, the taffy group had a decrease of 22 milliseconds, the blue light had a decrease of 3.8 milliseconds, and the control had a gain of 17 milliseconds.

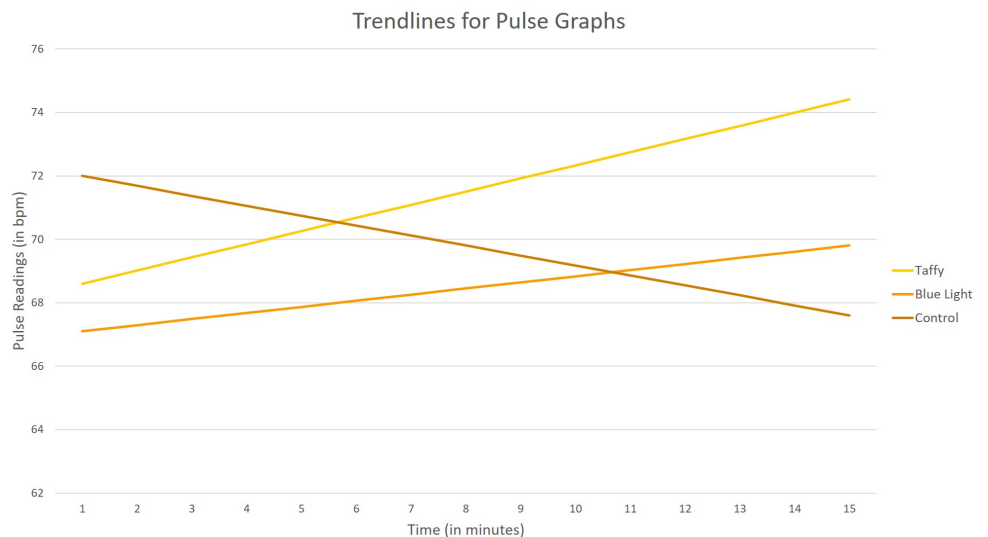


Figure 18: Pulse vs. method of testing

Discussion

Two of the most challenging aspects of this project were the time and funding constraints. The constraints pushed us to come up with multiple strategies to test which ones worked best, rather than creating only one prototype that may be unwelcome or ineffective.

Table 1: Prototype pros and cons

Prototype	Pros	Cons	Use
Eye detection	<ul style="list-style-type: none"> - Can detect when a person's eyes are closed too long - Room for improvement to detect other facial features as well - Most reliable mode of detection 	<ul style="list-style-type: none"> - May have to be re-calibrated for every driver in order to account for eye shape - Requires a power supply in the car - Can't use standard cameras due to drivers being drowsy at night 	<ul style="list-style-type: none"> - Detection
Seat Cover	<ul style="list-style-type: none"> - Can be used as a sleeping mat - Houses other devices - Portable and washable - Allows for better rest between shifts - Prototype materials and manufacturing locally sourced in Mandi 	<ul style="list-style-type: none"> - Requires a skilled tailor to manufacture 	<ul style="list-style-type: none"> - Means of holding alert devices - Comfort for drivers
Edible solution (50 candies)	<ul style="list-style-type: none"> - Gives a quick burst of energy - Enjoyable - Low cost 	<ul style="list-style-type: none"> - Limited effectiveness time 	<ul style="list-style-type: none"> - Continuous drowsiness protection
Blue lights	<ul style="list-style-type: none"> - Can prevent the amount of melatonin produced in the body to keep drivers awake 	<ul style="list-style-type: none"> - Most drivers expressed disapproval - May be distracting - Could lead to less quality sleep - Cannot be used within an hour or two before the driver expects to sleep 	<ul style="list-style-type: none"> - Continuous drowsiness protection

While our focus is mainly keeping drivers awake at the wheel, the difference between awake and alert is extremely important. Even if our strategies are effective, the brain's functioning will still be significantly slower and less dependable than if the driver has gotten proper rest; extended wakefulness does not eliminate the potential for driver error. As mentioned previously, motor skills and reaction time invariably suffer as the brain fatigues, which is something that our strategies cannot completely remedy (Lal and Craig, 2001). One major concern with our strategies is that they could inadvertently encourage companies to even further overwork drivers. Since our strategies can be wrongly perceived as "solutions" for fatigue, companies may impose

more frequent night shifts or longer hours for their drivers. To properly implement our recommended strategies, they must only be used as intermediate strategies to ensure the safety of drivers and their passengers in the event that a driver becomes drowsy during a trip. Therefore, a maximum hours-of-service policy regulation for drivers is imperative to coincide with the implementation of our recommended strategies, since consistent, healthy durations of sleep is the only way to physiologically restore the brain's functional abilities.

Moreover, some limitations we encountered during our project were due to our taxi driver sampling in Mandi, because many of these drivers do not make as many long distance trips as drivers stationed in larger cities such as Delhi or Manali. Additionally, the taxi surveys were designed to gather information quickly. Because of the time constraints, some of our ideas may not have been properly explained to the drivers, such as the blue light system. Many drivers were against the idea, but we did not have time to properly explain the benefits supported by research behind this concept.

Project Outcomes

We developed four prototypes that we recommend drivers to use to stay awake on the road: a camera-based drowsiness detection system, a caffeinated snack, ambient blue lighting, and a portable seat cover. We have identified areas for improvement and future work for these prototypes, as well as two additional recommendations to mitigate drowsy driving in Himachal Pradesh.

Recommendations for new strategies

First, our camera-dependent drowsiness detection system consists of a raspberry pi computer, a night vision camera, a power supply, and software that analyzes facial features to detect drowsiness. It detects the closing of eyes and relays an alert that a driver may be drowsy. Currently, our prototype offers an eyelid closure detection method that is not calibrated to individual facial structures and uses a night vision camera. In the future, this prototype could be further developed to include yawn detection, individual face calibration, and variable camera lighting to provide clearer images during all times of the day. Nonetheless, this strategy is recommended since it provides an unobtrusive way to detect driver drowsiness.



Figure 19: A team member being warned of drowsiness using our eye detection system on April 3, 2018

Second, the taffies were well-received by those who tried them. For commercial output, the taffies should be made on a much larger scale than our small-scale prototyping system. Bright packaging also needs to be developed to increase the drivers' willingness to buy these candies while at tea stops. This recommendation is based upon the taffy's ability to be used continuously as drivers can eat the taffies whenever they start feeling tired.



Figure 20: A team member pulling taffy on April 11, 2018

Third, the blue light solution suffered mainly in terms of willingness for the drivers to use it. The drivers were not aware of the scientific effects of blue lights on humans, which is the chemical delay of sleep. In addition, we could have more clearly conveyed that we would be using ambient light rather than bright, distracting light. There should also be testing done to see how the blue light affects the drivers' long term abilities in

order to determine the maximum amount of time that the blue light should shine before it becomes too detrimental to the drivers. We still recommend this strategy due to the research that has been done that verifies how successful blue light is in keeping people awake.

Fourth, our seat cover provides a more comfortable ride for the drivers, causing less physical strain on their bodies. In addition, it can be laid flat to double as a sleeping mat to give drivers more restful breaks. Finally, this cushion was designed to have a pocket behind the headrest

which can house our other devices, such as our prototype computer vision drowsiness detection system. Our recommendation of this prototype stems from its portability, versatility, and comfort.

Moreover, after the results of the prototype testing, we recommend that there be more research done on implementing a pulse sensor as a drowsiness detection method. Since there was a positive correlation in our results between how awake the participant felt and how high their pulse was, a further developed pulse sensor could be used alongside or in lieu of our facial recognition software as a “detection” strategy.

To be able to properly improve our products, we would need more testing. For further development, we recommend teaming up with a driving company to have the device placed in 50 taxis to collect data on the amount of microsleep incurred by the driver, as per recommendation from our sponsor. This data would then be stored and sent back to the testing coordinator to determine the device’s success rate and potential improvements for effective application in a commercial setting. To avoid threatening the participating drivers’ job security, the collected data should remain anonymous.

Recommendations for policy making

Our final set of recommendations pertains to policies that could reduce drowsy driving and improve driver safety in Himachal Pradesh. As previously mentioned, the United States has laws in place that protect drivers from being forced into driving unreasonably long hours.

Understanding the inherent cultural differences between the US and India, interviews with driving companies and government authorities would be necessary to determine the viability of a major policy change. If possible, we recommend legislation be implemented by the Government of Himachal Pradesh Transport Department that will enforce hours-of-service regulations upon companies and their drivers. We believe prioritizing sufficient sleep for drivers will be the most effective way to improve safety on the roads.

The second policy recommendation is to improve driver accommodations at their bus stops. Because of the unsatisfactory conditions of these stops, we recommend companies make improvements to better accommodate their drivers. The companies should implement policy that includes higher quality standards for these stops, such as having separate rooms with doors that can close and quiet hours at certain times of the day. These areas are the best and sometimes the only option for long distance bus drivers to sleep and achieve proper rest; improving these driver stops in turn improves the drivers’ awareness on their next trip.

Conclusion

Interviews conducted with bus drivers and taxi drivers indicated some of the many reasons drivers feel tired while traveling, especially over long distances. Our survey results indicated that commercial taxi drivers were not completely satisfied with their current drowsiness prevention strategies, and that they were willing to adopt new strategies presented to them. Given that commercial drivers struggle with strict occupational rules, we offered them four low-risk strategies: a removable seat cover with alarm integration, ambient blue light, two flavors of taffy, and a camera dependent drowsiness detection system. With future development, these strategies can become common, reliable methods to improve driver safety.

