Newfound Passenger and Pedestrian Safety Implications Regarding Autonomous Vehicles

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Signed: ______________________ Date: 05/11/2021

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Introduction

Motor vehicle accidents are the 13th leading cause of fatalities in the United States, accounting for over 32,000 deaths and 2 million non-fatal injuries annually (National Highway Traffic Safety Administration, 2015a; Sauber-Schatz et al., 2016). These accidents are not only life-threatening, but, according to the National Highway Traffic Safety Administration (2015b), cause damages that total more than $277 billion per year, a figure that amounts to nearly $900 per person in the United States. Furthermore, with the addition of harm from loss of life, pain, and decreased quality of life due to injuries, that cost increases to over $870 billion a year (ibid). A proposed solution to this social and economic hardship is the advancement and implementation of autonomous vehicles (Umland, 2018).

An autonomous vehicle is an automobile capable of sensing its surroundings and moving safely without human input (Anderson, 2016). The objective is for these vehicles to be both safer and more energy-efficient than the conventional human-driven vehicle. Unfortunately, as with nearly all new technologies, autonomous vehicles have their disadvantages. Society-wide implementation of driverless vehicles is considered a near-impossible feat in it of itself. Moreover, coping with the associated societal and economic costs that arise from such a rapid shift in the automobile industry is no easy task as well (Umland, 2018). To top it all off, autonomous vehicles pose a new threat to pedestrian and passenger safety.

The Society of Automotive Engineers discretizes autonomy into 6 levels, with Level 0 corresponding to no automation and Level 5 full automation, see Figure 1. At the moment, the companies at the forefront of autonomous vehicle technology, Tesla and Google, have not fully reached Level 5 autonomy. Google is closest, with their Waymo vehicles operating in the Phoenix metropolitan area at Level 4 autonomy (Hughes, 2017). This paper aims to examine newfound passenger and pedestrian safety implications regarding autonomous vehicles. By delving deeper into this topic, I can gain insights into the specific causes that would support or hinder widespread implementation of autopilot technology. Motor vehicle accidents are indubitably an avoidable tragedy in society, so further research and analysis on autonomous vehicles and their safety implications must be conducted in order to outline the most cost-effective and reliable system design. This paper explores the ways that autopilot technology poses new challenges to passenger and pedestrian safety, with an emphasis on modifications to vehicle design.

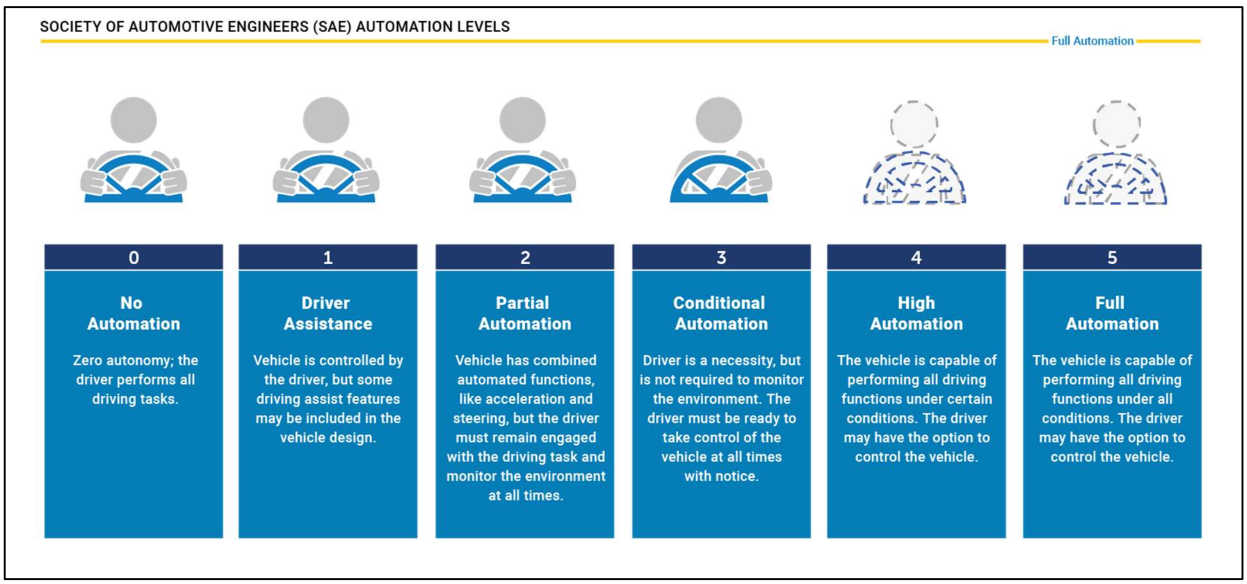

Figure 1. The six levels of autonomy, according to the Society of Automotive Engineers (Image source: Automated Vehicles for Safety, 2020).

Case Context

At first glance, it may seem as though this topic is purely technical in nature. After all, it is essentially a large-scale mechatronics project that culminates in the development of a physical product. One could argue that safety features are inherently technical. There is indeed prior literature that highlights the technical nature of automotive safety, such as a publication by a group of researchers at the University of North Carolina, Chapel Hill, The researchers' analysis of the

Fatality Analysis Reporting System concluded that while the use of multiple, leading edge pedestrian detection sensors in autonomous vehicles could significantly reduce pedestrian fatalities, the clear reality is that with more affordable sensors, pedestrian fatality mitigation is unlikely (Combs et al., 2019). Nonetheless, there is no doubt that human and social elements are fundamentally incorporated into autonomous vehicles. For instance, Moody, Bailey, and Zhao (2020), researchers at the Massachusetts Institute of Technology, considered the public perception of autonomous vehicle safety. They found more positive autonomous vehicle safety perception among the most risk-taking road users, young males, and in developing countries. These populations overlap with demographic groups and geographic areas facing the largest road safety concerns (ibid).

