UNIVERSITEIT TWENTE.

Smart Environment Project

DOCUMENTATION REPORT

Team Distracted Disasters

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Chapter 0: Introduction

Our team

We are a team consisting of seven people with each different skills and backgrounds. We have developed roles into this team that fit and compliment the strengths of each individual.

1. Lars Beumer is the team leader. He has the oversight on the work progress and the responsibilities of keeping the teams deadlines. He is facilitating the brainstorming and stimulates the group to work in a clear direction.
2. Nathan van Dijk is the researcher and solution finder of the group. He is responsible for gathering information on why and how things should be done in terms of hardware and software. As extension of this he will come up with ideas on the results from these findings.
3. Sandi Julardzija is responsible for the demo-day preparations and presentations. He is responsible for the integration of the software and hardware into one cohesive product. He will also be a researcher as part of the validation for the decisions made.
4. Floris Kempers is our first hardware designer. He will be responsible for creating sketches and the physical prototype. As extension he is managing the cables and connections.
5. Emir Prat is our second hardware designer. He is responsible for collecting all the information on materials and gathering them. He will create a visual prototype that Floris can build a physical prototype of.
6. Catelijne Drenth is the software designer of the group. She is responsible for processing the inputs from the sensors being used and to visualize them. Lastly she will be in charge of creating a virtual simulation for the final presentation.
7. Sietze Huisman is the programmer of the group. He will be working closely with Catelijne as he will get the data from the sensors and make sense of the data being received. He is in charge of the coding and programming.

Problem description

This team will focus on the problem of distracted driving with focus on drivers in autonomous cars. The goal is to lower the risks of accidents by creating a structure that prevents the driver from being distracted.

Motivation

This problem is relevant because everyday more and more cars become autonomous. Although self-driving cars generally cause less accidents, this does not mean that the driver does not have to pay attention. Especially because self-driving cars become more common, the risk of accidents when the driver has to take over the driving (thus not being distracted), becomes larger.

It is important to look into this problem, because in the future more and more cars will be autonomous. Also, distracted driving becomes more and more of a problem in traffic in general, because more people are for example addicted to their phones.

Proposed solution

The above mentioned problem also has the possibility of being solved from multiple angles. These different angles have different levels of feasibility to be considered. A solution has been picked which is both engaging and effective. This proposed solution is a smart steering-wheel with different sensors in it. Using these sensors, the car (or steering-wheel) should be able to know whether a user is distracted or not, and if so, alert the user, to avoid distraction. This solution could also be implemented in non-autonomous cars. There has also been thought of a basic versus an advanced model, in order to have possibilities for expansion, if there is still time left.

Chapter 1: Literature Review

In this chapter, orientation literature research has been conducted. The goal of this research is to get a general understanding of disasters in different environments. With this knowledge, it will be easier to pick a specific disaster to (try to) solve later on.

1. Preventive disaster management of extreme natural events [1]
By Alik Ismail-Zadeh and Kuniyoshi Takeuchi
This article looks at different impacts of natural disasters. The role of geoscience is discussed, and how science could and should be further implemented in governmental policy, to increase awareness of natural disasters.

2. Diseases Transmitted by Foods Contaminated by Wastewater [2]
By Frank L Bryan
This article is about pollution that affects our food. Food can transmit diseases which come from polluted (waste)water and/or polluted soil. For example vegetables and fruits have been considered as vehicles in multiple outbreaks.

3. Post-tsunami recovery in Tamil Nadu, India: combined social and infrastructural outcomes. [3]
By *Elizabeth Jordian, Amy Javernick-Will & Kathleen Tierney*
This article studied 15 different villages in India that were affected by a tsunami, and looked for pre- and post disaster conditions. They seek to find out which are the different pathways to infrastructural and social recovery in these regions and how they differ.

4. An integrated approach to natural disaster management: Public project management and its critical success factors [4]
By *Tun Lin Moe, Pairote Pathranarakul*
This article focuses on the tsunami that happened in Thailand in 2004 and looks at the disaster management from a public project management perspective. By using the tsunami as a case study, the article highlights some of the specific problems in relation to disaster management and the important strategies for good disaster management.

5. Climate change and disaster management [5]
By Geoff O'Brien, Phil O'Keefe, Joanne Rose and Ben Wisner
Climate change is a natural phenomenon, which is accelerated by humans. Reducing vulnerability is a key aspect in reducing climate change risks. It turns out that this is not yet universally the case.

6. Social media in disaster risk reduction and crisis management [6]
By David E. Alexander
The scope of this research is how social media could be useful in preventing and managing a disaster. Social media can be useful for, for instance listening to public debate, but also for extending reach of emergency messages.

7. Proceedings of WHO Meeting to Develop a 5-year Strategy for Road Traffic Injury Prevention [7]
By Murray Mackay, Geetam Tiwari
This article finds the general problems of road accidents by analyzing the data collected for the last 30 years. The authors point out the shared responsibility of everyone that is involved in car and road design, local and national facilities, educators, and many more. It also goes through mental prevention of drivers to sit behind the wheel in an unhealthy form.

8. Speeding [8]
By ERSO
This paper looks at speed as the primary cause of all road accidents. According to the report, speed regulations and education about speed's relevancy should be immensely improved upon. This paper goes into detail about various aspects of why people are speeding.

9.World Report on Road Traffic Injury Prevention. [9]
By the WHO and World Bank
This paper discusses preventable road traffic injuries and deaths. The authors of this article are looking for ways to fight the ignorance of drivers and help to raise safety on the streets. It contains ways to prevent these lethal impacts and lessen the harm done by vehicles.

10. Global Marine Pollution [10]
By Michael Waldichuk
This book is about marine pollution on a global level and how it not only affects marine life, but also human life. Discussed topics are about the major pollution contributors and the scientific aspects of those polluting substances. There is also a chapter about the regulation of current marine control and how it could improve.

11. Atmospheric pollution: a global problem [11]
By Elsom D.M.
This book is about pollution all around the world on a global level. Many different topics about causes and effects of pollution: oudors, noise, waste heat, radiation, acid rain, ozone depletion and greenhouse gases.

12. An earthquake disaster management mechanism based on risk assessment information for the tourism industry-a case study from the island of Taiwan [12]
By Chung-Hung Tsai and Cheng-Wu Chen
This article is about the risk management of earthquakes. It mainly focuses on Taiwan, but also looks to other islands. The article is about knowing when an earthquake will happen and thus being able to prepare for it.

13. Integrated flood risk assessment and zonation method: a case study in Huaihe River basin, China. [13]
By Wu, Y., Zhong, Pa., Zhang, Y. et al
This article is about how to minimize the effects of flooding by predicting where a flooding will occur and how intense this flooding will be. The article uses the Huaihe River as subject to check which parts are most vulnerable to flooding.