The issue of drowsy driving is multifaceted and relatively complex, so no single strategy will permanently address the problem for every driver on the road. However, we believe that our set of recommendations and prototypes sufficiently addresses the main aspects of the issue: the underlying cause of drowsiness, methods of drowsiness detection, and alert strategies. Even beyond the current functionality of our prototypes, our recommendations could be further developed for use in Himachal Pradesh. For instance, the blue light strategy can be refined and adjusted to address driver preferences, and the taffy production can be scaled up. With a bigger budget and more feedback on ergonomics, the seat can be designed to a higher quality standard to fit the drivers' need for better rest. Finally, the face detection software can be improved to be more easily calibrated to different drivers, and integrated to notice facial features such as yawning and head position. With all potential improvements in mind, our four prototypes and recommendations for policy change can serve as a strong foundation to future work and improvements in the field of driver safety.

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Appendices

Appendix A - Bus Driver Group Interview Guide (English)

Demographic information

- What is your educational level?
- Do you have a specialization?
- Age?
- Gender?

Introduction

1. Do you drive to earn a living?
2. How long have you been driving a four-wheeled vehicle?
3. To what extent do you believe drowsy driving is a common issue?
4. Do you think that feeling drowsy while sleeping is dangerous to you and your fellow passengers?
5. What is, in your opinion, the best way to avoid dangerous drowsy driving behavior?

Current Drowsy Driving Prevention Methods

5. What do you do when feeling drowsy?
6. Do you know of technologies that avoid drowsiness?
7. How effective would you say tea stops and road signs are in mitigating drowsy driving?

Pressures and Motivations

8. What motivates you to drive?
9. Do you get sufficient sleep before driving?
10. How often do you feel pressured to continue to drive while being tired?

Personal Experience with drowsy driving

11. How long do you have to drive before you start feeling drowsy?
12. What are the maximum number of hours you have ever driven at a stretch?
13. When you start feeling drowsy, what do you notice first? (such as nodding off, etc)
Please explain.
14. If you notice yourself feeling sleepy while driving, how likely are you to stop driving and rest?
15. What time of day do you tend to feel most drowsy while driving?
16. What types of road conditions do you tend to get drowsiest on, or is there a specific road? Please explain.
17. Can you tell us about a time you or someone you know drove while drowsy?

Prototype information

18. Do you have a smartphone?

19. How comfortable are you with an unobtrusive camera monitoring your face while you are driving?
20. Would you be willing to use a device separate from your cell phone to mount in your car to help you stay alert while driving?
21. Would you feel comfortable wearing a bracelet device if it helped you stay alert while driving?
22. Which of these do you think is effective as well as comfortable? (Music/Fragrance/Vibrating Armband/Alarm)
23. How much would you be willing to spend in rupees on a technology, if at all, which allows you to monitor your drowsiness?

Appendix B - Bus Driver Group Interview Guide (Hindi)

Introduction

1. Aap kab se gaadi/bus/truck chala rhe hai?
2. Aapke hisaab se susti me gaadi chalaana kitni gehri samasya hai?
2. Kya aapko kabhi gaadi chalate waqt susti ya thakaawat mehsoos hui hai?
3. Aapke hisaab se sabse accha tareeka kya hoga is samasya se bachne kaa?

Current Drowsy Driving Prevention Methods

4. Jab bhi aapko susti ya thakaawat aati hai gaadi chalate waqt, to aap kya karte ho?
5. Aapko koi aisi takneek pata hai jisse ye samasya hal ki jaa sakti hai?
6. Aapke hisaab se kahi ruk ke chai peena ya sadak pe di gyi chetawni kitni asardaar hoti hai?

Pressures and Motivations

8. Kya cheez aapko gaadi chalane ke liye prerit karti hai?
9. Gaadi chalane se pehle kya aap paryapt neend lete hai?
10. Aisa kitni baar hota hai ki aap thake hue hai aur fir bhi aapko gaadi chalani padh rhi hai?

Personal Experience with drowsy driving

11. Kitni der tak lagataar gaadi chalane ke baad aapko thakaan ya susti mehsoos hone lagti hai?
12. Adhik se adhik aapne lagataar kitne ghante gaadi chalayi hai?
13. Jab thakaan hoti hai to sabse pehle aapko kya nazar aata hai, jaise aankhe band hona ya aur kuchh?
14. Agar aapko gaadi chalate waqt thakaawat hoti hai, to kya sambhawna hai ki aap ruk ke aaram karenge?
15. Din ka konsa samay hai aisa jisme sabse zyada susti ya thakaawat hoti hai gaadi chalane me?
16. Kis tarah ki sadak pe aapko sabse zyada susti ya thakaawat hoti hai, ya fir kya koi khaas sadak hai aisi? Kripya samjhaiye.
17. Kabhi aisa hua hai ki aapko ya aap ke kisi jaankaar ko gaadi chalate waqt thakaan mehsoos hui ho?

Prototype information

18. Aap ke paas smartphone hai?
19. Agar aapki gaadi me ek chhupa hua camera hai jo ki aapke upar nazar banaye rakhe hai, to kya aapko ajeeb lagega?
20. Agar koi aisa yantra ho jo aapki gaadi pe lag sake aur aapko gaadi chalate waqt satark rehne me madad kare, to kya aap wo istemaal krna chahenge?
21. Kalaai pe bandhe jaane wala yantra jo aapko gaadi chalate waqt satark rakhe, kya aapko ye aaramdayak lagega?
22. Aapke hisaab se inme se kya sabse asardaar aur aaramdayak rahega?

- Sangeet/ Gaane (achanak se gaana badalna)
- Sugandh (ajeeb si sugandh)
- Kalaai ya baazu pe baandhne wala yantra jo kampan se jagaaye
- Koi awaaz se jagaane wala yantra

23. Agar aisi koi takneek ho jisse ki aap gaadi chalte waqt apni susti par kaaboo rakh paaye, to aap uske liye kitne paise kharch karne ko taiyaar hai?

Appendix C - Taxi Driver Survey Guide (English)

Demographic Information

1. Gender?
2. Name?
3. Age?
4. What is your educational level?
5. Vehicle model
6. Affiliated or unaffiliated with a taxi company?

Introduction

7. How long have you been driving a four-wheeled vehicle?
8. On average, how many trips do you have per week for the duration of:
 - 2 to 4 hours
 - 4 to 6 hours
 - More than 6 hours?
9. How many night trips per week do you have?

Current Drowsy Driving Prevention Methods

10. What do you do when feeling drowsy?
11. What would you be willing to pay for a technology that allows you to stay alert even when feeling sleepy?
12. Which of these do you think is effective in alerting you about your drowsiness as well as keeping awake? (Music/Vibrating device to alert the driver/Alarm/Light/food/road signs/tea stops/cafeinated drinks/Something other than those specified.)

Pressures and Motivations

13. What percentage of your earnings do you earn on night shifts?
14. On average, how many days per week are you able to sleep for 7 to 9 hours?
15. In a week, how often do you feel pressured to continue to drive while being tired?
16. Do your passengers pressure you to drive when you are sleepy?

Personal Experience with drowsy driving

17. Which of the following signs do you experience while driving for long periods of time:
 - Falling asleep
 - Yawning excessively
 - Lack of energy
 - Heavy eyelids
 - Incoherent thoughts
 - Inability to focus
 - Some other (please mention _____)
18. If you notice yourself feeling sleepy while driving, do you stop driving and rest?

19. Do you ask passengers for their permission to take rest?
20. Do you ever have passengers tell you to pull over because they can tell you are tired?
21. What time of day do you tend to feel most drowsy while driving?

Prototype information

22. Are you comfortable with an unobtrusive camera monitoring your face that warns of your drowsy state while you are driving?
23. Would you want the video that monitored your face be saved or deleted for future analyses?
24. Would you be willing to use a device to mount in your car to help you stay alert while driving?
25. Would you be willing to use a detachable seat cover to help you stay alert?
26. Would you use a bracelet device if it helped you stay alert while driving?
27. Do you prefer sweet, salty, or spicy snacks?
28. Would you rather have a crunchy, soft, or chewy snack?
29. Do you want your passengers to be notified about your drowsy behavior?

Appendix D - Taxi Driver Survey Guide (Hindi)

Demographic Information

1. Gender?
2. Aapka naam kya hai?
3. Aapki umar kitni hai?
4. Aapne kaha tak padhai ki hai?
5. Aap konsi gaadi chalte hai? Model?
6. Kya aap kisi company ke liye gaadi chalte hai ya aapka apna khud ka kaam hai ye?

Introduction

7. Aap kab se gaadi chala rhe hai?
8. Do se chaar ghante ki hafte me kitni trips kar lete hai aap?
9. Chaar se chhe ghante ki?
10. Aur chhe ghante se zyada ki?
11. Raat ki kitni trips ho jaati hai ek hafte me?

Current Drowsy Driving Prevention Methods

12. Jap aapko gaadi chalte waqt thakaawat ya susti aati hai, to aap kya karte ho?
13. Aapke hisaab se inme se kon konsi takneek aapko gaadi chalte waqt satark rakhne aur neend se door rakhne me asardaar hogi:
 1. Gaane
 2. Chai ya coffee peena
 3. Kucch khaana
 4. Vibrate (kampan) karne wala device
 5. Aawaaz karne wala device jaise koi alarm
 6. Koi blue (neeli) light aapke upar
 7. Sadak pe lage sanket

Pressures and Motivations

14. Hafte me kitne din aapko saat se nau ghante ki neend mil jaati hai?
15. Jab aapko neend ya thakaawat hoti hai, to kya aapke passengers (sawaari) gaadi chalaate rehne ke liye (aapke upar dabaav daalte) /(zor dete) hai?