One of the crucial reasons that autonomous vehicles have not had such a major impact as some anticipated is the concern over safety. One life lost during real-world testing is already one too many, especially considering the fact that human lives are at stake. This has led to numerous controversies over passengers and pedestrians who have lost their lives due to the beta testing, the final round of testing in the development process, of autonomous vehicle technology (Chokshi, 2020). One such company is Tesla, who appear to be on the forefront of autopilot technology (Autopilot, 2020). As of March 2021, the National Highway Traffic Safety Administration was investigating 23 cases of motor vehicle accidents involving the company's autopilot feature (Boudette, 2021). Consequently, there is an ongoing moral debate over whether or not it is ethical to continue allowing consumers to use this incomplete technology. A paradox was found in a recent survey conducted in Pittsburgh, Pennsylvania by Bike PGH, an organization promoting safety and accessibility for bikers and pedestrians, and researchers from the University of Alabama and Texas A&M. Results indicated that people with direct experience interacting with autonomous vehicles have significantly higher expectations of the safety benefits of autonomous vehicles than respondents with no experience interacting with autonomous vehicles (Penmetsa et al., 2019).

Figure 2. Screenshot from Tesla's promotional video on the company's self-driving technology (Image Source: Tesla, 2019).

Technological Momentum In Relation To Driverless Technology

While there is no clear-cut answer to this problem, at least not at the moment, Thomas Hughes' (1987) concept of technological momentum can aid in analyzing this deeply complex issue. Hughes proposes that large technological systems capable of altering society as a whole, such as autonomous vehicles, in my opinion, undergo a series of stages: invention, development, innovation, transfer, growth, competition, and consolidation. Invention is the inception, defined as the creation of something novel, whether conservative or radical, with a conservative creation adding to a pre-existing technology and a radical creation bringing about something entirely original. Development is the second stage, defined as the transition from an initial invention to one that functions under economic, political, and social characteristics. Innovation requires the combination of invented and developed components into a complex system of manufacturing, sales, and service facilities. Transfer can be defined as an adaption of said characteristics to another era or environment. Such movement is often dictated by shifting markets or geographical and social factors. Growth is the stage wherein expansion occurs. More specifically, it concerns what steps are taken to solve problems such as reverse salients, which Hughes defines as components of a system that are either out of phase or no longer considered contemporary, or increase efficiency through logistical changes. Competition involves a sparring between two or more technologies. Each attempt to claim a permanent stake in the future by arguing they have fixed reverse salients. Finally, consolidation occurs when stakeholders of the large technological organizations hold much of the market share, specifically to a degree whereby they begin to drown out the voices of smaller contributors.

Hughes' overarching example throughout his presentation of technological momentum is the U.S. electricity grid. I believe this technology is deeply analogous to autonomous vehicles because of the similarities exhibited in their potentials to alter society at large. Just as the electricity utility system had predecessors in power generation through natural and propane gas, so too do autonomous vehicles in transportation through conventional automobiles. Just as Edison's electricity grid had the potential to enable the productivity of the American people throughout the dark, so too does autopilot technology further advance vehicle safety to a near flawless degree.

Research Question and Methods

What changes does autonomous vehicle technology bring to passenger and pedestrian safety? The answer is vital to the adoption of autonomous vehicles because personal safety is a fundamental human right. While there is no doubt that a small minority of trailblazers will be willing to put everything on the line to perform trials on this new technology, in order for mass adoption to occur, the technology needs to align with the values and preferences of the users, which, in most cases, are safety and everyday essentiality. However, with the vast majority of people already comfortable with conventional automobiles and unlikely to immediately make the switch, autonomous vehicles must feature an extraordinary innovation, such as a near-impeccable safety record.

This research topic will be analyzed using a descriptive approach. Evidence was collected through a survey and an interview. The survey was in a Google Forms format, sent to students, faculty, and staff at the University of Virginia, and included questions aimed to gauge public perception of autonomous vehicles and their perceived safety benefits and drawbacks. The survey began with some questions about demographics, including age and major or field of work. Then, there were questions asking how safe people feel in certain circumstances. For each one of those questions, the respondent answered on a "feel-safe" rating scale of 1 to 9, with 1 corresponding to "not at all" safe and 9 corresponding to "completely" safe. An example question asked how safe the survey participant felt about riding a vehicle with a seat design such as the one shown in Figure 3. The last portion of the survey asked participants how they might behave in, what concerns they have about, and how optimistic they are about autonomous vehicles. I then compared the results of my survey to conclusions from prior literature. Due to the survey population, I may have to account for some biases, such as above-average education and income levels, in making conclusions. The survey had a total of 75 respondents, with disciplines ranging from biomechanics to international management. The ages of the survey respondents ranged from 18 to 60 years old, with an average age of 24.96 years old. Of the respondents, 52% (n=39) identified as male and 48% (n=36) identified as female. Sixty-nine respondents (92%) operate a motor vehicle, while 6 (8%) do not. An interview was conducted with Dr. Jaeho Shin, a professor of mechanical and automotive engineering at Kyungil University with over 20 years of experience in the vehicle safety industry. Interview questions were centered around projected novel safety implications of autonomous vehicle technology and efforts of government regulation.

