AN INVESTIGATION INTO THE SOCIETAL PERCEPTION AND ACCESSIBILITY OF AUTONOMOUS VEHICLES

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On my honor as a student, I have neither given nor received unauthorized aid on this assignment

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Introduction

In the last decade, more people have become interested in the development of autonomous vehicles (AVs). Companies like Tesla have contributed to the excitement, and other manufacturers are trying to develop their own autonomous cars to compete. While there is a lot of discussion and excitement surrounding AVs, there are also many concerns that need to be addressed by car manufacturers. People are hesitant to be a passenger in or an owner of a self-driving car for a variety of reasons such as a lack of familiarity and trust, and companies should take steps to address these concerns in order to build confidence in their potential customer base. The aim of this paper is to investigate the various questions and concerns that have been raised about the integration of autonomous vehicles into society, what steps car manufacturers have taken to respond to them, and if the projected benefits corporations claim these vehicles to have can be accessed by everyone. Furthermore, recommendations will be made for what steps can be taken by manufacturers and the government to ensure the trust in autonomous cars through different methods that prioritize safety and transparency.

Literature Review

The Benefits of Self-Driving Cars

Numerous benefits of using self-driving technology to operate cars have been cited by companies and individuals alike. Firstly, controlling a vehicle using electromechanical controls greatly reduces or even eliminates the human error that appears when a car is manually controlled. Whether a driver is tired, distracted, or under the influence of a substance that impairs their vision and processing time, it is extremely risky for them to be behind the wheel. A car controlled by sensors and actuators have much faster processing speeds and reaction times, and

they would not be susceptible to any distractions or other types of these impairments (Birnbacher and Birnbacher, 2017).

Another major benefit to the widespread, commercial use of autonomous vehicles could be the reduction of gas emissions. In 2007, 2.8 billion gallons of gasoline were needlessly expended, with the standstill of traffic contributing to these emissions (Beiker, 2012). A self-driving car would maintain a closer following distance between itself and the car in front of it which would allow for more cars to fit in the same length of lane, potentially reducing emissions and time stuck in traffic (Fernandes & Nunes, 2010). This impact can be further recognized through the implementation of truck platooning, which involves a chain of 18-wheeler trucks autonomously following each other on commercial roads. As the gap between the trucks is minimized, each truck would experience less air resistance and less fuel would be expended per trip.

So, What's the Catch?

There appears to be great promise in what autonomous cars can achieve and bring for society. Many other positive impacts of AVs may not seem apparent now but could certainly become clearer as companies continue to develop, test, and spread this technology. Companies such as Waymo and Tesla have created cars that are extremely attractive to the general public and have generated conversation regarding the trajectory of AV development. Waymo cars are classified under Level 4 autonomy, which indicates the vehicle is capable of autonomous control to a great extent as seen in Figure 1 (*SAE Levels of Driving Automation™ Refined for Clarity and International Audience*, 2021).