14. TerraSAR-X reveals the impact of the mobile barrier works on Venice coastland stability [14]
By Tazio Strozzi, Pietro Teatini & Luigi Tosi
This article is about a research done about mobile barriers that try to keep the water level steady. The article reveals that, even though the barriers seem to have an effect on the water level, it will not be enough to save the infrastructure of the city.

15. Early fire detection using convolutional neural networks during surveillance for effective disaster management [15]
By Khan Muhammad, Sung Wook Baik & Jamil Ahmad.
This publication is part of a journal describing recent fundamental contributions in the field of neurocomputing. This particular chapter proposes a detection system using neural networks for cctv cameras to detect early fires.

16. Real-time forest fire detection with wireless sensor networks [16]
By Liyang Yu, Neng Wang & Xiaoqiao Meng
In this paper the authors propose a wireless sensor network to detect forest fires in real time, it can detect forest fires more promptly than a satellite based approach. The paper mainly focuses on data collection and processing in such a wireless network.

17. Psychological Impact of Fire Disaster on Children and Their Parents [17]
By Russell T. Jones, David P. Ribbe, Phillippe B. Cunningham, J. David Weddle & Audra K. Langley
This paper researches the psychological impact of a fire disaster like a wildfire on children and their parents, it does this by examining children's psychosocial functioning six weeks following a wildfire. To do this the short term mental consequences were evaluated from two groups, people lost a lot of things in the wildfire and people who did not lose that much.

18. Prepare your community for a disaster [18]
By Alan Henry
This news article focuses on what each individual person can do to prepare best for a disaster. The key point is to spend time in anything that adds value to the community and thereby get a connection to the people in the same area. Discussing a disaster plan in the community is proposed with some few tips and focus points.

19. Characteristics and trends of flash droughts in Spain, 1961–2018 [19]
by Iván Noguera, Fernando Domínguez-Castro, Sergio M. Vicente-Serrano
In this article the trends of droughts in Spain are touched upon and to reasons why they happen. In short, this article discusses how to identify flash droughts, as well as recognizing the upwards trend of droughts in Spain.

20. From hard-path to soft-path solutions: slow–fast dynamics of human adaptation to droughts in a water scarce environment [20]
by Pedro Medeiros, Murugesu Sivapalan
This article brings forward the issue of droughts in the Extended Jaguaribe Basin and as a general, adaptation to them and solutions for them. The main message discussed is that

there are better ways to deal with droughts and that it is important to think about ”soft-path solutions”.

Chapter 2: Identification of General Problems and Challenges

Chapter 2 will be about identifying general problems and challenges which occur during disasters. These problems are based on the research conducted in chapter 1.

Identified problems:

1. The main problem identified in the article: “Preventive disaster management of extreme natural events” [1] is the lack of awareness, even though this awareness could be enhanced by further integrating scientific knowledge.

2. The paper: “post-tsunami recovery in Tamil Nadu, India” combined social and infrastructural outcomes. [3] shows a clear challenge in the complexity of understanding how to get through a disaster. They show how some communities were able to recover without funds, while others did not recover despite receiving a large amount of funding. They highlight some of the key aspects in pre-disaster conditions and post-disaster strategies to recover a disaster.

3. “An integrated approach to natural disaster management: Public project management and its critical success factors” [4]**,** shows all the elements necessary for dealing with a disaster, both as proactive and reactive strategies. The greatest challenge highlighted in the article boils down to the governmental structure and how willing they are to adapt and invest in proper disaster prevention.

4. The main concern in “Climate change and disaster management” [5] is stated that there is a lack of focus on building resilience, which is key to diminish climate change risks.

5. A problem which is coherent with the use of social media in disaster management, is the privacy aspect of it, as follows from “Social media in disaster risk reduction and crisis management” [6].

6. In “Proceedings of WHO Meeting to Develop a five-year Strategy for Road Traffic Injury Prevention” [7] were multiple general problems with roads discussed. Three main problems were picked out from this article. The first being alcohol and drug users. These people are a big problem concerning road accidents. The second problem is transport vulnerability,
The third problem is about highways that go through villages. These roads are dangerous since the usual speed on highways is really high and it is very dangerous if these roads go through villages.

7. The publication: “Speeding” [8] looks at speeding as the primary cause of road accidents.
we found that the main problems were: speeding, The need for speed, and the lack of information about the relevance of keeping the right speeds.

8. “World Report on Road Traffic Injury Prevention” [9] discusses preventable road traffic injuries and deaths. in this paper the problems were mostly found from: Human error, a poor design of roads and a poor or even lack of enforcement of the traffic laws.

9. The article “From hard-path to soft-path solutions: slow–fast dynamics of human adaptation to droughts in a water scarce environment” [20] discusses the trend in new profound ways of dealing with droughts, focusing on soft-path solutions instead of structural and governance measures.

Chapter 3: Identification of Relevant Problems

In chapter 3 problems more relevant to specific situations are discussed. Using this information, a selection can be made as to what problem will be the topic of this research project.

Transportation

Two existing problems are already identified on the subject of car accidents. Two more specific problems are found to be relevant and interesting with regards to car accidents.

First is the phenomenon known as "phantom traffic jams" where one car lowering its speed, will affect other cars behind it to break, creating a harmonica-effect of cars that temporarily needs to stop. This can create a traffic jam caused by one car making a mistake. This especially occurs in highway roads where the chance of collision increases due to the stopping and going while driving at a high speed. It is very relevant because so many people can access cars and are daily users of it. There is no infrastructure in place at all that is dealing with these phantom traffic jams.

Another problem is that people can get distracted while driving and cause major accidents if they do not pay attention to what is going on in traffic. Some forms of being distracted or not paying attention are: looking at messages or calling, being intoxicated / under influence of hallucinogens or simply being tired. Each of these examples could lead to the driver not paying attention and undeliberately going off the road and/or crash in another car.

Self-driving cars could take over some of these responsibilities, but machines are not always perfect and can make mistakes, whilst even slight mistakes can result in big accidents. The driver has to be clear minded and pay attention to the road and their surroundings.

Wildfires

Early detection of wildfires is one of the biggest issues on the matter of prevention of wildfires. Today, the world mostly uses the satellite to detect a wildfire because it covers the entire earth in about one to two days, but it is not fast enough to do it in real-time. Fire detection systems could be implemented while having a low cost, due to already installed surveillance systems, fast response time, and crucial information about the fire, due to faster image-processing. These CCTV systems could be reprogrammed to timely detect fire and call the firefighters.

Similar to drought, the land on which the wildfire occurred will be damaged. Thus additional assistance is required to help the forests or lands to recover. Without that, forests may never recover, which is why it is in humanity's best interest to help them grow back as they produce oxygen.

