**The Role of Spatial Audio in Autonomous Car Safety**

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**Abstract**

Self-driving (autonomous) cars can drive people anywhere without a need to touch the gas pedal. How do we make these cars safe enough for consumers? One safety concern of self-driving cars is that the driver can relax while the car performs all of the necessary functions. However, the car can request to be overridden (the driver taking control of the car). Manual override will occur if the car is malfunctioning or if there is a danger/hazard nearby. If the driver is not paying attention, this could lead to danger on the road. To solve this problem, I have proposed a new implementation for autonomous cars using spatial audio. Spatial audio gives sound a 3D effect, orienting the noise in one place and giving audio a direction. I will test manual override in autonomous cars using spatial audio through earbuds. I will use the driving simulator at LMU and have participants perform certain tasks with earbuds in. Then, I will send them an alert and time how long it takes them to take control of the car. I expect that these times will decrease compared to previous research, creating a smoother transfer between the car and the human.

**Introduction:**

With the advancement of technology, it’s fascinating to think of the potential and future of inventions once thought impossible. This advancement has specifically affected and propelled the automobile industry through the introduction of the electric car and the implementation of artificial intelligence into automobiles. However, perhaps the biggest effect of this technological revolution has been the emergence of the self-driving car. A car that can drive you from your house to the grocery store without you even touching the wheel seems like fiction; however, this is possible and companies are investing billions of dollars into this industry.

Autonomous cars are split into 5 levels, starting from 0 (fully manual), to 5 (full automation) (Riedmaier 1). Currently, Tesla’s electric cars have reached level 2, meaning the car can drive itself, but a driver is necessary to monitor and take over if need be (Shwartz 2021). It will take years of testing and research to advance to levels 3 and 4. Todd Litman, who is the founder of the *Victoria Transport Policy Institute,* an independent research organization, estimates that level 5 autonomous cars will be affordable and reliable around 2030 (Litman 2022).

There have been many debates about the ethics and consequences of these cars. First off, some people don’t think that they are possible. People are also scared of the chance that hackers can take control of vehicles and/or take people’s personal data. Additionally, people are concerned about how these cars would operate in different weather conditions. However, the amount of benefits that these cars can bring greatly outweigh these negatives. These cars use sensors and cameras to be able to react a lot faster than humans. They also don’t have a blindspot; the multiple cameras and sensors can see all sides of the car. Furthermore, autonomous cars will reduce the amount of traffic on the road and lead to less emissions due to their ability to interact and communicate with other autonomous cars, and due to their ability to decrease rapid acceleration and breaking (Igini 2022). However, with all of this said, there is one feature of autonomous cars that brings up a significant safety concern: human override. Researching this issue further led me to my question, which is: how will spatial audio through earbuds affect the reaction time of human’s responding to an override request in autonomous cars? Answering this question will not only make these cars safer, but it will hopefully bring society closer to bringing autonomous cars to the marketplace and making all of the benefits mentioned earlier a reality.

**Background:**

Due to the nature and idea of self-driving cars, people will be able to sit back and relax while their cars do the work of driving them to their desired destination. People could be taking work calls, watching movies, or sleeping during their journey. In other words, there is a lack of communication between the car and the driver (Beattie 2017). This can lead to problems as there will be moments when the car requests to be overridden. This means that the human must take over control and drive again. For example, if the car starts malfunctioning, the human might need to grab the wheel and pull over, or if an animal runs into the street, the car could freak out and require the human to take over. If the human is sleeping or watching movies, they might not be able to react in time.

I am proposing the use of spatial audio in autonomous cars to improve the safety and efficiency of the transition between the car and the driver. Spatial audio is an emerging technology that gives audio a 3 dimensional effect (Lacoma 2022). A new implementation of spatial audio is called head-tracking, which basically has the audio you’re listening to move with your head. It provides a direction to the audio you’re listening to (Koe 2021). For example, if your headphones are connected to your computer and you turn your head away from your computer, the sound’s origin will still come from the computer. It is available in headphones such as Airpods or Beats.