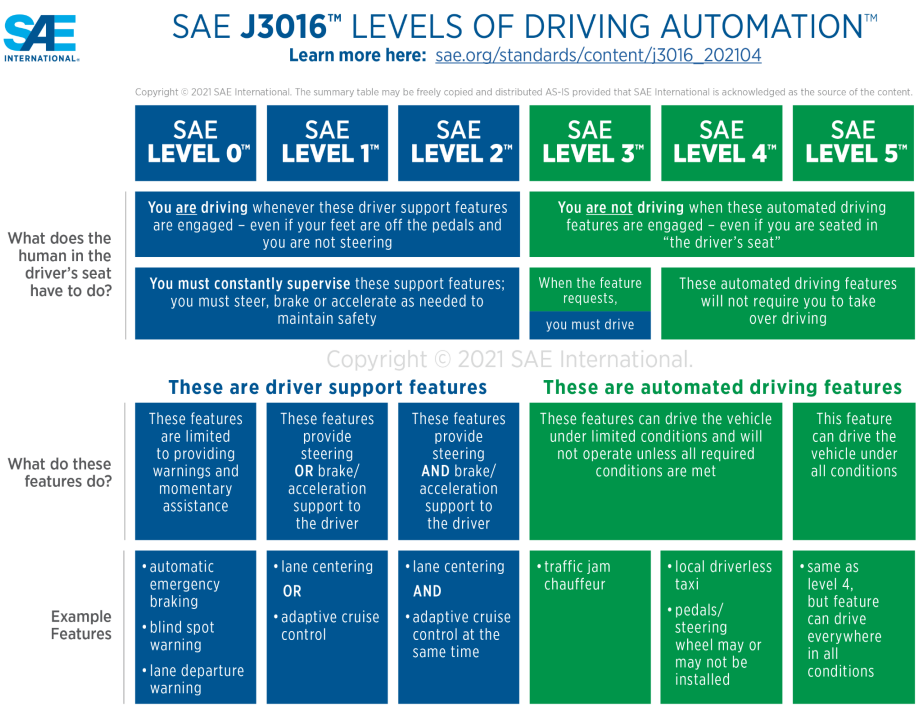

Figure 1: Infographic indicating the varying levels of autonomy according to the Society of Automotive Engineers.

On the other hand, Tesla is classified as Level 2 autonomy, so users must be fully aware of their surroundings while at the wheel and be ready to manually take control of the car at any time. Waymo cars are available to be used as a transportation service, while Tesla vehicles can be purchased by any individual.

The current advancements in this technology should theoretically suggest that self-driving cars are ready to be welcomed with open arms once more of them are on the market. However, it may not be that simple. On one hand, a variety of systems that perform driver assistance, such as backup, lane-changing, and cruise control, have been employed in many cars within the last couple of decades and are found to be particularly useful by drivers. On the other hand, the concept of technology controlling the acceleration, braking, and steering operations in a car is very novel and can be difficult for some to accept. An individual's interpretation of the

effects of driving an autonomous vehicle as being beneficial financially, timewise, and for safety can lead them to have a more optimistic outlook on this technology, while anxiety surrounding these systems could have adverse effects and lead people to be less likely to make use of self-driving cars themselves (Hohenberger et al., 2017).

Aside from individual perceptions of AVs, a number of ethical concerns have been raised with these cars on the road and how they might make decisions in driving scenarios with potentially fatal outcomes. With that being said, some of these ethics concerns tend to be posed as extreme hypothetical scenarios. Although they do serve the purpose of initiating conversations about what nuances are at play in the types of situations encountered while driving, they can be hard to address due to their unrealistic nature. The objective of raising ethical questions is to determine how the decision-making process can be incorporated into the vehicle's algorithm (Geisslinger et al., 2021). Ultimately, the course of action developers pursue to build a self-driving car should include a reflection on how humans drive, what they are thinking about while behind the wheel, and how these ideas can be implemented in the technology to optimize the safety and reliability of the vehicle.

Factors Influencing Acceptance of Self-Driving Cars

When asked to give their opinions on self-driving cars, many people end up reflecting on something that they themselves may not have experienced regularly or at all. Because of the novelty of this technology, people are forced to formulate opinions on the perceived usefulness and perceived ease of use of AVs, and ultimately how likely they are to use the technology themselves without a full understanding of how the vehicles work. A study conducted by Nastjuk et al. (2020) revealed that with regards to using a vehicle with Level 5 autonomy (fully

autonomous), trust, functional compatibility, and positive attitude were among some of the factors that had the most significant impact on intention to use self-driving cars in any capacity. Other studies have also highlighted the importance of trust in affecting whether an individual will choose to ride in an AV (Xu et al., 2018).