The awareness of wildfires has to be appropriately addressed as the number of victims is not low, about half a million a year [15]. People in regions of a dry climate, forests, and high temperatures need to be prepared for this kind of disaster because they are in the most vulnerable position.

Finally, people's perception of fire needs to be reevaluated because this is the most common cause of wildfires. The education on this matter should be taught in school and instructed upon entering wildlife. Signs, fines, and commercials could help raise awareness.

Consequences of drought

The biggest problem concerning the consequences of drought is that plants die when droughts occur. Trees stop producing oxygen and lakes dry out, killing every wildlife inside of the lake and outside, the animals who are dependent on that lake as their source of water. The droughts are especially dangerous in the area of farms because the droughts happen fast, the absence of water or sudden dry climate can kill the crop. Many businesses could go bankrupt without harvesting their lands. Another big issue of droughts is that the level of water in a well can be reduced due to extreme rain deficit. This water is used as drinking water as well as irrigation water.

Consequences of hurricanes and/or earthquakes

Hurricanes and earthquakes can cause massive damage, wreaking havoc in urban areas, destruction of buildings and roads make going from one place to another practically impossible. The force of an earthquake destroys buildings which can collapse and enclose people within, hurricanes can flood streets locking people in place to which they can only wait for help. We've all seen footage of people sitting on the roof of their house waving at news helicopters for help, or seen massive teams of emergency workers clearing out a collapsed building and finding a person that was lost for days.

Once a hurricane has passed or an earthquake has happened, the first problem emerges as emergency services are unlikely to help everyone in need because roads are obstructed, phone lines and cellular towers are likely destroyed which make contacting help very hard. The second problem follows from earthquakes, they're rather unpredictable and often have aftershocks which can deliver a harder blow than the first wave which often deal more damage as buildings are already weakened and destroyed. The third and hardest problem to solve is finding more people lost in rubble, often stuck or pinned down, they have no way of calling for help. It's up to the first responders to find them, and it becomes a very hard game of hide and seek. The use of rescue dogs helps greatly, however they can still miss a person hidden deep in rubble.

Chapter 4: Problem Selection and Motivation

The problem which has been picked from chapter 3, concerns the distraction of drivers in self-driving cars. The reasoning behind choosing this problem to work on, will be further explained in this chapter.

Firstly, disasters in the transportation sector happen quite often and cause a lot of casualties on a yearly basis. Furthermore, a lot of regulations and measures have already been implemented in the past, to lower risks whilst (for example) driving a car. These regulations and measures have definitely lowered the number of traffic casualties and accidents, but they still happen a lot. This shows that these problems are hard to solve, and still actual up to now.

Secondly, a lot of innovations have made their way into the car market nowadays. These innovations lower risks by implementing technology in a smart way, but they can bring up new risks. These risks themselves could lead to an increase in traffic casualties.

To pick between the transportation problems as stated in chapter 3, small research has been done on both of these problems and their possible solutions. It turns out that there has been a lot of research into the harmonica effect already. Nowadays, a lot of new cars have adaptive cruise control on board, which will lower the speed automatically if the car in front of you slows down. This way, the harmonica effect will be decreased.

In the fight against distraction whilst driving, a lot of early initiatives have been implemented as well, for example different apps for your phone or making it necessary to touch the steering wheel after a set amount of time. Unfortunately, these initiatives do not seem to be that widespread, there are a lot of fractionalized solutions.

Considering all of the above, the problem of distracted drivers in self driving cars has been chosen. This is relevant because self-driving cars are becoming more and more common, and the issue of drivers being distracted while the car does all the work for them (possibly making mistakes) could lead to dangerous situations.

Chapter 5: Potential Solutions

In order to eventually try to solve the selected problem from the previous chapter, it is important to orientate on different possible solutions. This will be done in this chapter.

Solution 1, Head/eye-movement tracking:

A possible solution for the problem as stated in chapter 4, could be hardware which could detect where the driver of the car is looking, and whether he or she is still paying attention to the traffic. If the driver is distracted and not paying attention to the road for a certain period, the car could notify the driver to start paying attention again. With the help of image recognition, the system could even identify whether the driver is looking at his phone, or for example just staring out of the side-window.

This could solve the problem almost completely. The issue with this solution would be deciding when a driver is actually distracted, and when he is just casually looking around him. This could of course be solved by advanced software (maybe using the AI already implemented in the car), but this is no easy task. Also, privacy of the user has to be respected, which would pose another large set of problems.

All of the above leads to the result that while the solution would work well in preventing distracted drivers, it may be hard to implement. Some variations on this solution could be made, to for example use other sensors for tracking a driver’s attention.

Solution 2, disabling the phone:

The main causes of distraction in a car are phones. By eliminating this element the problem is not completely solved, but it is for a majority. However, the car cannot just block phone signals or turn them off automatically, since the driver has to be able to call for help when in a car crash.

Some apps make driving safer and the phone can be turned off. However, this requires the driver to actively do this and they can choose to not do it. Thus, a solution would be that the car itself knows whether or not the phone is in a specific spot or has a driving app open. Many cars that are made now have Bluetooth or Wi-Fi. As a result, the car can detect if there is a phone inside and will not start if the phone is not placed at the spot that is just out of reach while driving or sending signals that the phone is in driving mode.

Solution 3, augmented reality game/notification system:

Another possible solution would be an augmented reality game, something like a visual attention keeper that makes you notice and pay attention to things around you via a game or notifications about things in your surroundings you should be paying attention to that is displaying on your front window. This augmented reality game/notification system would be made possible by using a screen under the window that gets reflected by the window, making it seem the objects on the screen are actually on the road or in the surroundings.

There are already speed meters that project the speed on the front window, so the same technique could be used, changing the things that are actually projected on the road.. Also just displaying various things is already better since you don't have to take your eyes off the road and give you something to pay attention to while still having your eyes on the road.

This would help with the problem but not exactly solve it completely. It would help with people keeping attention to the road, but it could easily go too far. Like with people that get so into a game that they are only busy with the game and don't pay attention to anything else which would make them distracted and that is exactly what we are trying to solve. This could be solved by focusing more on a notification system that makes you pay attention to potential dangerous things, this way the driver will always pay attention to the most important things. Even though this could be a possible solution it would be hard to prototype and test.

In conclusion, it could be a great solution, which might be too hard to prototype. Also, it is easy to overdo it, which could lead to dangerous situations, which is precisely the opposite of what is desired to achieve.

Solution 4, entertainment with trivia:
In order to keep people awake and aware of their surroundings, researchers have tried different strategies. In Australia, the government decided to use signs that ask the driver trivia questions, to which there is another sign with an answer just ahead. In many countries they use art to make figures and statues so that people will take interest in taking the road.

These kinds of entertainments can help people raise their concentration on the road. The focus is on strategy with signs. One of the risks of using this strategy is that people may actually put more attention on the sign or the question, thus distracting themselves.