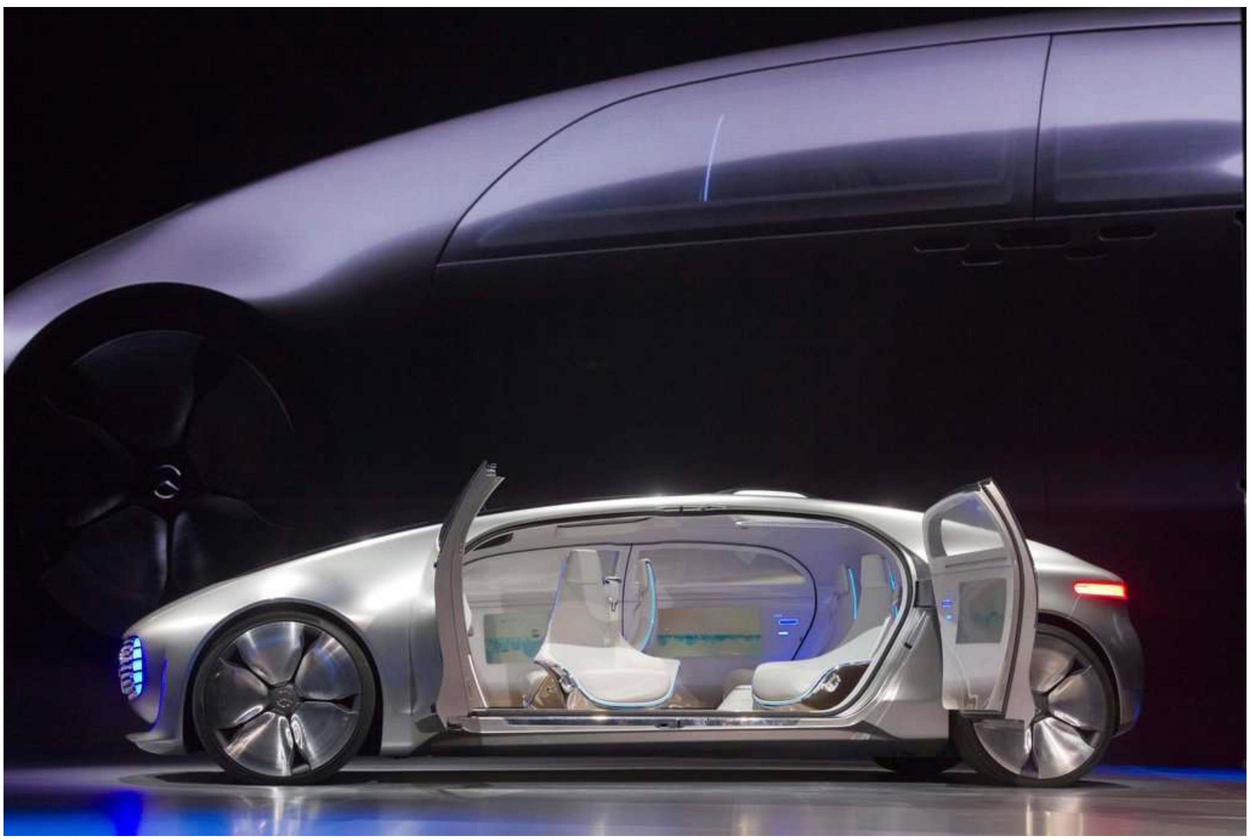

Figure 3. Mercedes-Benz F 015 Luxury in Motion Concept Car. Mercedes describes the seats as "four rotating lounge chairs that allow a face-to-face seat configuration" (Image credit: Steve Marcus/Reuters; Image source: Motavalli, 2015).

Results

Through an analysis of survey and interview responses, it is evident that autonomous vehicle technology will likely not bring significant, immediate changes to passenger and pedestrian safety in terms of vehicle structure design. Instead, autonomous vehicle technology will likely affect passenger and pedestrian safety simply due to the digitalization of the driving mechanism. In a conventional motor vehicle, the human is the driving mechanism, as they control the acceleration, braking, and steering. In an autonomous vehicle, on the other hand, this responsibility falls upon a computer running algorithms.

To begin with, survey respondents felt relatively more safe operating a motor vehicle themselves compared to riding in an autonomous vehicle, as evident in Figures 4 and 5. At the moment, the only major variable between a conventional motor vehicle and an autonomous vehicle is the aforementioned driving mechanism. The overall design of nearly all autonomous vehicles resembles that of a conventional car. And yet, even without any immense structural changes, people felt and, in a sense, trusted their driving skills over autonomous vehicle algorithms.

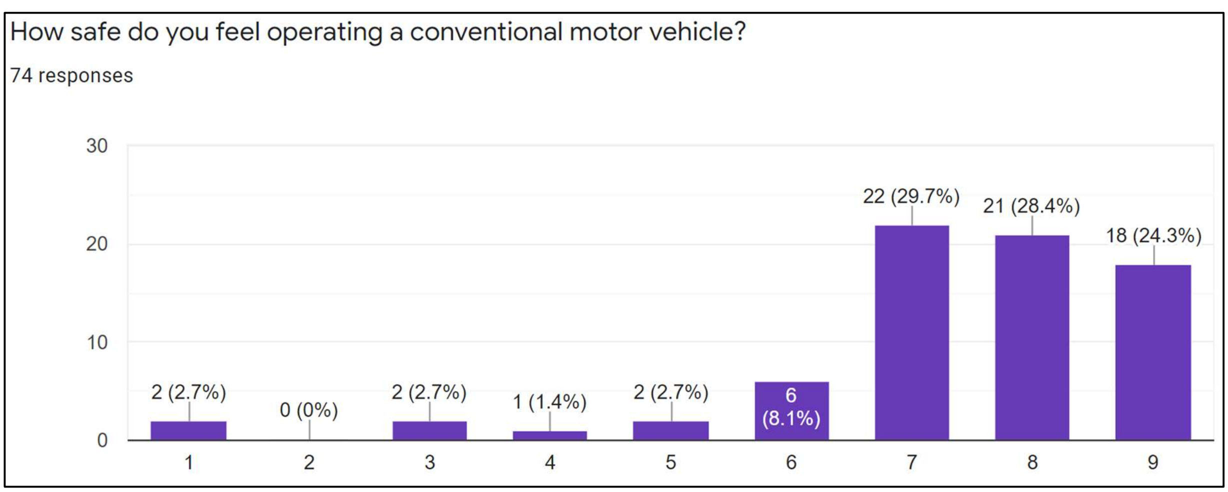

Figure 4. Distribution of "feel-safe" ratings for operating a conventional motor vehicle (only 74 responses because this question was left optional to those who did not operate a motor vehicle).