It might be hypothesized that the experience of riding in an AV would greatly boost a user's confidence and trust in the technology, but this may not necessarily be the case. In a study conducted by Xu et al. (2018), test subjects rode in a Level 3 AV in a controlled environment on a racetrack and were able to experience the car operating under conditions such as obstacle avoidance, path changing, and traffic signal responses. Participants were asked to rate how much they trusted the technology, the perceived usefulness of it, and how easy they believed it was to use on a scale of 1 (disagree) to 5 (totally agree) before and after their experience in the self-driving car. While an increase in the ratings was observed, it was not as large as expected. There was an approximate 2.1% increase in the average ratings for trust and perceived usefulness, and a 3.4% increase in the rating of perceived ease of use. Asking participants to reflect on their thoughts about Level 5 AVs after seeing how a Level 3 self-driving vehicle operates would still require them to guess what riding in a fully autonomous car would be like instead of having a directly informed opinion. Nonetheless, allowing people to directly see and experience the technology at some level in action should develop their trust once AVs become more prevalent on the road (Xu et al., 2018).

As much as it is helpful to identify what factors increase or decrease one's willingness to use AVs, anything that could undermine these factors must also be considered. General anxiety about self-driving technology could have a negative effect on people's willingness to use it regardless of their awareness of the numerous benefits the technology's implementation has to

offer (Hohenberger et al., 2017). To counter these anxieties and increase willingness to accept this technology, car manufacturers can create messaging that appeals to self-enhancement by stating the benefits that self-driving cars can have at a primary level (in one's personal life) and at a secondary level (in the ways they are perceived by others) (Hohenberger et al., 2017, Alicke and Sedikides, 2008). For example, when looking at what motivates consumers to buy electric vehicles, appealing to self-enhancement is more likely to result in people buying these cars (Barbarossa et al., 2017). However, this could encourage people to buy AVs for the wrong reasons. Due to the excitement that has been spurred on various media forms about the prospects of self-driving cars, people's expectations of how they operate may not match up with the final products (Xu et al., 2018). Therefore, trust in safety and reliability and knowledge of the operation and functionality of AVs would be among the best factors for manufacturers to appeal to to secure a larger customer base.

Are Autonomous Cars Accessible to Everyone?

Many studies aim to investigate the perceptions of AVs in people across different genders, ages, and driving experiences. However, there is a key demographic that is often overlooked: disabled people. While so many articles discussing the future of AVs cite the increase in independence for disabled people (and the elderly) as one of the many positive outcomes of this innovation, they are not explicitly accounted for in numerous studies. Car manufacturers need to survey disabled people as well as able-bodied people to incorporate features into their designs and make technology that lives up to their claims (Bradshaw-Martin & Easton, 2014). In a study conducted by Bennett et. al (2019) that surveyed perceptions of AVs by disabled and non-disabled people in London, more non-disabled participants expressed

reservations about self-driving technology than disabled participants, but the important factors between the two groups were quite different. While non-disabled people tended to comment on the optics of autonomous vehicle ownership and how they might perform while coexisting with automatic vehicles on the road, disabled people discussed the safety and usability of the AVs themselves (Bennett et. al, 2019). Car manufacturers' accessibility efforts should address these concerns by providing clear, concise information on the operability and safety of their vehicles.

Having access to quality and affordable transportation is an important part of living an independent life, connecting with the surrounding community, and having access to jobs and various goods and services. The ownership of a vehicle allows for people to go wherever they want whenever they want without having to rely on public transportation. Regular car ownership is not accessible for disabled people because of its excessive cost and lack of flexibility in their operation. Manufacturers have created and continue to create equipment that make vehicles more accessible; an early example of this is Honda's Franz system which allows drivers to control the car with their feet (Murata & Yoshida, 2013, 1). These systems are a great starting point, but they unfortunately do not accommodate as many people with various physical conditions as they could. For AVs to be usable by all disabled people, they would need to perform at Level 5 autonomy, thereby requiring zero human control or intervention. Until that is achieved, users will need to have a non-disabled person sitting at the wheel in case human control is needed. This would not be true independence and disabled people's lives would not be changed dramatically (Bradshaw-Martin and Easton, 2014).