Personal Experience with drowsy driving

16. Inme se kya-kya nazar aata hai jab aap bahot der tak gaadi chalte hai:
 1. Neend aana
 2. Ubaasi lena
 3. Himmat khatam hona
 4. Aankhen band hona
 5. Idhar udhar ke vichaar aana
 6. Dhyaan na laga paana

7. Koi aur ho to kripya bataye _____

17. Agar aapko lagta hai ki aap thak rhe hai ya aapko neend aa rhi hai, to kya aap gaadi rok ke aaram karte hai?
18. Kya aap apne passengers (sawari) se unki ijazat maangte hai gaadi rok ke aaram krne ke liye?
19. Kya kabhi kisi passenger (sawari) ne aapko bola hai gaadi rok ke aaram krne ke liye?
20. Din ke kis samay aapko sabse zyada neend ya thakaawat/susti mehsoos hoti hai?

Prototype information

21. Kya aap koi aisa yantra istemaal (use) karna chahenge jo ki aapki gaadi me lag sake aur aapko gaadi chalate waqt satark rehne me madad kare?
22. Ek chhota sa camera jo aapko har samay dekh rha ho aur aapko satark krde japki se pehle, usse aapko koi jhijhak (dikkat) hogi?
23. Us camera se jo video banegi, wo aap saath saath delete karwana chahenge ya kuchh din ke liye rakhwana chahenge?
24. Aisa yantra ek seat cover pe lagaya jaaye, jo ki nikaal bhi sakte hai, to kya aap ye istemaal karna chahenge?
25. Kya aap ek ghadi jaisa yantra istemaal karna chahenge jo ki aapko gaadi chalate waqt satark rehne me madad kare?
26. Gaadi chalate waqt satark rehne ke liye aap kaisi cheez khaana pasand karenge
 1. Meethi
 2. Namkeen
 3. Teekhi?
27. Gaadi chalate waqt satark rehne ke liye aap kaisi cheez khaana pasand karenge
 1. Kurkuri
 2. Soft
 3. Chewing gum jaisi
28. Kya aap chahenge ki aapke passengers (sawari) ko pata lage jab aap thak rhe hai ya aapko neend aa rhi hai?
29. Koi aisi takneek jo aapko gaadi chalate waqt sone pe utha de, uske liye aap kitne paise kharch karne ko taiyaar ho?

Appendix E - Map of taxi survey locations in Mandi



Appendix F - Experiment design

We will need 3 test groups of 5-10 people each (at least 90% male):

- control group
- blue light test group
- taffy test group

Before each participant begins the testing, they first need to answer a screening question:

“How long have you been awake for?”

Acceptable participants will have been awake for at least 15 hours, and ideally 18 or more.

Make note of caffeine consumption for the day.

Fill out the waiver that states they understand what is going on in the experiment.

This test will take approximately 20 minutes total.

The participant will be asked to take a psychomotor vigilance test (PVT) before and after reading a passage for 10 minutes.

Before the 10 minute timer is started, the participant will take a PVT test (linked at the bottom).

The participant will then be subjected to the prototype for 10 minutes:

- For the blue light, the ambient light will shine for the entire 10 minutes
- For the taffy, they will eat it every time they feel tired. If for some reason they don't feel tired, they need to eat a taffy every 3 minutes.
- For the control, they will just be asked to read for the 10 minutes

During the 10 minutes, the participant will be reading relatively dry text (linked at the bottom) to try to induce drowsiness.

At the end of the 10 minutes, the participant will retake the PVT on the laptop and compare the results.

Once they have finished the second PVT, they will be asked to fill out a quick survey.

Throughout the process, heart rate measurements will be taken.

Reading: <http://www.gutenberg.org/files/15193/15193-h/15193-h.htm>

PVT test: <http://www.sleepdisordersflorida.com/pvt1.html>

Appendix G - Post Experiment Survey

Thank you for volunteering your time in order to help us gather data on drowsy driving and external stimulants. By completing this survey, you will help us collect quality information to use in our development process.

Any answers that you provide will not have your personal information, so you can not be linked to your answers.

Volunteer #: _____

How focused were you while using reading? (circle)						
1 Very unfocused	2	3	4 Average	5	6	7 Very focused

How many times/how often did you sense yourself falling asleep? (circle)						
1 Never	2	3	4 Average	5	6	7 The whole time

How effective was the external stimulant you used? (circle)						
1 Very ineffective	2	3	4 Average	5	6	7 Very effective

How did you think your attentiveness was compared to your fully awake state? (circle)						
1 Much worse	2	3	4 Does not differ	5	6	7 Much better

How easy to use was the external stimulant? (circle)						
1 not very easy	2	3	4 average	5	6	7 very easy

Would the external stimulant make you feel any safer while driving? (circle)

1 not very safe	2	3	4 average	5	6	7 very safe
-----------------------	---	---	--------------	---	---	----------------

How strong were any urges to remove the external stimulant, if it were possible? (circle)

1 not very strong	2	3	4 average	5	6	7 very strong
-------------------------	---	---	--------------	---	---	------------------

How likely would you be to use your stimulant again, if you were to re-do the exercise? (circle)

1 not very likely	2	3	4 indifferent	5	6	7 very likely
-------------------------	---	---	------------------	---	---	------------------

How much mental effort did you put into staying awake and alert? (circle)

1 not very much effort	2	3	4 average	5	6	7 a lot of effort
------------------------------	---	---	--------------	---	---	-------------------------

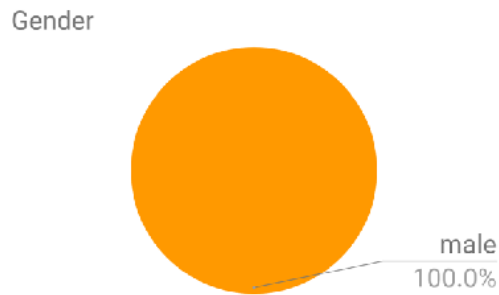
How much effort did it require to read? (circle)

1 not very much effort	2	3	4 average	5	6	7 a lot of effort
------------------------------	---	---	--------------	---	---	-------------------------

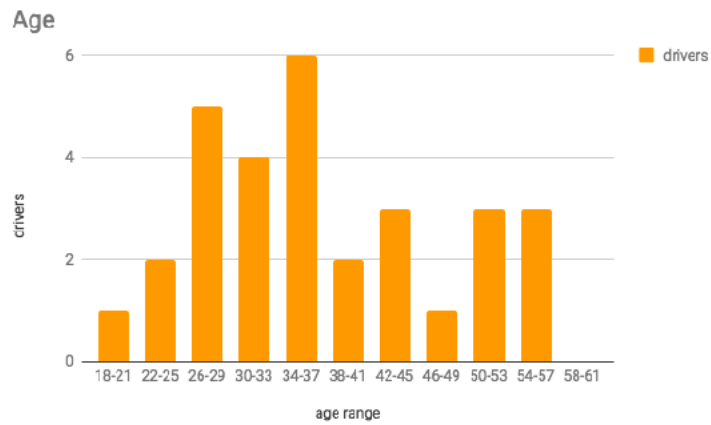
Appendix H - Graphs of taxi driver responses' to survey questions

*Please refer to Appendix C for numbering nomenclature

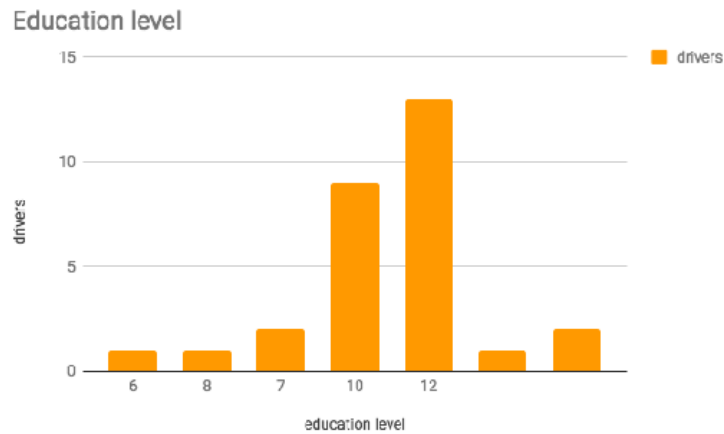
1. Gender?



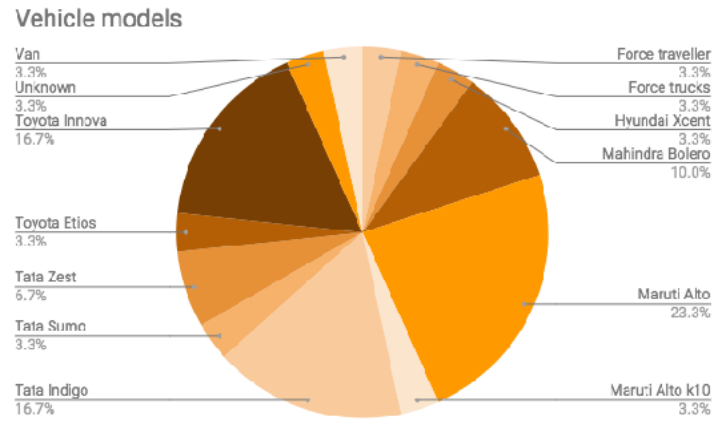
3. Age?