Requirements for this strategy are only signs and appropriate distance between the question and the answer. This could potentially bring life to those tireless drivers that have to cover a great amount of distance.

Solution 5, Steering wheel check:
This solution will counteract being distracted by implementing a smart device that has the ability to detect whether the driver has a firm enough grip on the steering wheel with both hands. If a driver doesn't have either hands on the steering wheel, he or she will be notified and the device alarms them. It's idea is simple enough by itself but without the proper necessities it could be circumvented easily.

In order to have the product work well, it should, for example be able to:

- detect whether enough pressure is exerted on the steering wheel
- detect warmth of a person's hands (as to prevent props being used instead of hands)
- have a build in alarm setting which notifies the drivers of his or her awareness
- have an ability to actively engage the user as such to increase awareness

Solution 6, checking vitals:
When you begin to get sleepy or 'too relaxed', your heart rate drops significantly and your temperature drops slightly. A possible way to measure this is with a device on the steering wheel which you hold while driving. This is a better option than for example a bracelet or something else because people might not want to wear that, but the device on the steering wheel shouldn't hinder the driver in any form or way.

This device should at least be able to detect the heart rate and if the drivers hands are indeed on the steering wheel. This can simply be done with a piece of conductive material on the steering wheel which the driver holds with his/her hands. Your body contracts the heart muscle by sending electrical signals, which can be measured. This could also double as a way to detect the hands of the driver on the steering wheel.

After measuring the heart rate, the device checks if this number is below a certain threshold. If this happens, an action occurs and will notify the driver. This can be a computer voice telling the driver to stay focused, but it could also be done with a light changing color or a small sound that alerts the driver.

Solution 7, digital driving partner:
The biggest obstacle for the selected problem is actually humans getting a false sense of security that the autonomous cars of today can drive with no human engagement. This may be the case in the future, but today's autonomous cars are by no means perfect yet and do require the drivers attention. To combat the essence of this problem, a solution could be to force the human driver to engage in a conversation of some sorts. The solution is to create this sense of having a digital driving partner as your co-pilot, by giving the AI options to ask for permission of doing specific maneuvers on the road. If the driver fails to respond it should be very clear that the car will either give sound notification or drive very conservatively and slowly. By having this solution you will still be doing most of the driving by deciding which actions the car should perform. By deciding it will require you to pay attention to the road.

This has the potential to solve the problem completely, but there are issues. There is a major fall back that the questions will be sporadic, and would be coming in intervals. Between questions there is always the option that the human driver will not be paying attention and only look at the road once the question is asked. In theory we would not need any extra material for the autonomous car, because the car makes decisions already. We would only need to circumvent it so that the car displays questions to the driver before executing a particular maneuver. We believe that this would create a psychological shift for humans with autonomous cars and would create the frame that two "people" are responsible and driving rather than thinking the car can do everything itself.

This solution would need to be tested on a small scale. As this is mainly a test of people's attention when they are dealing with something autonomous, the context of the car and the road is less important. This could be tested by other means in a more static environment. There are two cheap and easy ways of having a prototype test within the context of driving. The first would be to have another person act as the autonomous car and the person in the passenger seat next to the driver would be the one driving. This is by no means a good replacement for the real thing but an option as a first early test. The second option is to use the virtual reality technology and the driving simulators that exist today. Again this could be done by letting the driver only have the headset on and some other person using the mouse and keyboard and control the car, acting as the autonomous car.

Once the concept has been shown to work, it would be relatively easy to implement in the car. Not much needs to be changed or added to the existing technology of the autonomous car for it to be in effect. It is therefore both feasible and realistic and could change the human driver's perception of what it means to be in an autonomous car.

General remark:

It could well be that one of the above solutions will not suffice on it’s own, but that a certain combination of solutions would. This could mean that whilst picking a final solution, some alterations in multiple solutions or implementations could be made.

Chapter 6: Solution Selection

In order to select one solution to work on during this module, a pros and cons method has been applied. Some solutions from chapter 5 were already eliminated, because they were to0 complex to prototype in the time given. This goes for for example solution 1, concerning head movement and eye tracking. Although this solution would solve the problem pretty reliably, it would be hard to actually implement this.

In line with received feedback which mentioned that some solutions could be combined, this led to two remaining solutions: a combination between solutions 3 and 4, and a combination of solutions 5 and 6.

In short, the idea for a combination of solutions 3 and 4 is, based on for example a distance sensor, the distance to a certain object in front or around the car could be measured. Based on this data, questions, trivia or alerts could be projected over physical objects, using AR. Even though AR would not be realistic to implement, this could be overcome by using a simulation on screen. This solution is something which does not exist yet, and brings a whole different perspective to tackling the problem. The solution would probably not be economically feasible.

Moving forward to solutions 5 and 6, it was quickly discovered that this solution is a lot more physical. This is something which is desired by the research group, and also better connects with the course of Physical Computing. The basic idea behind this combination of solutions 5 and 6 is that we would come up with a smart steering wheel, which could detect whether a driver is still paying attention. In a basic prototype this could be done by for example just measuring whether the driver is actually holding the steering wheel, where in an advanced model this could be extended to monitoring vitals to detect whether a driver is distracted or sleepy.

This solution is an effective one, also because of the fact that it can be implemented in non-self driving cars too. This makes it so that the idea can be used on a larger scale, which would reduce risks even more. Also, because it is pretty much only an add-on device this solution would be economically feasible.

To decide between both options, the following pros and cons were used:

Solution 3 and 4 combined

Pros	**Cons**
Take advantage of the fact that we have a software designer (Maya & Unity).	Not as physical. Too much software oriented?
Better suited for the modular approach.	It has a chance of becoming complicated very fast
More parts that is not dependant of each other	Prototype will be further away from the actual thing. Conceptual.
It is easy to do from home.	If the game is not done right, the driver can actually be distracted towards the game. Destroying the point of keeping the driver focused.
Cool implementation between physical and digital world	

Solution 5 and 6 combined

Pros	**Cons**
Prototype will be closer to the actual product	Complicated physical implementation. Parts might be too dependent on each other.
It solves the problem better. Crashes are very connected to drivers not having hands on the steering wheels.	Comparable to what other groups said they would do
The option to “aim lower/higher” in case we do overestimate/underestimate ourselves.	might be a bit ‘ugly’ with exposed wires (if used)
Can be a product that is easily mounted on the steering wheel, so the car doesn’t need to be broken open to instal it etc.	Can be easily dis-mounted too if no precautionary measures against this are being taken.

Chapter 7: Methodology

Equipment:

- Arduino Uno
- USB gaming steering wheel
- Various wires (included in arduino, if needed more can be found in the university store)
- Heart rate sensors (ordered online)
- A board (to put all the materials together, can be locally bought)
- Tinfoil
- LED’s
- Speaker

Would the sensors need calibration?

