Self-Driving Cars: Poor Driver Alertness and Solutions

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Abstract

Organizations across various industries are currently working on or have already put a self-driving car on the public road. This phenomenon is not solely observed across car manufacturers. Ride hailing and technology companies are also competing to bring self-driving cars to the consumer market. Although often advertised as self driving cars, vehicles that are available today are only semi-autonomous. When operating a semi-autonomous car, a driver is required to stay alert at all times. This is because occasional hand-off from the car to driver may be necessary when the car is unable to safely plot a journey forward. Therefore, driver alertness is paramount to avoid road accidents when operating a semi autonomous car. In this paper, contributing factors that lead to poor driver alertness are identified. These include passive fatigue, distraction, less effective driving interfaces, and an over reliance on automation. Solutions that are available to mitigate these contributing factors are also noted. Solutions can range from simple techniques such as measurement of grip strength on the steering wheel to more advanced techniques such as drowsiness monitoring systems. Based on the assessment of available solutions, the paper concludes by highlighting recommendations for stakeholders.

1.0. Introduction

Self driving cars offer driving automation of varying levels. The Society of Automotive Engineers (SAE) has defined a classification system to measure this degree of driving automation and it is considered the industry standard. This classification system defines 6 levels of autonomy (i.e. Level 0 to Level 5). A level 0 car offers no automation and the driver is required to perform all dynamic driving tasks (van Wyk, Khojandi and Masoud, 2020). Dynamic driving tasks can be defined as all the functions that a driver must carry out in real time in order to operate the vehicle safely on the road. In a car with level 0 automation, There may be systems in place such as warnings or intervention systems to help the driver but that is not considered as driving automation. For example, an emergency braking system is considered as an intervention system but it does not technically drive the vehicle and thus is not considered as driving automation (The 6 Levels of Vehicle Autonomy Explained, 2021).

A level 1 self driving car will be able to execute either steering or acceleration/deceleration. "Level 2 automation is present if one or more assisted automation tasks are performed by the autonomous system where the driver is responsible for the monitoring of the driving environment and ultimately the control of the vehicle" (van Wyk, Khojandi and Masoud, 2020).

A level 3 self driving car is able to automate all dynamic driving tasks in favorable conditions. It is still expected that a driver remains alert at all times because they may be asked to take over if uncertain conditions such as wet or icy roads arise.

Level 4 and 5 self-driving cars are able to perform all dynamic driving tasks even if a request for driver intervention goes unnoticed and thus driver alertness is not a requirement when operating such cars. If the driver wants to perform the dynamic driving tasks, Level 4 self-driving cars still offer this functionality via the steering wheel and pedals. However, Level 5 self driving cars eliminate all dynamic driving tasks entirely. There is no steering wheel or pedals and the car only operates in full autonomous mode.

Self driving cars that are available to consumers today can only provide up to Level 3 driving automation and are also known as semi autonomous cars. Due to insufficient information or limited design choices, semi autonomous cars suffer from a scenario known as disengagement mode. At the time of disengagement, full control of the car is handed over to the driver and this can occur at short notice (Favarò, Eurich and Nader, 2018). This handover of control from the car to the driver can often be problematic because it requires the driver to remain alert and also respond quickly to a request for intervention.

2.0. Context and Research Questions

A notable finding of a recent Australian National Survey states that more than 20% (i.e. 1 in 5 people) of the population believe that a self-driving car can maneuver by itself to prevent any accidents between road users or objects (Cunningham et al., 2019). This means that 1 in 5 people put a high level of trust on self driving cars to avoid collisions. Factors such as a high level of trust in semi-autonomous vehicles may lead to reduced driver alertness. Therefore, it is important to first answer the following research question in relation to semi autonomous cars:

- What are the contributing factors that lead to reduced driver alertness?

Improving driver alertness would directly reduce road accidents and the safety of all road users would improve. Therefore, after identifying the contributing factors that lead to poor driving alertness, it is also important to address the following research question:

- What are the solutions that mitigate the contributing factors and lead to improved driver alertness?