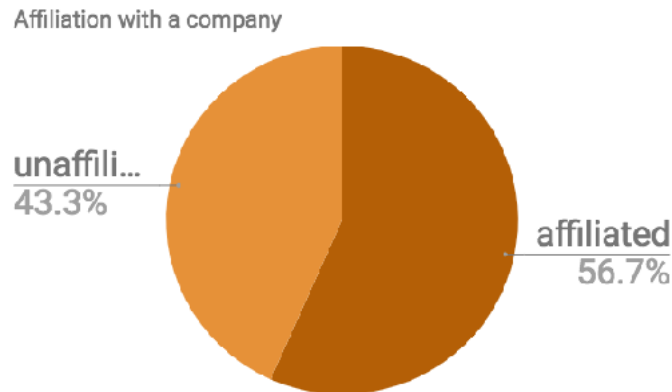
4. What is your educational level?



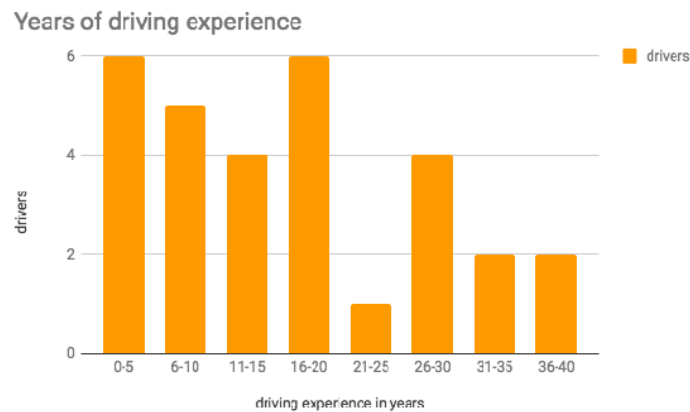
5. Vehicle model



6. Affiliated or unaffiliated with a taxi company?

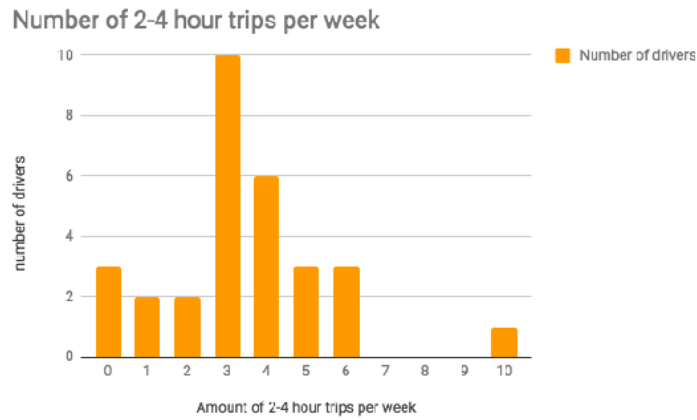


7. How long have you been driving a four-wheeled vehicle?

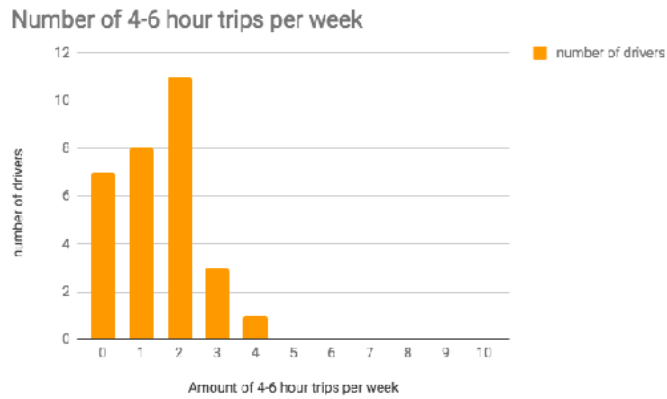


8. On average, how many trips do you have per week for the duration of:

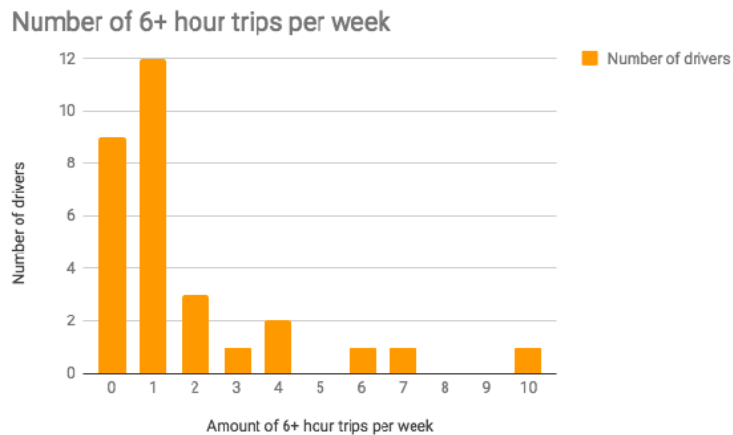
1. 2 to 4 hours



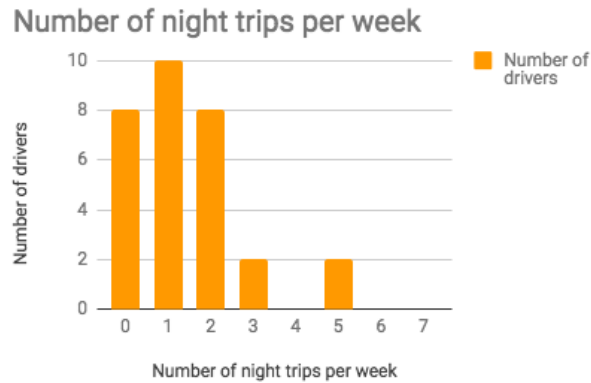
2. 4 to 6 hours



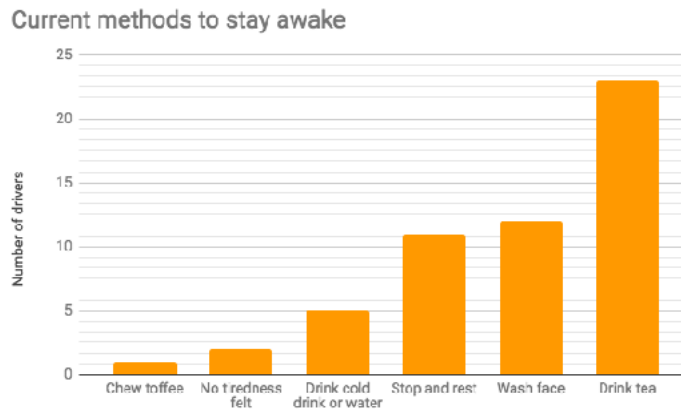
3. More than 6 hours?



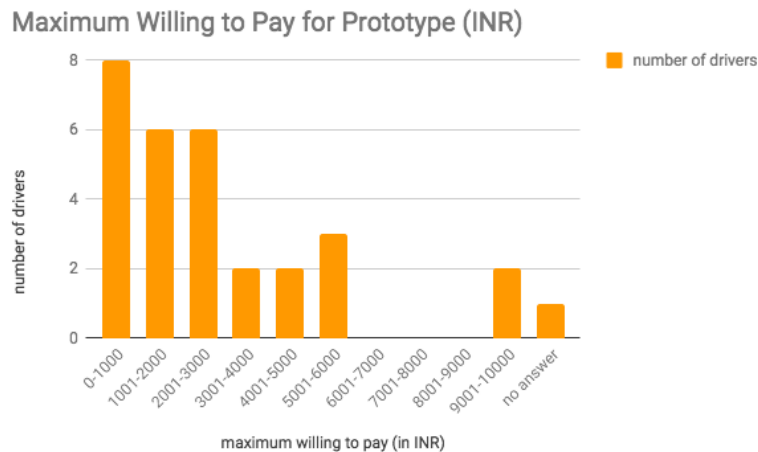
9. How many night trips per week do you have?



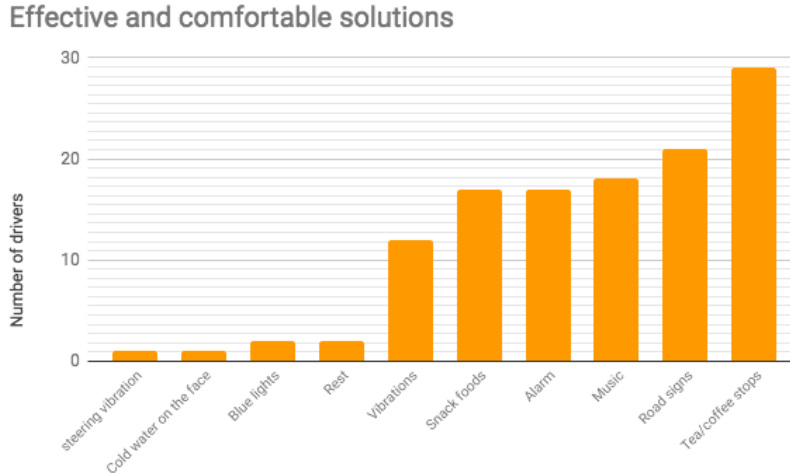
10. What do you do when feeling drowsy?



11. What would you be willing to pay for a technology that allows you to stay alert even when feeling sleepy?



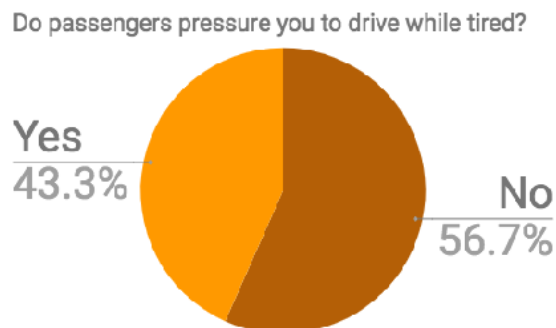
12. Which of these do you think is effective in alerting you about your drowsiness as well as keeping awake? (Music/Vibrating device to alert the driver/Alarm/Light/food/road signs/tea stops/caffeinated drinks/Something other than those specified.)