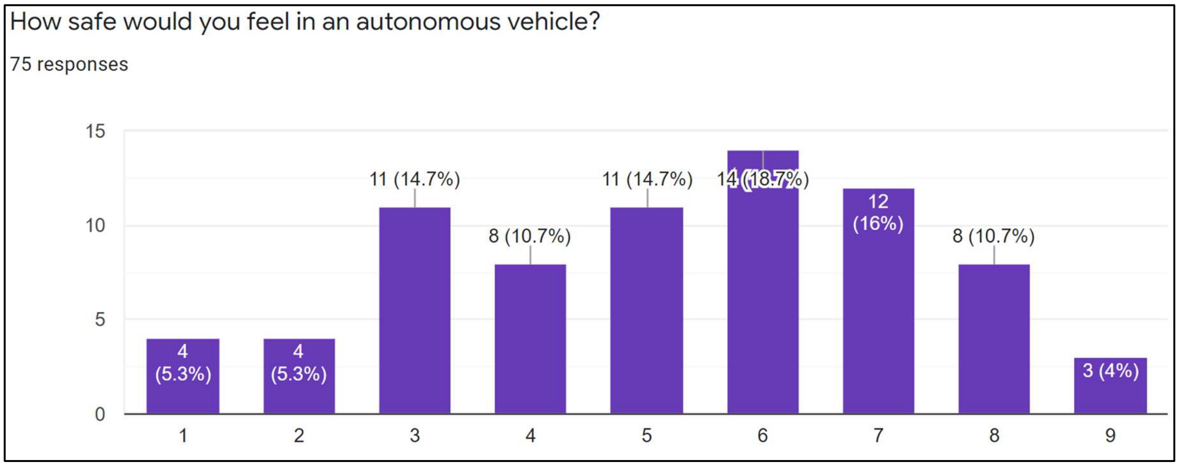

Figure 5. Distribution of "feel-safe" ratings for riding in an autonomous vehicle.

Drastic changes to the interior layout of autonomous vehicles would likely not gain much public interest because respondents felt that they would not feel safe in an autonomous vehicle without a manual takeover option. As evident in Figure 6, 40% of respondents felt "not at all" safe in an autonomous vehicle without a manual takeover option. In order for there to be a manual takeover option, conventional driving mechanisms, such as a steering wheel, accelerator, and brake pedal, must not only be included with the car, but also in a familiar layout, as drivers would need to be accustomed to said layout.

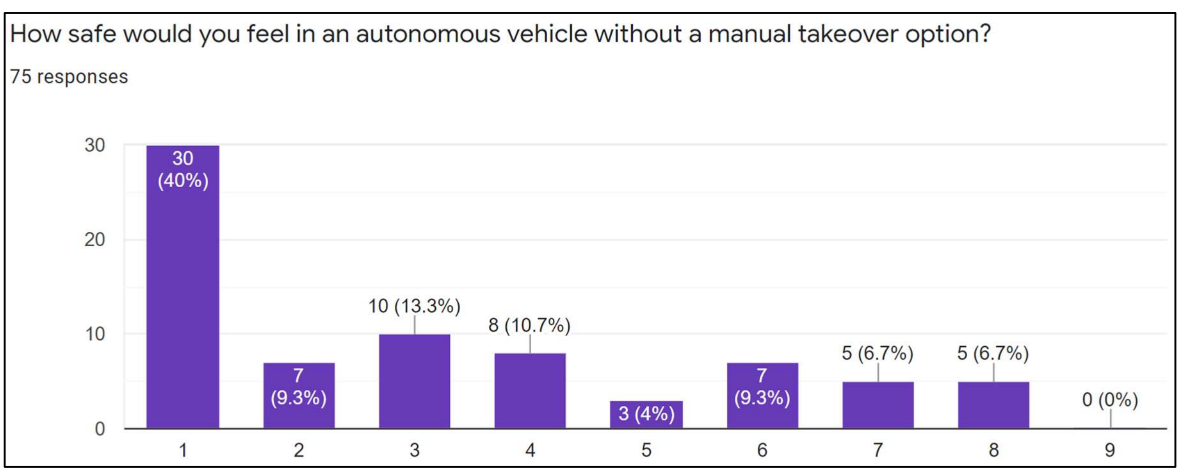

Figure 6. Distribution of "feel-safe" ratings for riding in an autonomous vehicle without a manual takeover option.

Furthermore, survey participants responded negatively towards riding in an autonomous vehicle without windows, as evident in Figure 7. In a fully autonomous-vehicled society, cars would not need windows. The removal of windows would definitely bring about new safety implications because a windowless vehicle can increase safety through more ideal placement of airbags or increased structural rigidity, for instance. Nonetheless, based on this data, it is likely a windowless car is not a popular proposition.