3.0. Project Aims

This paper aims to identify the contributing factors or activities conducted by the driver that leads to poor driver alertness when operating a self driving car. A thorough evaluation and comparison of available solutions that deter or mitigate these contributing factors will then be conducted. Based on the analysis of these solutions, concise recommendations to improve driver alertness will be provided to all major stakeholders that are involved in the life cycle of a car.

4.0. Expected Outcomes

The three main outcomes of this research paper are detailed below:

- Identification of contributing factors that leads to reduced driver alertness when operating a semi autonomous car.
- An assessment of existing research papers that demonstrate solutions to improve driver alertness.
- Recommendations for stakeholders regarding available solutions to improve driver alertness.

5.0. Benefits of Improved Driver Alertness in Semi Autonomous Cars

In the U.S., it is reported that in 2016, over 90% of road accidents were caused by human error (National Highway Traffic Safety Administration, 2017). Improving driver alertness could substantially and directly lead to a reduced number of road accidents and thus improve safety for all road users.

This research will also make car manufacturers and governments more aware about solutions available to improve driver alertness and this will allow them to make targeted and sound investments. Therefore, this research could be beneficial for all major parties involved in the life cycle of a car - drivers and other road users, car manufacturers, and the government.

Several passive benefits can also be associated with improved driver alertness. For example, improved driver alertness will allow a driver to take control of the vehicle in uncertain road conditions. This can lead to a more stable driving experience. For example, a self-driving car may not detect wet or icy roads but improved driver alertness will allow a driver to spot such conditions. The driver can then take control of the vehicle and slow down in order to prevent the vehicle from drifting or braking unexpectedly.

6.0. Research Methodology

Identifying the contributing factors is the first step towards improving driver alertness. This will be achieved by examining existing literature such as survey results from drivers and road users. Furthermore, findings reported by investigation bodies, car manufacturers, and researchers will also be evaluated.

After identifying the contributing factors that lead to reduced driver alertness, the project will aim to evaluate and compare proposed solutions to mitigate these factors. This area of research will be conducted by reviewing existing literature such as research papers.

7.0. Literature Review

Upon examining the existing literature, the contributing factors were categorized into four major areas:

1. **Passive Fatigue:** The results of existing simulator studies have shown that automation may actually increase passive fatigue (Saxby, Matthews, Hitchcock and Warm, 2007). While active fatigue is associated with work overload, passive fatigue is related to fatigue that occurs due to lack of direct control and low workload (Desmond and Hancock, 2001). Passive fatigue can also result from other conditions such as monotonous roads (May and Baldwin, 2009). Another study also notes the effects of subjective fatigue induced by automation and its effects on performance (Persson et al., 2003). Increased fatigue can lead to reduced situational awareness and thus reduced driver alertness. Evidence of this low situational awareness has been recorded by the slower braking responses performed by the driver when operating a semi autonomous vehicle in comparison to conventional vehicles (Young and Stanton, 2007). Low situational awareness associated with passive fatigue can lead to reduced driver alertness and road accidents. Research has been conducted to identify why passive fatigue occurs. It has been widely studied that performing monotonous tasks such as supervised driving can actually be detrimental to performance and be a major reason as to why passive fatigue occurs (Dunn and Williamson, 2012).

2. **Distraction:** Due to work underload and monotony associated with passive fatigue, a driver may seek active engagement elsewhere. Hence, distraction can also be noted as a resultant effect of passive fatigue. Distraction may also be caused by systems that provide access to information and entertainment (Feng, Liu and Chen, 2017), conditions in the external environment (Horberry et al., 2006), or a compromised state of mind. Respondents in a survey were asked about the type of activities they would conduct when operating a self-driving car. 59.4% of the respondents said that they would look

out the window. 59.5% of the respondents also said that they would talk to other passengers (Bansal and Kockelman, 2016).