13. On average, how many days per week are you able to sleep for 7 to 9 hours?



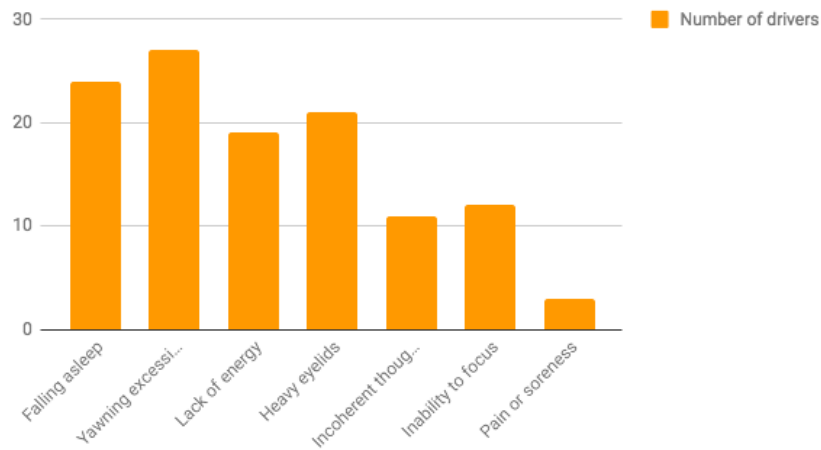
14. Do your passengers pressure you to drive when you are sleepy?



15. Which of the following signs do you experience while driving for long periods of time:

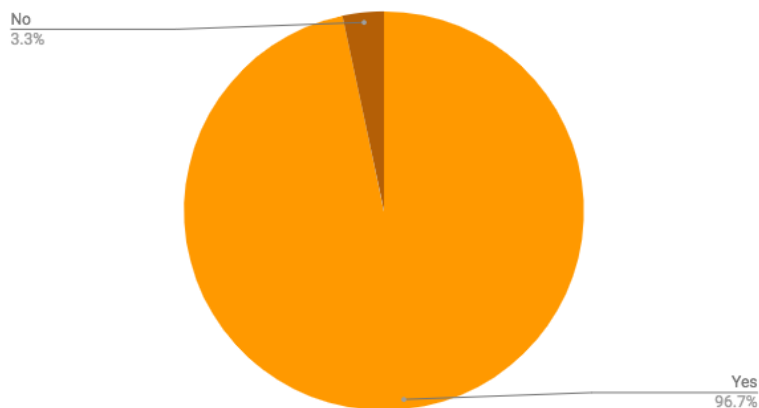
- Falling asleep
- Yawning excessively
- Lack of energy
- Heavy eyelids
- Incoherent thoughts
- Inability to focus
- Some other (please mention _____)

Drowsiness symptoms experienced

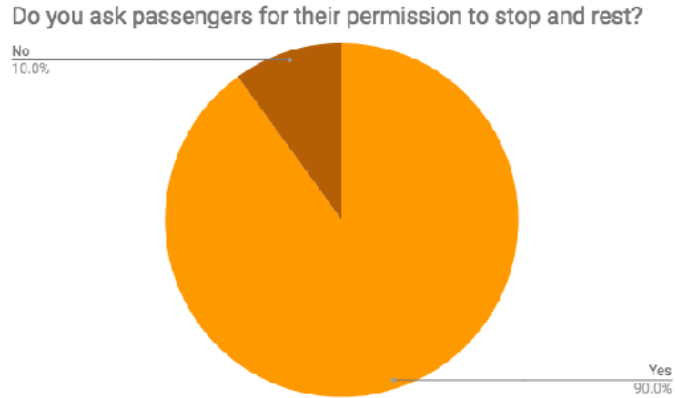


16. If you notice yourself feeling sleepy while driving, do you stop driving and rest?

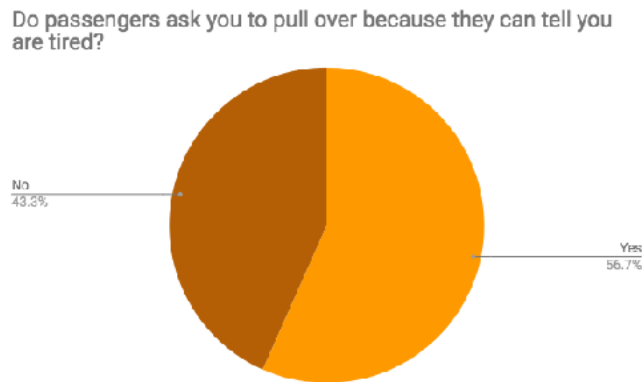
Do you stop and rest when you feel tired?



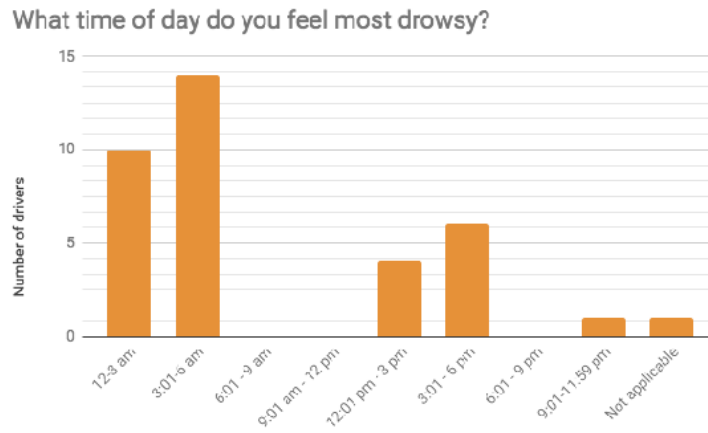
17. Do you ask passengers for their permission to take rest?



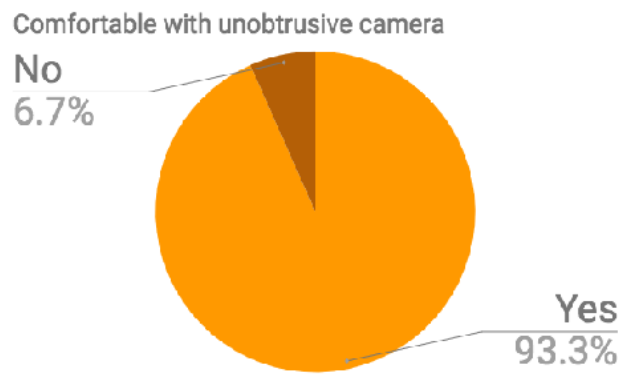
18. Do you ever have passengers tell you to pull over because they can tell you are tired?



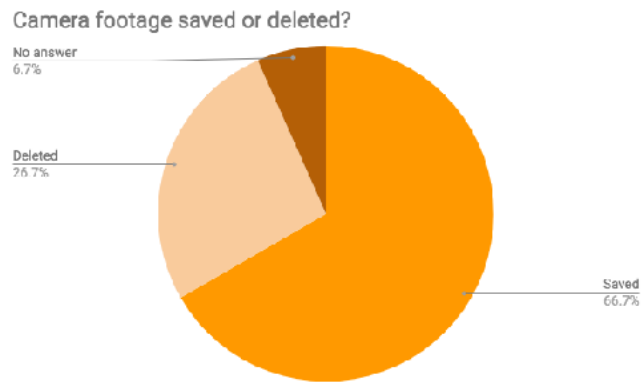
19. What time of day do you tend to feel most drowsy while driving?



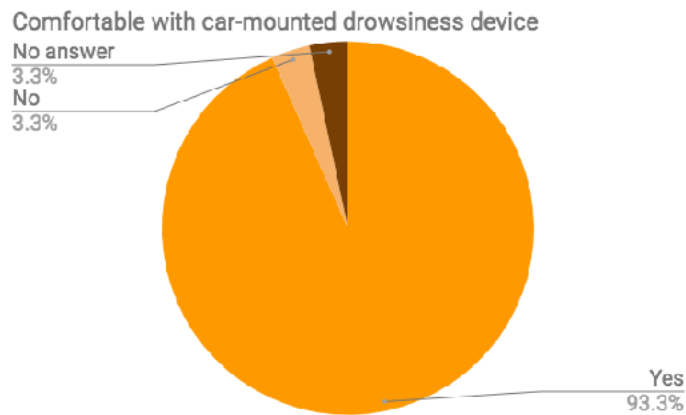
20. Are you comfortable with an unobtrusive camera monitoring your face that warns of your drowsy state while you are driving?



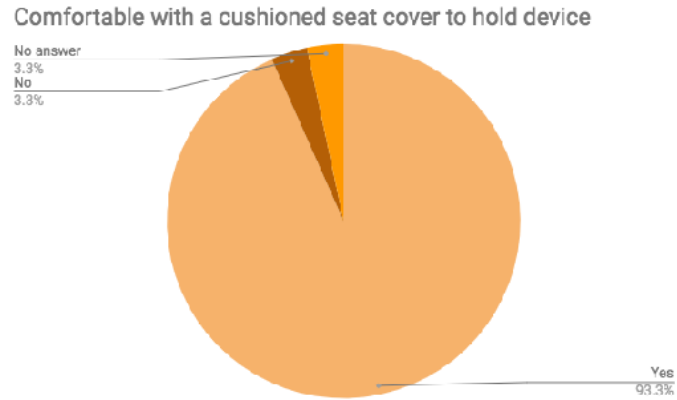
21. Would you want the video that monitored your face be saved or deleted for future analyses?