If Level 5 self-driving vehicles are the best option for disabled people to live a more independent life, this begs the question of how much these vehicles could cost and if many disabled people could afford these cars. In 2020, Social Security and Disability Insurance (SSDI)

disabled-worker benefits in the U.S. were around $1,236 per month, with 90% of those who claim these benefits earning less than $2,000 a month (*Chart Book: Social Security Disability Insurance*, 2021). Since disabled workers also have a challenging time finding work, in addition to the rising cost of living, it will be hard for disabled folks to comfortably afford self-driving vehicles without significant help from car manufacturers and/or the government.

Recommendations

While it is not necessary for car manufacturers and software developers to spend too much time trying to incorporate every individual's reservations about AVs into their algorithms, it is essential to use these as a foundation upon which the planning, development, and implementation of self-driving cars is built. Manufacturers and government organizations can take steps to promote the responsible use of autonomous technology and instill trust into the minds of the public.

Corporations that contribute to self-driving technology, whether through providing hardware such as sensors and actuators, writing the algorithms that make decisions and control the car subsystems, or car companies that make the final products available for commercial use, must engage in practices that increase the transparency of their contributions. This can be done by explaining to customers what decisions were built into the algorithms, why particular sensors were chosen, and a breakdown of the cost of the vehicles. A study conducted by Nastjuk et al. (2020) revealed that an alignment between a person's own driving patterns and the vehicle's decision-making process indicates more willingness to use self-driving cars. With trust also being a key factor in how likely one would be to use a self-driving car, manufacturers can include visual interfaces that allow users to see what the sensors detect and display the actions

that the car plans on taking, such as changing a lane or stopping at a red light. This would give passengers a clear understanding of the system's functionality and reliability and can increase their confidence in their ability to operate the system if necessary. Manufacturers could also offer the chance to ride in an AV in a controlled environment without purchasing one to help people become familiar with the technology.

Self-driving car manufacturers must also deliver on their promises that AVs can improve the quality of life for disabled folks. This could be done by giving disabled people special access to test drive an AV for an extended period of time through a short-term or long-term leasing program with special payment plans. This would be an affordable option for disabled people to try operating an AV for a considerable period of time so that they can determine its helpfulness and ease of use. Special fleets of self-driving cars can be built for public use to specifically accommodate disabled people, similar to car-sharing or bike-sharing systems currently in place. For those who intend to purchase an AV for themselves, manufacturers can offer reduced costs and payment programs that make the technology more financially accessible to disabled people. Additionally, the federal government can increase their disability benefits to include money for any form of transportation disabled people choose to use, including self-driving cars.

In order to hold companies accountable for their technological advancements and ensuring that safe, robust vehicles are being put on the streets, the federal government should reform current legislation that only pertains to automatic vehicles in which a driver is present and actively driving (Bradshaw-Martin & Easton, 2014). Next, legislation should be drafted that explicitly states what standards AVs must meet before they are permitted to be available for public use; the coexistence of AVs and automatic vehicles must be considered in these laws as well. Government transportation departments should conduct independent inspections and testing

of AVs manufactured for public use to determine if they are safe to have on the roads. In the United States, car manufacturers currently voluntarily report information about their self-driving vehicles to the Department of Transportations' National Highway Traffic Safety Administration (*Automated Vehicle Safety*, n.d.). Although it is good for companies to conduct rigorous testing of their products and report their honest findings, the sincerity in reports written by manufacturers themselves could be doubted. Testing responsibilities should fall on the federal government as the push to put these vehicles on the market increases. The NHTSA can develop a testing protocol that examines the decision-making of autonomous algorithms, the reaction times of cars, and the reliability and safety of the entire system.