3. **<u>Less Effective Driving Interface:</u>** Singular modes of communication such as audio signals are less effective than systems that use a combination of techniques such as audio and video signals (Lundkvist and Nykänen, 2016).

4. **<u>Over reliance on Automation:</u>** Consumers often place a high level of trust on semi autonomous vehicles and this can lead to reduced driver alertness. The consumers cannot be solely criticized for this as these cars are often advertised as having 'self driving' or 'Autopilot' features. It may lead consumers to believe that the car is fully autonomous even though it is not. In 2020, a German court ruled that the word 'Autopilot' is misleading because it suggests that the vehicle can drive on its own (Ewing, 2020).

Several research papers have identified solutions to mitigate contributing factors such as reduced situational awareness associated with performing monotonous tasks and passive fatigue. Identified solutions have been categorized into three main mitigation strategies:

1. **<u>Prevention:</u>** One study notes the importance of active engagement systems as a solution when operating semi autonomous vehicles to prevent passive fatigue (Hancock and Szalma, 2003). Strategically timed verbal tasks such as a trivia is one such technique that has been proposed to improve driver alertness (Atchley, Chan and Gregersen, 2013).

2. **<u>Detection:</u>** Another technique notes the implementation of driver monitoring systems such as the usage of cameras to track and evaluate the driver's face for drowsiness or distractions. For example, since 2008, Toyota has offered a monitoring system in their vehicles that track a driver's eyelids. This system allows the vehicle to check for any signs of drowsiness (Dong, Hu, Uchimura and Murayama, 2011). Several car manufacturers have employed more advanced techniques in their driver monitoring systems to test for reduced driver alertness. Some examples of such techniques are measuring grip strength on the steering wheel, speed of the vehicle and the way the driver operates the pedals and indicators.

3. **<u>Correction:</u>** In some instances, preventive solutions may fail to improve driver alertness. In such cases, the driving interface must implement corrective measures in order to prevent road accidents. For example, automated fallback functions such as emergency or real time parking have been proposed in an event where the driver is not responsive. A combination of feedback mechanisms can also be used to gain attention of a driver

more quickly. For example, a driver may notice a combination of audio and haptic signals (Example: vibrating seat or steering wheel) more quickly than singular modes of communication such as utilizing only audio signals.

8.0. Analysis & Results

Contributing factors that lead to poor driver alertness have been identified and categorized into four major areas: Passive fatigue, distraction, less effective driving interface, and over-reliance on automation. Various solutions have been identified to mitigate these contributing factors. Identified solutions are categorized into four major areas: Prevention, Detection, and Correction. These results are summarized in the table below:

Mitigation Strategy	Solution	Passive Fatigue	Distraction	Less Effective Driving Interface	Over-reliance on automation.
Detection	Measurement of steering wheel grip strength.	✅	✅		
Detection	Measurement of the way pedals and indicators are operated.	✅	✅	✅	
Detection	Measurement of driving speed.	✅	✅		
Detection	Advanced monitoring methods such as driver's face for drowsiness.	✅		✅	✅
Prevention /Correction	Utilization of multiple methods of communication to gain attention such as audio and visual or audio and haptic signals.	✅	✅	✅	✅
Prevention	Interactive trivia or games.	✅		✅	✅
Correction	Automated fallback function for crash prevention such as emergency or real time parking.	✅	✅	✅	✅

The table below demonstrates a detailed assessment of the solutions that have been noted in this paper.