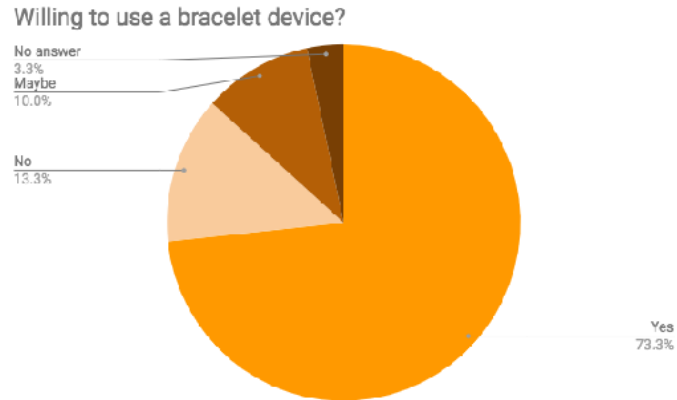
22. Would you be willing to use a device to mount in your car to help you stay alert while driving?



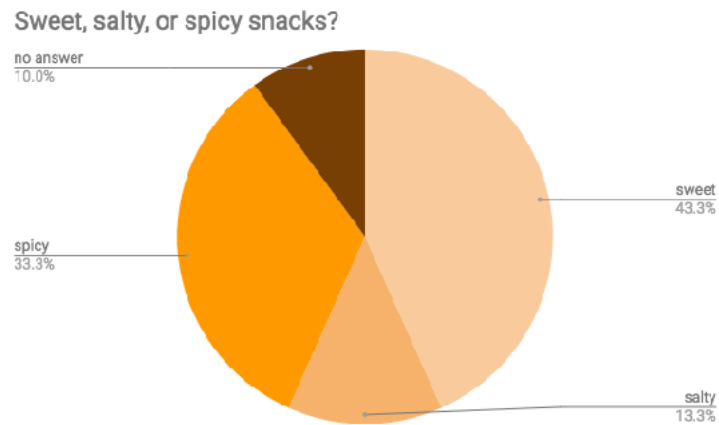
23. Would you be willing to use a detachable seat cover to help you stay alert?



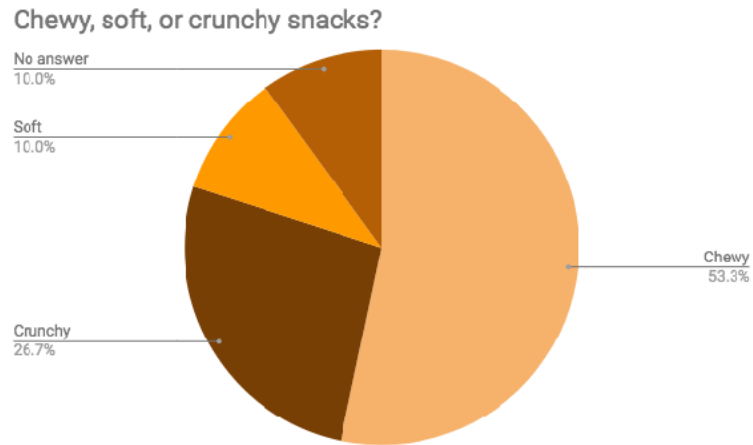
24. Would you use a bracelet device if it helped you stay alert while driving?



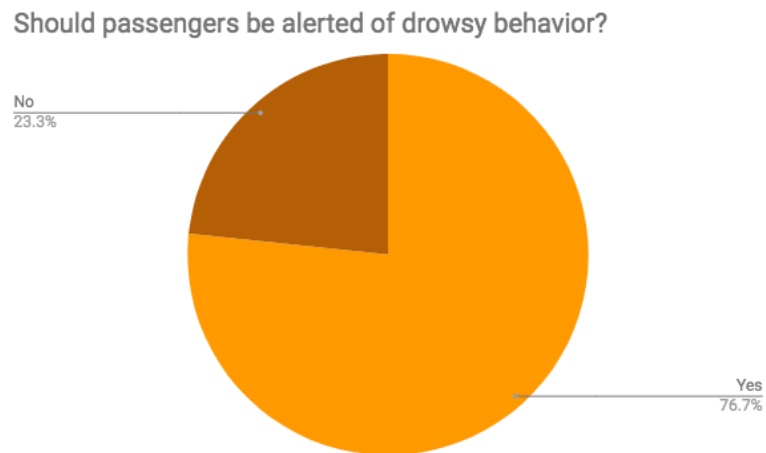
25. Do you prefer sweet, salty, or spicy snacks?



26. Would you rather have a crunchy, soft, or chewy snack?

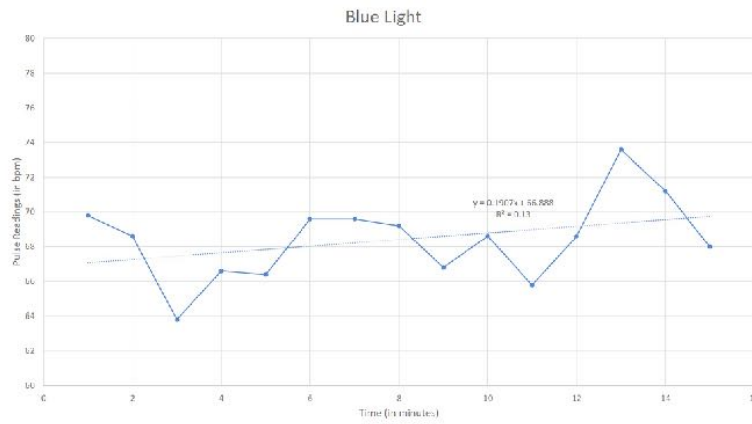


27. Do you want your passengers to be notified about your drowsy behavior?

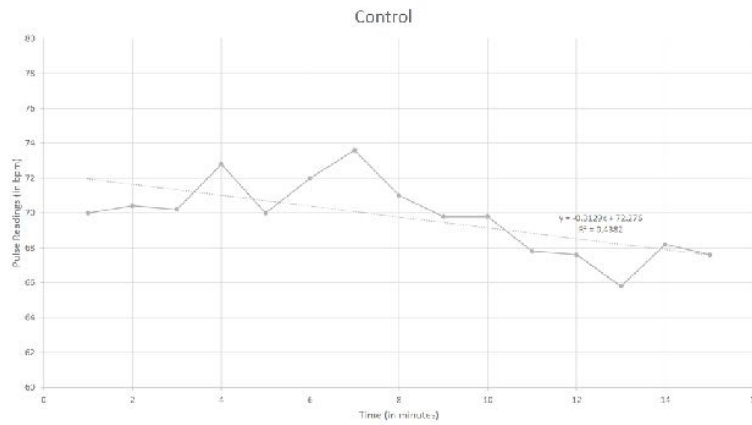


Appendix I - Testing results from prototype experiments

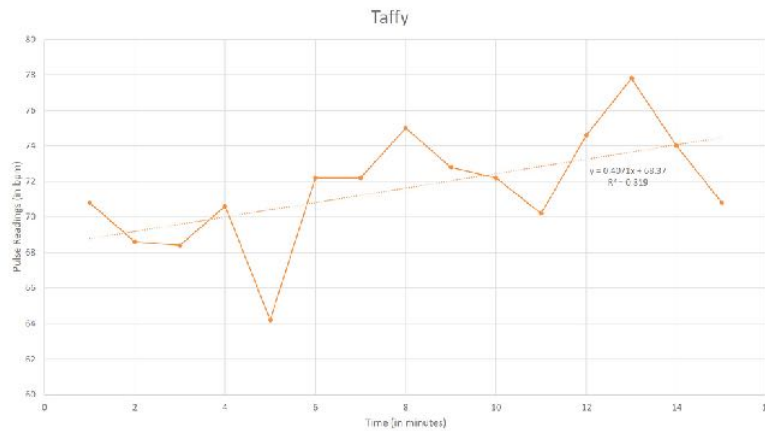
Average pulse of each group at every minute during testing (time in minutes vs. pulse reading (bpm))



Blue light:
 $y = 0.1907x + 66.888$
 $R^2 = 0.13$



Control:
 $y = -0.3129x + 72.276$
 $R^2 = 0.4382$



Taffy:
 $y = 0.4071x + 68.37$
 $R^2 = 0.319$

Appendix J - PVT Testing Results

Major	Degree	Last woke up	Group	Average PVT(be	Average PVT (after reading text)	difference in PVTs
ME	btech	5:30 AM	blue light	315 msec	308 msec	7
me	btech	9:30 AM	blue light	303 msec	299 msec	4
ECE	BTech	10:30 AM	blue light	301 msec	295 msec	6
CSE	BTech	6:30 AM	blue light	306 msec	311 msec	-5
CSE	BTech	8:30 AM	blue light	338 msec	331 msec	7
ME	be	7:00 AM	control	432 msec	406 msec	26
ME	Btech	6:00 AM	control	384 msec	477 msec	-93
ME	BTech	8:00 AM	control	317 msec	342 msec	-25
Bio	BTech	6:00 AM	control	351 msec	376 msec	-25
CSE	BTech	6:30 AM	control	400 msec	368 msec	32
ME	Btech	8:30 AM	taffy	374 msec	330 msec	44
EE	Btech	7:00 AM	taffy	400 msec	329 msec	71
ME	Btech	8:45 AM	taffy	354 msec	350 msec	4
VLSI	PhD	6:30 AM	taffy	351 msec	359 msec	-8
ME	BTech	9:00 AM	taffy	317 msec	318 msec	-1