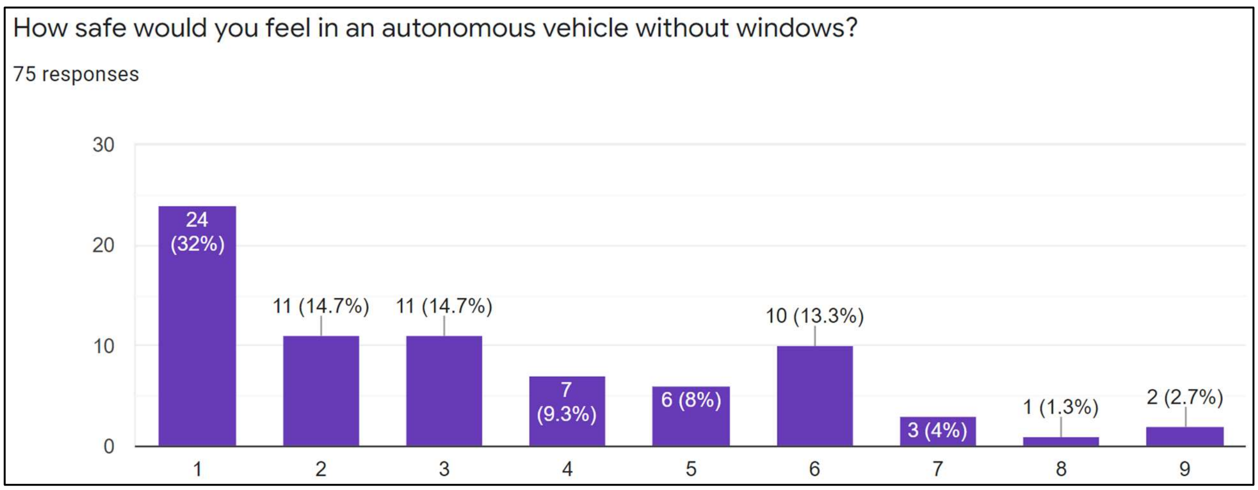

Figure 7. Distribution of "feel-safe" ratings for riding in an autonomous vehicle without windows.

Survey respondents also felt less safe sitting in a rear-facing seat in an autonomous vehicle compared to a local-traffic bus, train, and even a conventional motor vehicle. Table 1 outlines how respondents felt sitting in a rear-facing seat on a local-traffic bus, on a train, in a conventional motor vehicle, and in an autonomous vehicle. Respondents felt the safest riding faced rearwards on a train, followed by a local-traffic bus. This data suggests that even more so in autonomous vehicle, people do not feel safe riding with their backs faced towards the front end of the car. This hints at an uphill battle for mass overhaul of conventional seat layouts and orientations.

Method of transportation	Average "feel-safe" rating
Train	7.45
Local-traffic bus	6.44
Conventional automobile	5.35
Self-driving automobile	4.93

Table 1. Differences in the average "feel-safe" ratings between varying modes of transportation.

Survey participants also felt more safe riding an autonomous vehicle in some circumstances than others. Respondents felt the safest on a highway with minimal traffic, followed by a highway with stop-and-go traffic, followed by local roads. A highway was defined as a road without traffic lights and speed limits of 60 miles per hour and higher and local roads were defined as roads with traffic lights and speed limits under 60 miles per hour. Highway with minimal traffic received a "feel-safe" rating of 5.48, highway with stop-and-go traffic received a "feel-safe" rating of 4.76, and local roads received a "feel-safe" rating of 4.73. However, as evident from Figures 8 and 9, there is more variation in ratings for local roads than those for a highway with stop-and-go traffic.

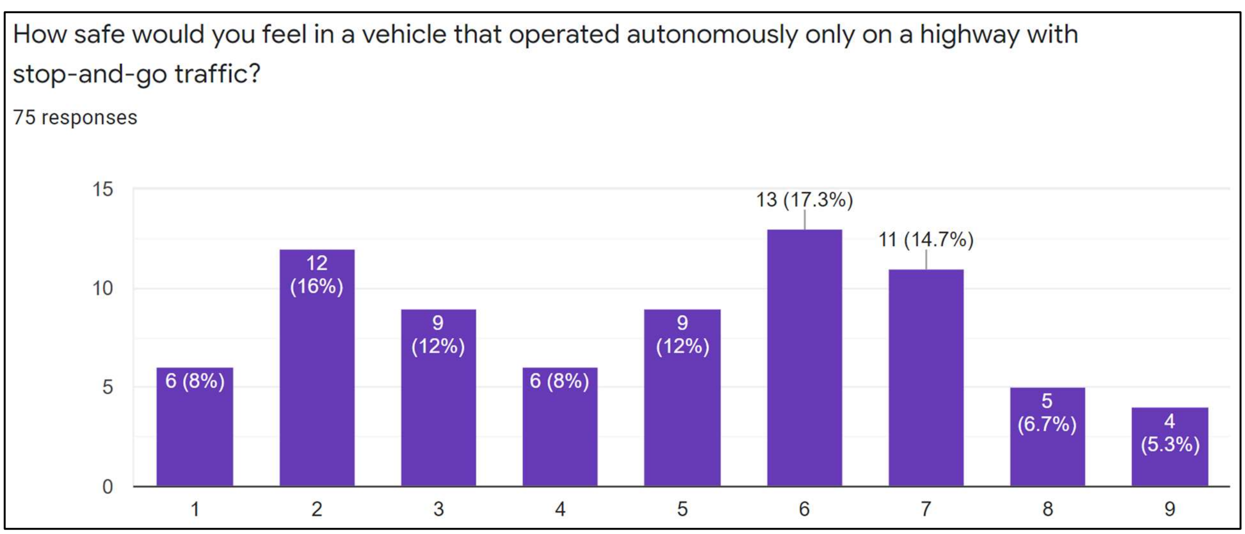

Figure 8. Distribution of "feel-safe" ratings for riding in a vehicle that operates autonomously only on a highway with stop-and-go traffic.