Mitigation Strategy	Solution	Description of solution	Limitations of solution
Detection	Measurement of steering wheel grip strength.	A low grip strength on the strip wheel may indicate that the driver is fatigued or distracted.	System can be easily deceived by attaching weighted objects to the steering wheel to simulate the driver’s hand. Hence, it is not very effective and does not mitigate contributing factors such as less effective driving interfaces and an over reliance on automation.
Detection	Measurement of the way pedals and indicators are operated.	Late use of pedals and indicators may mean that the driver is fatigued or distracted.	The driver only uses the pedals and indicators when they are operating the car. Hence, this measurement / solution to improve driver alertness is only applicable when the driver is controlling the car and not when it is being driven semi autonomously.
Detection	Measurement of driving speed.	A low or high driving speed may indicate that the driver is distracted or fatigued.	The solution may not be applicable in all situations. For example, a driver may have a high driving speed in case of a health emergency or natural disaster.
Detection	Advanced monitoring methods such as driver's face for drowsiness.	Measurement of variables that indicate that a driver is distracted or fatigued such as yawn rate, eye blink rate and position of head. By being able to ensure that the driver’s focus is on the driving tasks, such solutions can also mitigate over reliance on automation.	If a driver is wearing a sunglass or face mask, the accuracy of the drowsiness monitoring system may be greatly reduced. Hence, the solution may not mitigate contributing factors such as less effective driving interfaces.
Prevention/ Correction	Utilization of multiple methods of communication	The utilization of a combination of communication methods such as audio and haptic	By being able to gain attention of a driver more quickly, the solution is able to improve poor driver alertness but not detect poor driver alertness.

	to gain attention.	(i.e. vibrating seat or steering wheel) can be more effective in gaining a driver's attention than using singular methods such as only audio signals.	
Prevention	Interactive trivia or games.	Driver's can be periodically asked to perform a simple task such as interactive trivia or game to prove that they are alert. Such solutions are usually auditory based and can be employed via technologies such as Voice Assistants.	If the trivia/game is too challenging, it may actually distract the driver and reduce driver alertness. Hence, the solution may not mitigate contributing factors such as distraction but actually has the possibility of aggravating it further. Additionally, trivia/games are generally audio based and may not be suitable for hearing impaired drivers.
Correction	Automated fallback function for crash prevention such as emergency or real time parking.	If preventive solutions are unable to improve driver alertness, corrective measures such as emergency / real time parking can be activated until it can be confirmed that driver alertness has been regained.	Emergency parking may not always be available (For ex: highway or busy roads) and it may take time to activate it.

9.0. Conclusion & Future Outlook

Self driving cars that are available to consumers today offer up to Level 3 autonomy. Drivers are required to be alert at all times as they may need to take control in unfavorable conditions. Failure to stay alert and take control will significantly increase the likelihood of road accidents. Hence, it is vital to identify contributing factors that lead to poor driver alertness and corresponding solutions to mitigate them. The contributing factors that were identified were categorized into four major areas: Passive fatigue, distraction, less effective driving interface, and an overreliance on automation. Solutions were categorized into three main mitigation strategies: Prevention, detection, and correction. The identified solutions are able to mitigate the contributing factors significantly and thus reduce road accidents. However, the contributing factors can only be entirely eliminated when self driving cars are able to offer level 4 or 5 autonomy.

References

Atchley, P., Chan, M. and Gregersen, S., 2013. A Strategically Timed Verbal Task Improves Performance and Neurophysiological Alertness During Fatiguing Drives. Human Factors: The Journal of the Human Factors and Ergonomics Society, 56(3), pp.453-462.

Bansal, P. and Kockelman, K., 2016. Are we ready to embrace connected and self-driving vehicles? A case study of Texans. Transportation, 45(2), pp.641-675.

Cunningham, M., Regan, M., Horberry, T., Weeratunga, K. and Dixit, V., 2019. Public opinion about automated vehicles in Australia: Results from a large-scale national survey. Transportation Research Part A: Policy and Practice, [online] 129, pp.1-18. Available at: <https://www.researchgate.net/publication/319006657_Preliminary_findings_from_the_first_Australian_National_Survey_of_Public_Opinion_about_Automated_and_Driverless_Vehicles>.