Yes, both the capacitive sensors and the heart rate sensor require calibration. For the capacitive sensor this means that values need to be determined for which the hands are close enough or touching the steering wheel. If this threshold is known, it is also known when the hands are not touching the steering wheel.

The heart rate sensor needs to be calibrated with a known working heart rate sensor, such that any constant offsets can be determined beforehand. Also the reliability can be tested this way, which helps with determining thresholds for the heart rate.

Would the equipment be used in a controlled environment?

Since we will be making a steering wheel that is not attached to a car for our prototype, we have to make a simulation to show the steering wheel in action. This means that our equipment will be tested in a completely controlled and programmed environment. Since cars can be quite dangerous, we think it is better to test our product in a simulated environment than to put it in a real situation. This way, we can simulate different scenarios.

What data needs to be collected?

<u>In the product itself:</u>

Using the capacitive sensors, presence of the hands on the steering wheel can be detected. Using this information, the program will know if the driver is holding the steering wheel. As for the heart rate sensor, this would obviously collect the drivers heart rate.

<u>Determining thresholds for the product:</u>

The next step is to decide what heart rate is considered ‘dangerous’ in terms of getting tired/sleepy. An importing side of this decision is having to look into multiple different variables in behavior, environment and health that affect the heart rate. For example: The time of day, age, activity level (if a person rushes to their car), emotions, body temperature, insufficient nutrition, medication and more.

The resting heart rate could be anywhere between 40BPM to 100BPM depending on the individual. This is quite a large gap where the “the heart rate of being sleepy” might overlap between certain individuals. To decipher what heart rate should be used, some information about the individual must be known. This could also be determined by measuring the actual heart rate in rest of a certain driver, and using this information to our advantage.

Also the delay after which the system will send an alarm needs to be determined. To obtain this knowledge, research is being done.

How to collect and analyze data?

The data is collected into the arduino, which also takes care of the processing of the data. This analysis is, as mentioned above, dependent on certain variables and thresholds. Furthermore, analysis should also take historical data into account, in order to predict sleepy or distracted driving as accurately as possible.
All this analyzing will lead to an outcome, which will trigger certain actions in our simulation.

How to use data for automation, control or actuation?

When we have collected the data, we need to make sure the driver gets alerted if any of the input is not as it should. If the grip of the driver is loosening, audiovisual notifications should pop up after a set period of time, trying to get the driver’s attention back on the road. There will be different levels of alarms, to create some sort of build-up in alarm intensity.

Literature review

Additional literature research has been done, to further investigate underlying problems of distracted driving, but also to look into different levels of autonomous driving. This resulted in valuable information and concepts which we will use when designing our prototype. This additional research can be found in Appendix D.

Validation & research

With the measured data we can alert the driver of a dangerous situation if applicable. The phenomenon of boredom / sleepiness which leads to being unfocused will be reduced and the driver will be able to regain control and their attention will increase again. With this effect a lot of accidents caused by not being focused enough will decrease too. But to make proper decisions on the design process we need validation for our decisions. Research into this field is needed. Literature research will help us understand the potential risks with distracted drivers and perhaps some fundamental truths about human attention in this environment. We are interested in three key points:

1. The most important part is checking if our prototype actually works in terms of keeping the driver focused on the road.
2. Additionally we are interested in finding validation for which type of notification is best for driving. Ideally we would like empirical evidence whether something like a sound signal has a different effect than a light signal in terms of getting someone's attention.

Basic idea versus advanced implementation:

- **Basic idea:**
  - Checking if the driver has one or both hands on the steering wheel.
  - Different levels of notifications/alarms.

For this basic idea we have sketched digitally an outline of how the implementation would be possible in appendix A. It shows a minimal viable product of the concept which can be produced with an arduino and something that resembles a steering wheel. Alternatively we can 3D print that material.

- **Advanced implementation:**
  - Measuring the heart rate of the driver and if the driver has one or both hands on the steering wheel.
  - Multiple types of notifications.
  - Use the steering wheel to actually drive around in the simulation
  - Switch between autonomous driving and manual steering in the simulation.

As an addition of the existing design, we can add on more sensors and measurements. One thing we considered was the measurement of the heart rate which can tell us certain things about the driver. In appendix B, we have made an example of how these additional measurements will affect the whole system, and how it would lead to multiple notifications/alarms which would vary depending on the urgency of attention. This would add complexity to the existing design which would make the concept more interesting and perhaps opens up the door for customization in the way the notifications happen.

Modular approach
In order to work towards the end goal effectively, we've divided the tasks between the team members. This way, everyone has their own responsibilities.

Team leader (Lars):
- Coordination
- Time management
- Thinking of real-world implementation of prototype (what would be changed in a real product)
- Assist where-ever is needed
- Responsible for deadline deliveries
- Receive, digest and implement feedback into prototype/documentation

Researcher & Solution finder (Nathan):
- Collecting information about how or why things should be done about:
- Hardware
- Software
- Coming up with ideas based on the results of the findings above.
- Documenting everything which is found from the two points above.

Demo-day preparation & presenter (Sandi)
- Integrating the software and hardware
- Researching on validation for our decision
- Analyzing the design critically according to the problem statement
- Responsible for the final presentation of the final prototype & concept

Hardware Designer(Emir):
- Collecting all the information on materials.
- Gathering the materials needed.
- Making a visual prototype.
- Helping Floris to create a sleek physical prototype.

Hardware Designer (Floris):
- Creating a virtual design (sketch)
- General wiring (cable management)
- Allocating a (realistic) steering wheel
- Creating a sleek physical prototype

Programmer and Simulator (Catelijne)
- Process the input from the sensors
- Visualize input
- Simulation

Programmer (Sietze)
- Get data (input) from the sensors
- Make sense of the data from the sensors
- Main programming

Chapter 8: Conclusion and discussion

Finding/conclusions from the project

From testing, it can be concluded that the prototype made actually requires the driver to be paying attention to the driving. Even though the car is not autonomously driving (the driver has to manually steer using a gaming steering wheel), two hands need to be on the steering wheel in order to be certain that the driver is paying attention.

The implementation of the heart rate sensor has failed. This is unfortunate because it would have given a lot of additional data to process and to better understand whether the driver was paying attention.

It has been found that a combination between acoustic and visual signals work the best. Only visual signals could be easily overlooked, whereas only using acoustic signals, the amount of information being sent in a notification is limited. A combination between the two mentioned above will gain the attention of a driver by the acoustic signal after which additional information is given to the driver by the visual notifications.

Observations during testing/verifying

The prototype acts as an additional layer to the wheel, that detects whether the driver has his/her hands on the wheel. The setup consists of 2 LEDs that act as indicators, red for the warning to put hands on the wheel and orange for the sign that hands are off the wheel. The closer the hands are to the sensor, the higher the value that is received by the Arduino. This way a threshold can be determined, to assign a certain value to a certain distance between the hands and the steering wheel. When the value becomes lower than the set threshold, the notifications will go off.