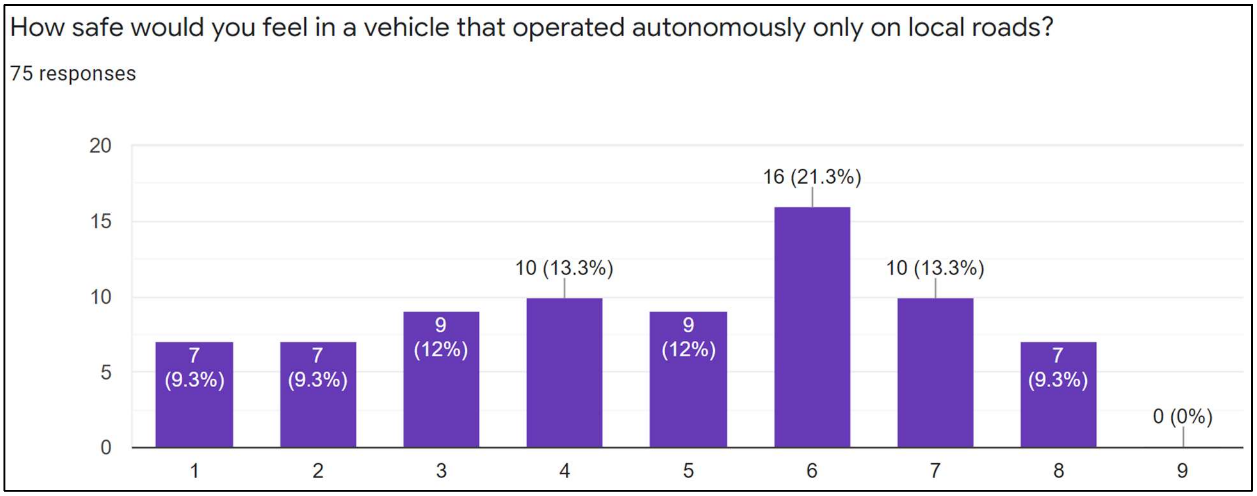

Figure 9. Distribution of "feel-safe" ratings for riding in a vehicle that operates autonomously only on local roads.

When asked about concerns about autonomous vehicles, at least 7 in 10 respondents were worried about three issues: liability in the event of an accident, functionality and reliability of technology, and cybersecurity, or vulnerability to hacking. The latter two of these three issues will likely effect a change in passenger and pedestrian safety. A society with only autonomous vehicles running flawless algorithms will yield an accident rate of 0%. No technology is perfect, but even with a minimal margin for error, car accidents will be greatly reduced, since the number of cases of drunk and tired driving will drop to significantly lower levels.

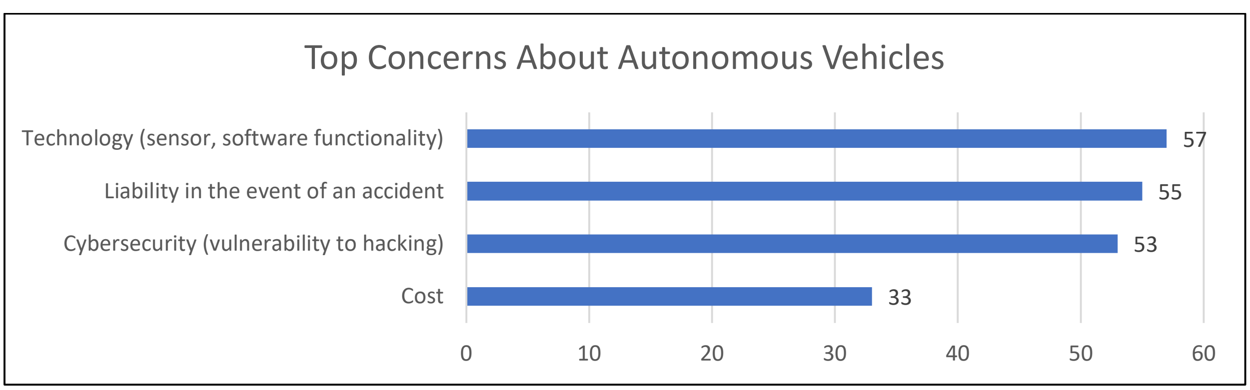

Figure 10. Most common concerns survey participants had about autonomous vehicles.

Additionally, respondents indicated that they are most likely to watch the road and chat with others in the car when asked which activities they would partake in if they no longer had to drive the vehicle themselves, as shown in Figure 11. There was also high interest in eating, use of cellphone, and sleeping. These are all actions auto manufacturers should take into consideration when designing their driverless cars since current vehicles are not designed with that in mind.