Desmond, P. and Hancock, P., 2001. Stress, workload, and fatigue, Eds. Peter A. Hancock and Paula A. Desmond, Lawrence Erlbaum Associates, Publishers, Mahwah, NJ, 2001, 682 pp., Hardcover: ISBN 0-8058-3178-9, $75. Human Factors and Ergonomics in Manufacturing, 11(2), pp.189-190.

Dong, Y., Hu, Z., Uchimura, K. and Murayama, N., 2011. Driver Inattention Monitoring System for Intelligent Vehicles: A Review. IEEE Transactions on Intelligent Transportation Systems, 12(2), pp.596-614.

Dunn, N. and Williamson, A., 2012. Driving monotonous routes in a train simulator: the effect of task demand on driving performance and subjective experience. Ergonomics, 55(9), pp.997-1008.

Ewing, J., 2020. *German Court Says Tesla Self-Driving Claims Are Misleading (Published 2020)*. [online] The New York TImes. Available at: <https://www.nytimes.com/2020/07/14/business/tesla-autopilot-germany.html> [Accessed 14 October 2021].

Favarò, F., Eurich, S. and Nader, N., 2018. Autonomous vehicles' disengagements: Trends, triggers, and regulatory limitations. Accident Analysis & Prevention, [online] 110, pp.136-148. Available at: <https://www.sciencedirect.com/science/article/pii/S0001457517303822> [Accessed 6 September 2021].

Feng, F., Liu, Y. and Chen, Y., 2017. A computer-aided usability testing tool for in-vehicle infotainment systems. Computers & Industrial Engineering, 109, pp.313-324.

Hancock, P. and Szalma, J., 2003. Operator Stress and Display Design. Ergonomics in Design: The Quarterly of Human Factors Applications, 11(2), pp.13-18.

Lundkvist, A. and Nykänen, A., 2016. Response Times for Visual, Auditory and Vibrotactile Directional Cues in Driver Assistance Systems. [online] Available at: <https://www.jstor.org/stable/26167740?seq=1> [Accessed 7 October 2021].

May, J. and Baldwin, C., 2009. Driver fatigue: The importance of identifying causal factors of fatigue when considering detection and countermeasure technologies. Transportation Research Part F: Traffic Psychology and Behaviour, 12(3), pp.218-224.

National Highway Traffic Safety Administration, 2016. 2016 Fatal Motor Vehicle Crashes: Overview. [online] National Highway Traffic Safety Administration. Available at: <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812456> [Accessed 16 August 2021].

Persson, R., Garde, A., Hansen, Å., Ørbaek, P. and Ohlsson, K., 2003. The influence of production systems on self-reported arousal, sleepiness, physical exertion and fatigue-consequences of increasing mechanization. Stress and Health, 19(3), pp.163-171.

Saxby, D., Matthews, G., Hitchcock, E. and Warm, J., 2007. Development of Active and Passive Fatigue Manipulations Using a Driving Simulator. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 51(18), pp.1237-1241.

Synopsys.com. 2021. The 6 Levels of Vehicle Autonomy Explained | Synopsys Automotive. [online] Available at: <https://www.synopsys.com/automotive/autonomous-driving-levels.html> [Accessed 6 September 2021].

van Wyk, F., Khojandi, A. and Masoud, N., 2020. Optimal switching policy between driving entities in semi-autonomous vehicles. Transportation Research Part C: Emerging Technologies, [online] 114, pp.517-531. Available at: <https://www.sciencedirect.com/science/article/pii/S0968090X19300981> [Accessed 6 September 2021].

Young, M. and Stanton, N., 2007. Back to the future: Brake reaction times for manual and automated vehicles. Ergonomics, 50(1), pp.46-58.

Yurtsever, E., Lambert, J., Carballo, A. and Takeda, K., 2020. A Survey of Autonomous Driving: Common Practices and Emerging Technologies. IEEE Access, [online] 8, pp.58443-58469. Available at: <https://ieeexplore.ieee.org/document/9046805> [Accessed 16 August 2021].