Spatial audio can come in handy with autonomous driving because if the car is approaching a hazardous situation requires human takeover, spatial audio can alert the driver of this danger and can inform the driver what direction the hazard is coming from, using the 3D effect (Stojmenova 2020). For instance, if there is a drunk driver that is out of control in the lane behind you to your left, this audio will alert you where the car is coming from and you can safely get out of the way. Through the use of spatial audio, the driver will hear the alert in the direction of the threat. This will decrease the reaction time of the driver and will make for a more seamless transition between the car and the human, thus making the autonomous car safer.

Kristina Stojmenova and other fellow researchers tested the time taken for a driver to respond to an override request in autonomous cars using spatial audio through the car’s speaker system. They found that the reaction time was quicker by around half a second using spatial (directional) audio compared to non-directional audio (Stojmenova 2020). Using this information, I started wondering if spatial audio through earbuds could decrease this reaction time even more, leading to my research question: how will spatial audio through earbuds affect the reaction time of human’s responding to an override request in autonomous cars? This question arose for many reasons. First off, earbuds can be much louder compared to a car's stereo system. For example, if the driver is sleeping and the car requests to be overridden, hearing an alert through earbuds would be louder and more direct. Furthermore, David Beattie conducted a survey and found that people found hearing alerts through earbuds in autonomous cars made them feel more in control of the vehicle (Beattie 2017).

**Methods:**

In order to answer my question, I want to start by using the driving simulator in the LMU Engineering building. I will initially have to ask for permission to use this space for the four weeks that I have cut out for it in my timeline. I will choose certain participants and have them sit in the driver seat with earbuds in. Next, each of the students will partake in specific activities, such as watching a movie or taking a phone call. While they are distracted with these activities, I will send them an auditory alert, timing from when they get the alert to when they take control of the car. Finally, I will compare these times with the times from Stojmenova’s experiment.

**Expected Results:**

I am expecting the reaction time of participants wearing earbuds to be lower compared to Stojmenova’s research, and I will display these times in an academic report. Any decrease in reaction time will have a large enough impact to save thousands of lives on the road. I want to use this report to inform companies who are working on autonomous cars about my new way to make these cars safer. Hopefully, my research can bring engineers one step closer to making autonomous cars a reality.

I think that my paper can also help inform and educate the general public on the rise of automated cars. Furthermore, I hope that I can alleviate some of the doubts that people have regarding the safety and possibility of these cars.

**Conclusion and future work:**

The implementation of autonomous cars into society is inevitable due to the amount of time and money that companies are putting into perfecting them; thus, it is necessary to try and make them as safe as possible. With the application of spatial audio through earbuds, these cars will have a more efficient way to inform the user if they need to hand over control, and they can let the driver know if any danger is coming and from what direction.

Many states throughout the U.S. have laws prohibiting drivers from wearing earbuds or headphones. These laws make sense, because wearing earbuds could limit a driver's awareness of what is happening around them (Smith 2022). However, with autonomous cars, these laws shouldn’t be necessary as the driver won’t be driving most of the time. If my research proves successful, I can present my case to experts and start a discussion around modifying this law in the future.

**Budget and Timeline**

| **Timeline** | **Weeks 1-3** | **Weeks 4-7** | **Weeks 8-10** |
| --- | --- | --- | --- |
| **Activities** | Conducting any further research I need, buying my airpods, finding participants to take part in my research, preparing certain tasks for them, and getting permission to use the driving simulator from the LMU School of Engineering. | Conducting my research, having my participants perform one task per week. Recording and tracking all of my data. | Gather all of my times, compare my times to Stojmenova’s times, and write a report with this data. |
| **Charges:** | **15 x 6(3) = $270** | **15 x 6(4) = $360** | **15 x 6(3) = $270** |
|  | **$250 (airpods)** | **-** | **-** |
|  | **$520** | **$360** | **$270** |
| **Total Cost:** |  |  | **$1150** |

**References**

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