Conclusion

In the near future, it could become normal to see mostly self-driving cars on the streets. This technology shows many promising benefits and is exciting to a large number of people, but some key factors regarding safety and general attitude towards this technology must be considered before the growth rate of its implementation skyrockets. To make them more accessible for disabled and non-disabled people, it is imperative that car manufacturers take the time to address various personal concerns in their technology and through campaigns. Additionally, they must comply with updated government regulations and legislation to ensure the safety of the public and help this technology to grow in a positive direction. Autonomous driving technology has the potential to make many positive changes in individuals' lives, in the productivity of society, and potentially on our planet. Therefore, these systems must be managed with sincerity and care by all parties involved in its development and implementation.

References

Alicke, M. D., & Sedikides, C. (2009, February 11). Self-enhancement and self-protection: What they are and what they do. European Review of Social Psychology, 20(1), 1-48. Taylor & Francis Online. https://doi.org/10.1080/10463280802613866

Automated Vehicle Safety. (n.d.). NHTSA. Retrieved April 18, 2022, from https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

Barbarossa, C., De Pelsmacker, P., & Moons, I. (2017, October). Personal Values, Green Self-identity and Electric Car Adoption. Ecological Economics, 140, 190-200. ScienceDirect. https://doi.org/10.1016/j.ecolecon.2017.05.015

Bennett, R., Vijaygopal, R., & Kottasz, R. (2019, September). Attitudes towards autonomous vehicles among people with physical disabilities. Transportation Research Part A: Policy and Practice, 127, 1-17. ScienceDirect. https://doi.org/10.1016/j.tra.2019.07.002

Birnbacher, D., & Birnbacher, W. (2017, September/October). Fully Autonomous Driving: Where Technology and Ethics Meet. IEEE Intelligent Systems, 32(5), 3-4. IEEE Xplore. 10.1109/MIS.2017.3711644

Bradshaw-Martin, H., & Easton, C. (2014). Autonomous or 'driverless' cars and disability: a legal and ethical analysis. European Journal of Current Legal Issues, 20(3). http://webjcli.org/index.php/webjcli/article/view/344/471#_ftn69

Chart Book: Social Security Disability Insurance. (2021, February 12). Center on Budget and Policy Priorities. Retrieved April 27, 2022, from https://www.cbpp.org/research/social-security/social-security-disability-insurance-0

Fernandes, P., & Nunes, U. (2010). Platooning of autonomous vehicles with intervehicle communications in SUMO traffic simulator. Annual Conference on Intelligent Transportation Systems, 1313-1318. doi:10.1109/ITSC.2010.5625277

Geisslinger, M., Poszler, F., Betz, J. et al. Autonomous Driving Ethics: from Trolley Problem to Ethics of Risk. Philos. Technol. 34, 1033–1055 (2021). https://doi.org/10.1007/s13347-021-00449-4

Hohenberger, C., Spörrle, M., & Welpe, I. M. (2017, March). Not fearless, but self-enhanced: The effects of anxiety on the willingness to use autonomous cars depend on individual levels of self-enhancement. Technological Forecasting and Social Change, 116, 40-52. ScienceDirect. https://doi.org/10.1016/j.techfore.2016.11.011

Murata, Y., & Yoshida, K. (2013). Automobile Driving Interface Using Gesture Operations for Disabled People. *International Journal on Advances in Intelligent Systems*, *6*(3,4), 329-341. 10.1.1.679.2206

Nastjuk, I., Herrenkind, B., Marrone, M., Brendel, A. B., & Kolbe, L. M. (2020, December). What drives the acceptance of autonomous driving? An investigation of acceptance factors from an end-user's perspective. *Technological Forecasting and Social Change*, *161*. https://doi.org/10.1016/j.techfore.2020.120319

SAE Levels of Driving Automation™ Refined for Clarity and International Audience. (2021, May 3). SAE International. Retrieved April 20, 2022, from https://www.sae.org/blog/sae-j3016-update