Appendix K - Bill of Materials

PROTOTYPE	ITEM	QUANTITY	COST (INR)
EYE DETECTION & BLUE LIGHT	Raspberry pi 3 kit	1	4500
	RGB LEDs	10	60
	Male to Female jumper wires	20	60
	Male to Male jumper wires	20	60
	Female to Female jumper wires	20	60
	Connecting wire (by metre)	5	10
	USB car charger	1	200
	Raspberry pi camera (night vision)	1	2089
	Raspberry pi camera (day)	1	659
	Breadboard	1	79
	Pulse sensor	1	390
	GSM module	1	1150
	Delivery charges	1	39
	Sub-total for eye detection and blue light		
SEAT COVER	Foam sheet	1	900
	Covering Fabric	1	767
	Miscellaneous materials	1	125
	Workmanship	1	600
Sub-total for seat cover			2392
TOTAL			11748

Appendix L - Taffy recipes

Spicy taffy ingredients

- ½ cup sugar
- ½ tablespoon cornstarch
- ¼ cup light corn syrup
- 3/16 cup of water
- ½ tablespoon butter
- ¼ teaspoon salt
- red chilli powder

Sweet taffy ingredients

- ½ cup sugar minus a tablespoon
- ½ tablespoon cornstarch
- ⅛ cup light corn syrup
- 3/16 cup of brewed black tea
- ½ tablespoon butter
- ¼ teaspoon salt
- ½ tablespoon orange marmalade
- soya flakes

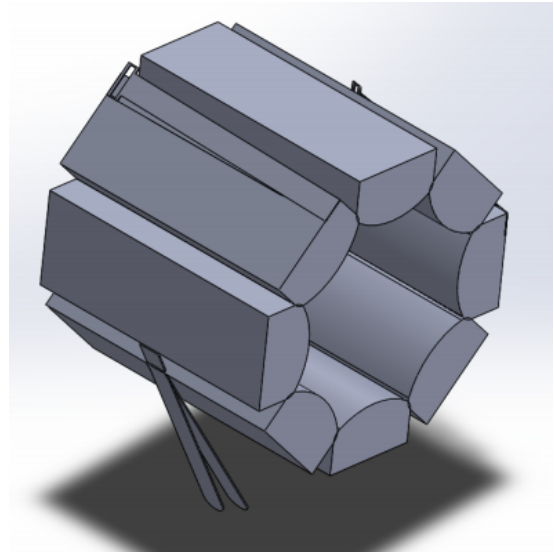
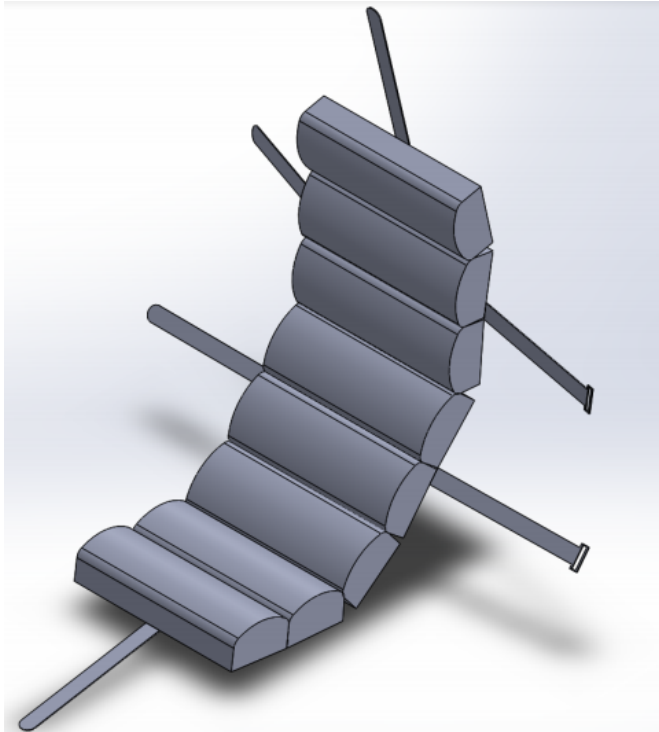
1. Mix together sugar and cornstarch in the saucepan
2. Stir in the corn syrup, water (or tea for sweet taffy), butter, and salt. Place the saucepan over medium heat and stir until sugar dissolves.
3. Continue stirring until mixture begins to boil, then let cook, undisturbed, until it reaches about 270 degrees or the soft-crack stage.
4. Remove the saucepan from the heat (for the sweet taffy, add in the orange marmalade at this point). Stir gently, then pour onto a greased ceramic plate or into a shallow greased cookie sheet to cool. Once the sugar is poured, place powdered ingredients on top. For spicy, cover the entirety of the top with red chilli powder if you like really spicy, but this may take some playing around with in order to find the spiciness level you want. For the sweet one, crush up the soya flakes until they make a powder and sprinkle them on top in a thin layer. Try not to get big chunks of flake in there because then you'll have crunchy bits in your taffy.
5. When the taffy is cool enough to handle, grease your hands butter and pull the taffy until it's light in color and has a satiny gloss. This step should take about 10 minutes.
6. Roll the pulled taffy into a long rope, about 1/2 inch in diameter, and cut it with a greased butter knife (I used butter) into 1/2-inch-long pieces. Let the pieces sit for about half an hour and then dust them in cornstarch so they don't stick to each other when you store

them. (These are small batches, but should still make about 20 pieces each)

Based this recipe off of the one found at: <https://www.exploratorium.edu/cooking/candy/recipe-taffy.html#>

For the corn syrup, I also made my own to cut back on cost. I used the recipe found at: <http://www.geniuskitchen.com/recipe/homemade-corn-syrup-substitute-simple-syrup-74080#activity-feed>

Appendix M - CAD models of seat cover



Appendix N - OpenCV face recognition code

```

from scipy.spatial import distance as dist
from imutils.video import VideoStream
from imutils import face_utils
from threading import Thread

import numpy as np
import playsound
import argparse
import imutils
import time
import dlib
import cv2

class FaceDrowsinessDetector:
    def __init__(self):
        # initialize dlib's face detector (HOG-based) and then create
        # the facial landmark predictor
        print("[INFO] loading facial landmark predictor...")
        self.detector = dlib.get_frontal_face_detector()
        self.predictor = dlib.shape_predictor(args["shape_predictor"])

        # grab the indexes of the facial landmarks for the left and
        # right eye, respectively
        (self.lStart, self.lEnd) = face_utils.FACIAL_LANDMARKS_IDXS["left_eye"]
        (self.rStart, self.rEnd) = face_utils.FACIAL_LANDMARKS_IDXS["right_eye"]

    def set_image(self, image):
        """
        Set the image cache for the FaceDrowsinessDetector.

        This is the image that will be used for future computation.
        We'll also use this for visualisations.
        This makes sure that the computationally heavy operations of
        face detection and shape detection are all done only once per image.
        """
        # Get a greyscale image with width 450 from the given frame
        # (that's what our models works on)
        self.image = imutils.resize(image, width=450)
        self.gray = cv2.cvtColor(self.image, cv2.COLOR_BGR2GRAY)

        # Get all the different faces in the image

```

```

self.rects = self.detector(self.gray, 0)

self.shapes = []
for rect in self.rects:
    shape = self.predictor(self.gray, rect)
    shape = face_utils.shape_to_np(shape)

    self.shapes.append(shape)

def compute_drowsiness_parameters(self):
    """
    Given an image, returns the drowsiness parameters for that image
    Currently, we're only using EAR as a parameter, but in the future
    We might use more things like yawning detection and head tilt
    """

    # This is the minimum ear
    self.minear = 1.0

    # loop over the face detections
    for eye_shape in self._get_eye_shapes():
        leftEye, rightEye = eye_shape
        leftEAR = self._eye_aspect_ratio(leftEye)
        rightEAR = self._eye_aspect_ratio(rightEye)

        # average the eye aspect ratio together for both eyes
        ear = (leftEAR + rightEAR) / 2.0

        if ear < self.minear:
            self.minear = ear

    return self.minear

def draw_computed_ear(self):
    # draw the computed eye aspect ratio on the frame to help
    # with debugging and setting the correct eye aspect ratio
    # thresholds and frame counters
    cv2.putText(self.image, "EAR: {:.2f}".format(self.minear), (300, 30),
                cv2.FONT_HERSHEY_SIMPLEX, 0.7, (0, 0, 255), 2)

def draw_eye_shapes(self):
    """
    Draws the eye shapes that it detects onto the cached image
    """

```



```

"""
for eye_shape in self._get_eye_shapes():
    leftEye, rightEye = eye_shape
    leftEyeHull = cv2.convexHull(leftEye)
    rightEyeHull = cv2.convexHull(rightEye)
    cv2.drawContours(self.image, [leftEyeHull], -1, (0, 255, 0), 1)
    cv2.drawContours(self.image, [rightEyeHull], -1, (0, 255, 0), 1)

def render_image(self):
    # show the frame
    cv2.imshow("Driver Drowsiness Detection", self.image)

def _eye_aspect_ratio(self, eye):
    # compute the euclidean distances between the two sets of
    # vertical eye landmarks (x, y)-coordinates
    A = dist.euclidean(eye[1], eye[5])
    B = dist.euclidean(eye[2], eye[4])

    # compute the euclidean distance between the horizontal
    # eye landmark (x, y)-coordinates
    C = dist.euclidean(eye[0], eye[3])

    # compute the eye aspect ratio
    ear = (A + B) / (2.0 * C)

    # return the eye aspect ratio
    return ear

def _get_eye_shapes(self):
    eye_shapes = []
    for shape in self.shapes:
        # extract the left and right eye coordinates, then use the
        # coordinates to compute the eye aspect ratio for both eyes
        leftEye = shape[self.lStart:self.lEnd]
        rightEye = shape[self.rStart:self.rEnd]

        eye_shapes.append((leftEye, rightEye))

    return eye_shapes

def sound_alarm(path):
    # play an alarm sound