Sometimes the driver´s touch is not registered and the driver needs to let go of the steering wheel quickly and then grab a hold of it to stop the alarm. If the driver tries to use the steering wheel with one hand, they will be notified just as if they did not have any hands on the steering wheel.

The steering wheel itself is static and does not affect anything in terms of direction.
At early stages of testing the capacitive sensor was only able to cover a small portion of the wheel. The driver will not have his hands only in one position, so a decision was made to improve it. After some brainstorming, the sizes of the two capacitive sensors were increased to cover each half of the wheel. This way it is easier for the driver to calmly drive with hands anywhere on each side of the wheel.

The arduino had to be close to the wheel, but should not affect the process of driving. A small box was made to put the setup with the Arduino and breadboard on the “dashboard”. This way the wires have enough distance to connect to a wheel and it does not affect the steering.

The driving and notifications are simulated in a simulation made in Unity. The steering has to be done by the driver himself. This makes testing easier. Using this simulation, actual driving can be simulated which leads to more realistic results. This also leads to a more realistic usage of the prototype.

Sensory measurements collected

The only data from the sensors that need to be collected is the data from the capacitive sensors. Initially information from the heart rate sensor was supposed to be collected as well, but due to technical difficulties the heart rate sensor has not been implemented.

The data that was actually collected is the data from the capacitive sensor. After the data is collected, that data is put through a map function to make the values a little bit more manageable since the values gotten can be more than 40000. The values from the map function are also handy when there needs to be an analog signal. In appendix E there are two graphs. One is the raw sensor data from the capacitive sensor library, the second one is the mapped value.

The arduino code for the prototype can be found in appendix F.

Problems encountered

During the design process a problem occurred, with the heart rate sensor namely: the sensor which was acquired should have been able to display a measured heart rate. However, it was defective and didn't give any readings. It seemed only to pick up noise and did not display expected values. This issue prevented the implementation of monitoring the heart rate.

When making the prototype, additional problems were encountered, namely:

- The sensors do not react equally well at any place. The sensor is most sensitive at the top of the steering wheel, where the cables are connected to. The whole steering wheel has foil around it. But it does not always react to the touch.
- A resistor of 1MΩ. When the resistors used were of lower value, the sensors were not sensitive enough to the touch and therefore gave us no useful data.

Assumptions made

Hardware

1. Having a heart rate monitor would be a safety net to have, which could provide valuable information to the driver.
2. Implementing a heart rate monitor to our system will be simple and easy

Users/drivers

1. Drivers can only keep a focus on something where little to no change is happening, for thirty minutes maximum. It is therefore necessary for drivers to have something stimulating that is a passive experience and does not affect the eyes of the driver. Audio entertainment is one example. This can lead to a synergy where the driver can keep their focus on the road without wavering.

2. Drivers getting used to assisted steering is only a concern if they have their hands off the steering wheel. This creates a bad habit as the hands will naturally find something else to do. Having the hands off the steering wheel puts the driver in a situation where it is significantly more likely to get distracted.
3. The phone is the biggest problem for drivers. Somehow removing the option to use the phone while driving is a difficult task but an ideal situation.

Cars

1. Today's autonomous cars are at level 2 of automation. Therefore it is still very important for the driver to keep the eyes on the road and be ready at all times to take over the steering wheel.
2. It will be a long time before we have fully automated cars, thus the need for something that prevents the humans in driver-assisted cars to be present and focused.
3. Automated systems can give us a false sense of security. It is important to combat this.

Assumptions on the design

1. People have a tendency to distract themselves with the use of their hands. Removing their ability to use their hands for anything other than the steering wheel will prevent them from any manual interference.
2. By locking the hands on the steering wheel, we can limit the amount of visual distraction for items inside the car, as the person cannot fiddle or touch other things.
3. By having a simple design that is simple and binary will have minimal cognitive distraction on the driver. Keeping the driver-assisted systems inside the car as simple as possible to lower the interactions needed between the driver and the system.

Discussion

A fully realized product of the final prototype could be very feasible to integrate in society. Apart from the steering wheel itself, the components needed for the capacitive sensing, alarm (and possible heart rate sensor) are fairly cheap and easy to buy. For mounting the product, it is possible to make a custom steering wheel with the technology already inside it. Another way is to make a ‘casing’ with the same technology inside it, but it can be easily mounted on the already existing steering wheel in a car.

In practice only two metal surfaces on the steering wheel would be seen, which do not interfere with driving in any way. Because this product is not annoying or uncomfortable, consumers will be less likely to disapprove of this product. This product is also easy to scale because of the low price cost of the extra hardware needed.

For future research, a couple of things are of interest:

- Further research and tweaking of the time a driver can remove their hands off of the steering wheel. Right now these periods are fairly short, which suffices for conceptual testing, but not for actual usage. To determine a proper period of time, additional research and testing should be done
- Implementation of a heart rate sensor

- Implementation of sensors which can sense other vitals
- Implementation of autonomous driving in the simulation

Chapter 9: References

Note: some of the below references are actually used in chapter 10, Appendices.

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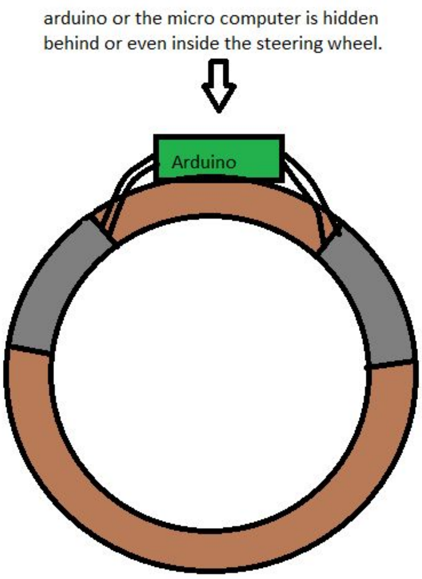
Chapter 10: Appendices

Appendix A:



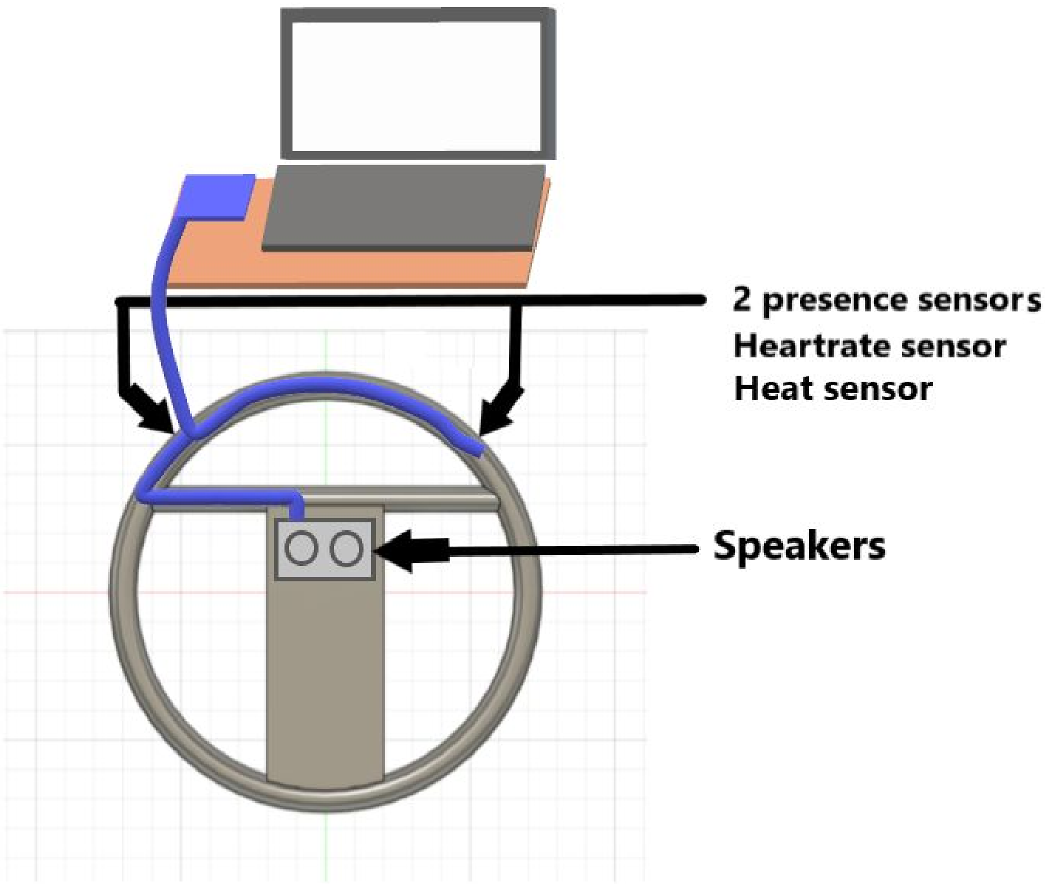
A sketch of the concept and potential prototype

Appendix B:

Notification	Eyes	Hand grip	Vitals
Nothing	On the road	Tight and firm	Pulse normal & blinking within normal range
Yellow alert	Away from the road less than 2 seconds	Loose	Pulse normal & blinking more than normal
Red alert	Away from the road more than 2 seconds	No grip	Pulse lower/higher than normal, more blinking than normal

An example of parameters and degrees of measurement

Appendix C:



A model of how the setup with arduino will look like.

Appendix D, additional literature review:

It is well established that traffic accidents are a big and complicated problem. It has been estimated both by WHO and CDC that more than 1 million people are killed in road accidents each year and many millions more are injured [8], [9]. WHO's projections indicate that road accidents will increase by about 65% within 20 years. There are a lot of underlying problems that play a role for road accidents. But the main focus for us will be driver-oriented problems. The driver and the mental state of that person. We can broadly categorize 3 mental states that have been shown to be critical factors to car accidents.

1. Intoxicated drivers
2. Sleep deprived / fatigued drivers
3. Distracted drivers

One technology that is trying to deal with these problems is the driver-assistance technology. At the end of that technological road, we have autonomous vehicles, that are independent of human intervention. This is not a new idea and has been under development since the 1940´s. [21]

Driver-assistance technology

This technology has 6 levels which describes the practical steps needed to go through until we have fully autonomous cars.

Level 0: No automation

Level 1: feet off - Adaptive cruise control.

Level 2: hands off - Assist in controlling speed and steering

Level 3: eyes off - Car able to drive itself but only under ideal certain conditions and areas. Human needs to remain alert and needs to override in case the task cannot be performed

Level 4: brain off - Difference between 3 and 4 is that level 4 can intervene if something goes wrong or there is a system failure. It almost never will require human intervention but a person can still override and drive manually. Only geofenced to certain areas.

Level 5: Fully automated - No human intervention. Pedals and steering wheels are gone and the vehicle can drive anywhere.

Paul Newman, professor of robotics at University of Oxford, has described some of the current problems we are facing today with autonomous cars [21]. Today the machine learning algorithms that drive cars are created mostly with probabilistic inference. And this is really a good way for people to create good autonomous cars but there are some problems:

1. Driving on a long thin road when a car is driving opposite towards you from a long distance. For the algorithm it will look like it is going to collide.
2. A lot of contextual stuff that has nothing to do with driving like: Understanding the tunes of an ice cream van and what that means, or passing a group of kids playing with a ball near the road.
3. When a car should break the rules of the road for the safety of others or the driver. One example is when an ambulance needs space to get through.

At the current moment with Tesla cars we are in level 2, where people are able to have their hands off of the steering wheel but still need to remain their eyes towards the road. Considering how long it took to get to level 2, and the problems we still face with this technology, it is unreasonable to assume we will have fully autonomous cars anytime soon. The technology is a good step towards dealing with driver-oriented problems, but it needs solutions to properly handle the driver-oriented problems.

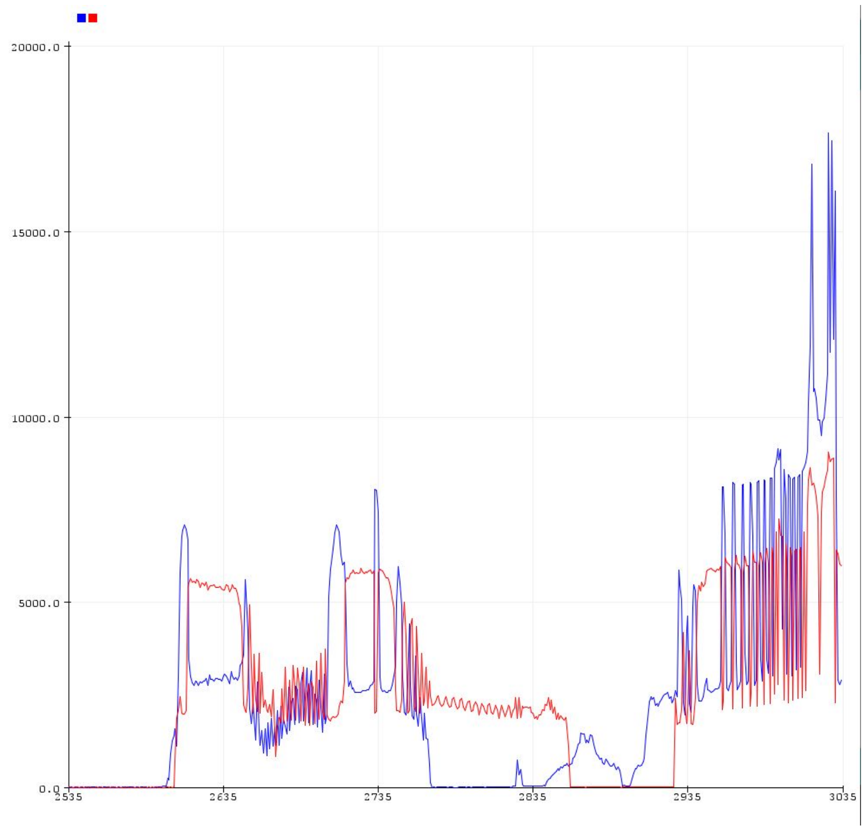
A study has been made to assess distracted driving and to come up with a framework for understanding and measuring the driver being distracted [22]. They categorize three main distractions:

1. Competition for visual processing (phone as an example)
2. Manual interference (hands off the steering wheel)
3. Cognitive sources of distraction (talking to someone as example)

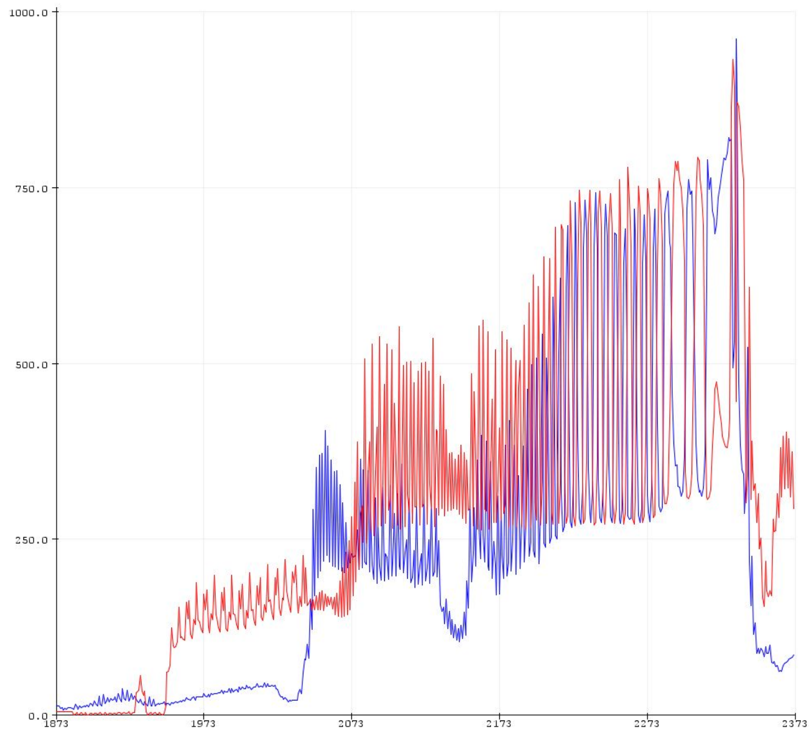
The two first are easy to spot as they are visual whereas the third one is more complicated. One way to measure the cognitive distraction is by testing the driver on their reaction time. Their results show us that more passive actions, like listening to music or audiobooks, do not affect the driver's reaction time and are as low of a cognitive distraction as doing nothing in the car. Talking to someone, whether it is on the phone, on speaker or even hands free, decreases the driver's reaction time significantly. This is relevant information for us when considering designing something that needs to prevent these cognitive distractions.

There have been multiple studies on dealing with eye-tracking detection. Everything from detecting the drivers eyes blinking in order to deal with fatigue [23], to using deep neural networking to spot whether the driver is distracted [24].

Appendix E, sensor data:



Raw sensor data.



Mapped sensor data. (from 0 to 1024)

Appendix F, arduino code:

```
#include <CapacitiveSensor.h>


CapacitiveSensor touch = CapacitiveSensor(3,2);
CapacitiveSensor touch2 = CapacitiveSensor(5,4);
// treshhold, the higher it is the more you can touch the foil. ctrl, shift, L will get you a graph
int treshold = 130;

unsigned long firstTime;
boolean holding = false;

const int ledPinMax = 13;
const int ledPin = 12;



// time it takes the led to go on in milliseconds
int maxLettingGo = 5000;
int minLettingGo = 2000;

long capHigh = 0;
long capLow = 400000;

byte sensorCheck = 0;
byte simulation;

boolean s1 = false;
boolean s2 = false;


void setup() {
```

```
Serial.begin(9600);

pinMode(ledPinMax, OUTPUT);

pinMode(ledPin, OUTPUT);


while(millis() < 5000){



  if(touch.capacitiveSensor(30) > capHigh){

    capHigh = touch.capacitiveSensor(30);

    }

    else if(touch2.capacitiveSensor(30) > capHigh){

      capHigh = touch2.capacitiveSensor(30);

      }


  if(touch.capacitiveSensor(30) < capLow){

    capLow = touch.capacitiveSensor(30);

    }

   else if(touch2.capacitiveSensor(30) < capLow){

     capLow = touch2.capacitiveSensor(30);

    }


  }


}


void loop() {



//sensor value

unsigned long sensorValue  = touch.capacitiveSensor(30);

unsigned long sensorValue2 = touch2.capacitiveSensor(30);
```

```
int sv1 = map(sensorValue, capLow, capHigh, 0, 1024);
int sv2 = map(sensorValue2, capLow, capHigh, 0, 1024);

//Serial.println(simulation);

Serial.print(sensorValue);
Serial.print(",");
Serial.println(sensorValue2);
if(sv1 > treshold && s1 == false){
  sensorCheck += 1;
  s1 = true;
  }
  else if(sv1 < treshold && s1 == true){
    s1 = false;
    sensorCheck -= 1;
    }

if(sv2 > treshold && s2 == false){
   sensorCheck += 1;
   s2 = true;
  }
   else if(sv2 < treshold && s2 == true){
    s2 = false;
    sensorCheck -= 1;
    }


//checks if you are holding more than one sensor
if(sensorCheck > 1){
```

```
  holding = true;
  }

//checks if you only touch one or none  of the sensors
if(sensorCheck < 2 && holding == true){
  firstTime = millis();
  holding = false;
  }

//checks if it has been 5 seconds since you where holding both sensors
if(millis()-firstTime > maxLettingGo && holding == false){
digitalWrite(ledPinMax, HIGH);
   tone(8, 500, 20);
   simulation = 2;
  }

else if(millis()-firstTime > minLettingGo && holding == false){
  digitalWrite(ledPin, HIGH);
  simulation = 1;
  }

else{
  digitalWrite(ledPin, LOW);
  digitalWrite(ledPinMax, LOW);
  simulation = 0;
  }
}
```