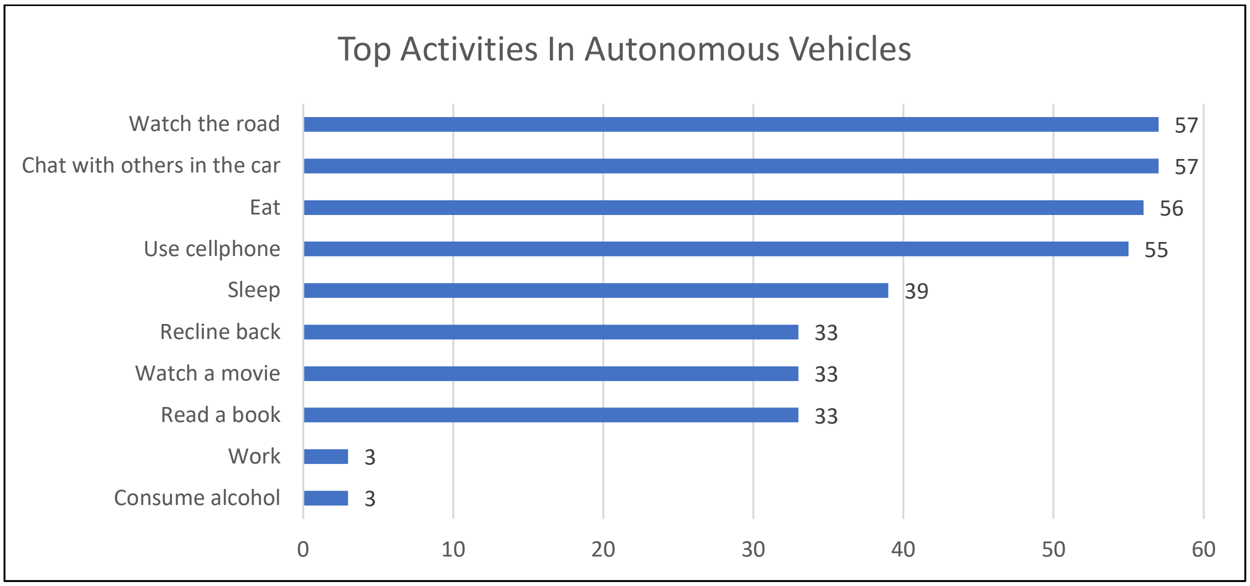

Figure 11. Most common activities about survey participants would partake in if they no longer had to drive a vehicle themselves.

Lastly, public optimism towards autonomous vehicles appears to be moderately strong, as evident in Figure 12. In fact, over 78% of respondents indicated that they would be willing to ride in a driverless vehicle if presented with the chance. Despite the concerns that some may have on the technology, it is clear that people are hopeful and willing to give it a chance to flourish.

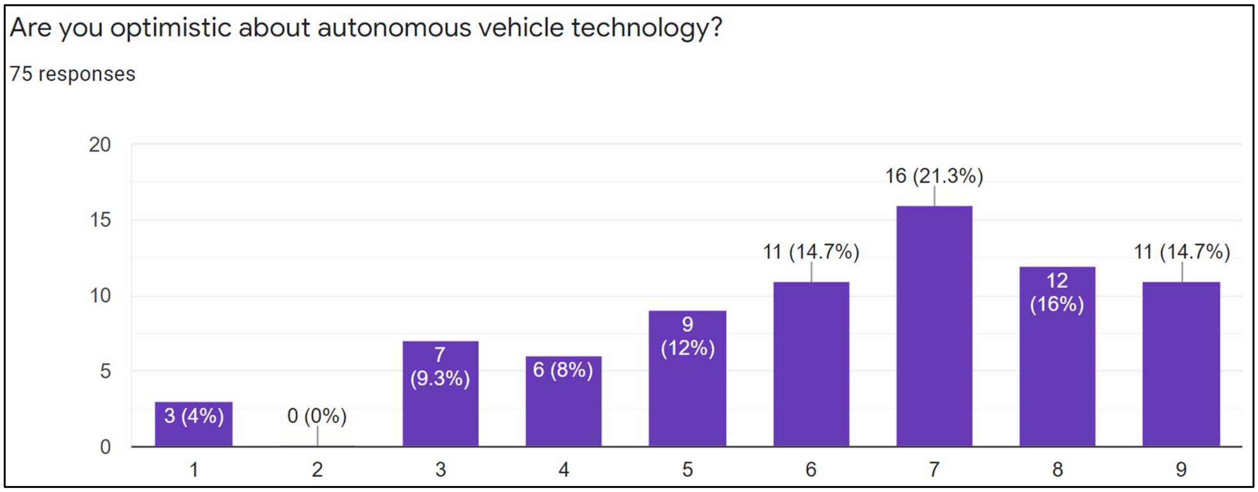

Figure 12. Public optimism about autonomous vehicle technology. The higher the rating, the greater the optimism.

Upon my interview with Dr. Jaeho Shin, some of the above data analysis was confirmed, while some new information was brought to light. In general, Dr. Shin said that there are two main facets to novel safety implications due to autonomy. First, posture changes are not covered by current restraint systems. In other words, nearly all vehicle safety research done up to this point has been focused on protecting an occupant in a fixed, typical, sitting position. With autonomous vehicles, there will likely no longer be a "typical" position. Second, occupants are likely to pay minimal attention to the road. Nonetheless, he claims that currently, the biggest issue is the autonomous vehicle algorithm itself, as it has proven to be faulty at times. He articulated that he believes the technology is almost perfect at this point, but there is a lack of failsafe technology, and thus without it, the technology as a whole is imperfect.

When asked about efforts to regulate autonomous vehicles, Dr. Shin mentioned that he hopes for regulation on where and how to use the driverless technology. For example, much like there is a speed limit on roads, despite modern vehicles being able to travel upwards of 100 miles per hour, there may be a limit on autonomous vehicle technology to operate only on the highway.

This aligns well with public opinion as survey respondents indicated that they would feel more safe riding in an autonomous vehicle operating only on a highway with minimal traffic. Such restraints can be extended to occupant posture as well, Dr. Shin says. For example, occupants may be asked to refrain from sitting in unnatural positions, such as having feet up on the dashboard. Further, he strongly expressed that it is on the government to regulate driverless technology and its usage as it is not worth risking the health of the general public as test subjects.

In terms of pedestrian safety, Dr. Shin indicated that there will likely be no significant changes, other than the fact that the number of pedestrian accidents itself will just decrease. He did, however, mention two specific new cases that may arise. First, headlights will likely be replaced with sensors, as a driver will no longer need to be able to view the road ahead and most sensors paired with autonomous systems do not require light. Coupled with an increase of electric vehicles, which are very quiet, this may pose a new danger to unwary pedestrians. Second, airbags could be added to the exterior of the vehicle as it can be paired with the driverless algorithm. For example, in a situation with an unavoidable pedestrian impact, a car may deploy exterior airbags on the region where the vehicle is likely to hit the pedestrian. Currently, this is difficult because it is impossible for the car to know how the driver will react to such a situation.