```

```

playsound.playsound(path)

# construct the argument parse and parse the arguments
ap = argparse.ArgumentParser()
ap.add_argument("-p", "--shape-predictor", required=True,
    help="path to facial landmark predictor")
ap.add_argument("-a", "--alarm", type=str, default="",
    help="path alarm .WAV file")
ap.add_argument("-w", "--webcam", type=int, default=0,
    help="index of webcam on system")
args = vars(ap.parse_args())

# define two constants, one for the eye aspect ratio to indicate
# blink and then a second constant for the number of consecutive
# frames the eye must be below the threshold for to set off the
# alarm
EYE_AR_THRESH = 0.25
EYE_AR_CONSEC_FRAMES = 48

# initialize the frame counter as well as a boolean used to
# indicate if the alarm is going off
COUNTER = 0
ALARM_ON = False

# start the video stream thread
print("[INFO] starting video stream thread...")
vs = VideoStream(src=args["webcam"]).start()
time.sleep(1.0)

drowsinessDetector = FaceDrowsinessDetector()

# loop over frames from the video stream
while True:
    # grab the frame from the threaded video file stream, resize
    # it, and convert it to grayscale
    # channels)
    frame = vs.read()
    drowsinessDetector.set_image(frame)
    ear = drowsinessDetector.compute_drowsiness_parameters()

    # Draw the visualizations for the parameters

```

```

drowsinessDetector.draw_eye_shapes()
drowsinessDetector.draw_computed_ear()

# check to see if the eye aspect ratio is below the blink
# threshold, and if so, increment the blink frame counter
if ear < EYE_AR_THRESH:
    COUNTER += 1

# if the eyes were closed for a sufficient number of
# then sound the alarm
if COUNTER >= EYE_AR_CONSEC_FRAMES:
    # if the alarm is not on, turn it on
    if not ALARM_ON:
        ALARM_ON = True

    # check to see if an alarm file was supplied,
    # and if so, start a thread to have the alarm
    # sound played in the background
    if args["alarm"] != "":
        t = Thread(target=sound_alarm,
                  args=(args["alarm"],))
        t.daemon = True
        t.start()

    # draw an alarm on the frame
    cv2.putText(frame, "DROWSINESS ALERT!", (10, 30),
               cv2.FONT_HERSHEY_SIMPLEX, 0.7, (0, 0, 255), 2)

# otherwise, the eye aspect ratio is not below the blink
# threshold, so reset the counter and alarm
else:
    COUNTER = 0
    ALARM_ON = False

drowsinessDetector.render_image()
key = cv2.waitKey(1) & 0xFF

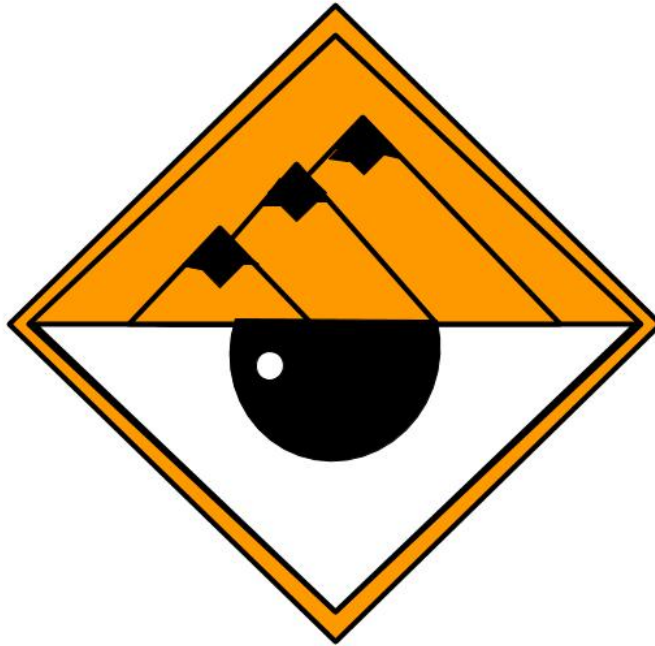
# if the `q` key was pressed, break from the loop
if key == ord("q"):
    break

# do a bit of cleanup
cv2.destroyAllWindows()

```

vs.stop()

Appendix O - Project logo for handouts



Appendix P - Information pamphlet for open house

Side 1

What is "drowsiness" and why is it dangerous?

- Transition between awake and asleep
- Can cause a person to fall asleep at "inappropriate" times of the day
- Decrease in brain activity
- Worsened driving performance
- Being awake for more than 18 hours is equivalent to having a blood alcohol content (BAC) of 0.05%. India's legal BAC limit is 0.03%

Why is drowsy driving an issue in Himachal Pradesh?

- 55.33% of drivers report being unsafe on Himachali roads
- Most common reasons are high traffic speeds, blind turn, and bad or narrow roads
- Popular trips from Manali to Delhi take up to 13-14 hours
- Long hours of driving increase risk of drowsiness and emotional or mental stress
- No hours of service laws in place in India

Contact information: driveindia2018@wpi.edu

Link to full report: <http://www.wpi.edu/F-project-db/E-projectsearch/search> using key words from the project title. Outcomes delivered after May 1 will appear on the IIT's ISTP page at: <http://www.iitmandi.ac.in/istp/projects.html>

Our team

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Mitigating Drowsy Driving

An educational pamphlet designed by a team of IIT Mandi students and WPI students to supplement their ISTP project pertaining to developing drowsy driving mitigation strategies in Himachal Pradesh



Side 2

Symptoms of drowsiness

- Falling asleep
- Yawning excessively
- Heavy eyelids
- Incoherent thoughts
- Inability to focus

Drowsy driving causes more than **30,000** accidents annually. **730** is the number of fatal car accidents caused each year by drowsy driving. **66%** of 19-29 year olds have driven drowsy.

WATCH FOR THESE SIGNS

- Difficulty focusing
- Missing exits
- Freeway markings/ heavy roads
- Drifting from your lane
- Having trouble remembering the last few miles driven
- Falling asleep or restless

COMBAT DROWSY DRIVING

- Get a full night's sleep before driving
- Build over and take a quick nap
- Don't schedule driving time when you'd normally be sleeping
- Stop for a caffeine fix
- Bring a buddy on the drive to split up drive-time
- Take a break and stretch or grab a snack

www.GuardYourHealth.com

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Recommendations for new strategies

- Utilize all prototypes
- Do further research on pulse sensing
- Do field testing on prototypes

Recommendations for policy

- Develop legislation for hours-of-service regulations for drivers
- Improve bus driver stops



What prototypes have we developed?

- Edible: two tatty flavors

- 100% vegetarian
- Two flavors, sweet and spicy
- Sweet flavor contains caffeine and energy providing ingredients

- Environmental: Blue lights

- Inhibits secretion of melatonin, the hormone that regulates sleep in the body
- Continuous prevention of drowsiness



- Physical: Seat cover

- Doubles as a mattress
- Foam filled
- Foldable
- Easy maintenance
- Provides housing to other devices
- Straps to hold it in place

- Technological: Eye detection

- Video capturing from night vision camera
- Video processing in Raspberry Pi using OpenCV
- Alarming the driver if drowsy

Appendix Q - WPI poster

Developing Drowsy Driving Mitigation Strategies in Himachal Pradesh

Utkrish Dhanekar, Nico Fabbri, Archit Kumar, Glenn McCormick, Sierra Palmer, Rushil Singh
Advisors: Dr. Varun Dutt, Dr. Ingrid Shockey, Dr. Seth Tuler

Abstract

The goal of our project was to develop and improve strategies to mitigate drowsy driving in Himachal Pradesh. To achieve this goal, we spoke to local drivers to gauge their preferences on drowsiness prevention strategies, and we used their feedback to create four prototypes to detect drowsy driving and improve rest for drivers.

Methodology

Goal:
Develop and improve drowsiness mitigation strategies applicable in Himachal Pradesh

Objective 1:
Document and compare drivers' experiences with drowsy driving

Objective 2:
Identify key aspects of existing drowsiness prevention strategies

Objective 3:
Develop and test prototypes to mitigate drowsy driving

Survey Results

Prototypes

Eye Detection

EAR: 0.21

Video capturing from night vision camera
Video Processing in Raspberry Pi using OpenCV
Alarming the driver if drowsy

Blue Lights

- Inhibits secretion of melatonin, the hormone that regulates sleep in the body.
- Continuous prevention of drowsiness

Taffies

- 100% Vegetarian
- Two flavors: Sweet and Spicy
- Caffeine in the sweet flavor
- Energy providing ingredients in the sweet flavor

Seat Cover

- Doubles as a mattress
- Foam filled
- Foldable
- Easy maintenance
- Provides housing to other devices
- Straps to hold it in place

Test Results

Recommendations

Prototypes:

- Face detection can include yawning and head position
- Blue light strategy refinement for driver preferences
- Taffy production can be scaled up
- Seat can be customized as per driver needs

Policy:

- Hours of service legislation to prevent overworking

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Graphs showing pulse readings of participants with time when experimented for the prototypes