One final comment Dr. Shin had about the future of automobile safety as a whole is that many safety regulations may change simply due to the fact that as more and more vehicles replace a traditional combustion engine with an electric motor, automobile shape will no longer have to conform to the current norm, since the engine bay that houses the engine and transmission is no longer necessary. This alone may present safety challenges that leapfrog those presented by the switch to autonomy.

Discussion

Many researchers have considered public perception of autonomous vehicles, but there are very few, if any, studies that have incorporated newfound safety implications as a part of the research. A survey conducted in 2020 found that the majority of occupants in autonomous vehicles would spend most of their time watching the road (Laterza, 2020). Furthermore, the same study found that people strongly disfavor a self-driving car that cannot be manually driven (ibid). This is consistent with the findings from my survey, as the vast majority of respondents stated that they would spend a partial amount of time watching the road and disfavored the lack of a manual takeover option. This consistency in public attitude towards autonomous vehicles is important because it will allow for auto manufacturers to properly anticipate the behavior and needs of occupants in the cabin.

My research leads me to believe that driverless technology is currently on the cusp of the innovation stage. Autonomous vehicle technology has been under development for nearly a decade now. As it begins to take center stage in the transportation field, it will inevitably be subject to economic, political, and social conditions. This is already evident through actions from both the public sector, such as legislation and guidelines developed by the United States Department of Transportation, and the private sector, such as Tesla and Google's massive research and development investments into autopilot technology. Likewise, the results from my research highlight the social aspect of such scrutiny. Though there are nominal signs of overwhelming support of this new technology at its current stage, the general sense of optimism puts autonomous vehicle technology in a good place as it progresses through Hughes' latter stages of technological momentum.

Through additional innovation techniques, such as the integration of finite element model (a method for computationally solving differential equations arising in engineering) simulations and traffic simulations, many future deaths can be avoided, while also elevating the software and thus autonomous vehicle technology as a whole (Harish, 2020). Clearly, real-world data provides the best form of statistics needed to accurately predict real-world situations. Even so, it would be brazen of society to continue on a path towards neglecting human lives for the sake of developing a product. Moreover, Hughes also argues that innovation is the stepping stone for a technology to become a radical invention, rather than a conservative one, which follows this line of reasoning because autonomous vehicle technology has the capacity to become a revolutionary invention.

In general, there does appear to be a slight positive trend toward favorability of autonomous vehicle technology, but this is likely due to increased ubiquity. A previous study found significant concern and lack of enthusiasm towards driverless technology and then found significantly more optimistic results a year or two later when surveying a similar population (Kyriakidis et al, 2015). The results of my research suggest that public perception of autonomous vehicles has not taken a substantial hit. My hope is that more research be done on evaluating new safety concerns associated with the switch to autonomous technology because though public perception alone is a decent indicator of how well a new technology can etch itself into the fabric of history, any risk to public wellbeing can prove to be catastrophic if not dealt with properly at an early stage.

When considering the comments from the interview, the Congressional testimony delivered by Nidhi Kalra, a senior information scientist at the RAND Corporation, on the challenges and approaches to realizing autonomous vehicle safety and mobility benefits comes to mind (Challenges, 2017). In her testimony, Kalra argues that policymakers possess the power needed to create legislature promoting the safety of autonomous vehicles. More specifically, she points out that there is no general consensus on how safe autonomous vehicles should be. She claims that this stems from Americans' different values and beliefs when it comes to human and machine fault. This aligns well with Dr. Shin's comments about the need for government regulation to ensure the safety of both occupants and pedestrians. Such a duty should fall on congresspeople because they are responsible for both voicing their constituents' concerns and thoughts on the degree to which regulation is required and coordinating with scientific experts to reach a widely-accepted, yet practical plan moving forward.

All in all, though there seem to be some new safety implications associated with autonomous vehicle technology, due to both changing occupant habits and the novelty of the technology itself, people seem to be distancing themselves from becoming potential test subjects, slowing down its development. I believe this is positive news for autonomous vehicle technology. Radical change is often met by unforeseen consequences. But for now, many people seem to be comfortable with a conventional motor vehicle and its safety performance. This will allow for the adequate time instrumental in presenting the safest platform for users.

Due to the scope of my research, there are some limitations. First, the average age of survey respondents was on the lower end. Second, a majority of the respondents are in the engineering field. Lastly, nearly all the respondents are college-educated. All three factors contribute to the survey group not being entirely indicative of the population as a whole. Also, the sample is not representative of the population as a whole, and thus not statistically significant. In the future, I would mitigate these pitfalls by surveying a greater number of people across more disciplines and varying levels of education. Moreover, I would ask more specific questions about pedestrian safety. For example, I could ask if people could see themselves purchasing a car with special safety features for pedestrians, such as airbags that deployed on the outer surface of the vehicle. Further, I would conduct two or more interviews with other researchers in automotive safety to garner a better sense of the thoughts of experts and determine if there is a general consensus about the topic or disagreement even among those that are most involved.

This research helped me better understand not only the concerns and thoughts of the average consumer, but also those of experts in the field. As a prospective graduate student in the automobile safety discipline, I will take this information into consideration when deciding my area of focus for my personal research. I will be able to make better-informed decisions on how to effectively resource my time and effort to advance the vehicle safety field. This research has also helped me realize how diverse public thought can be. As such, I hope to continue research in not only the technical field, but also in the science, technology, and society field. Likewise, knowledge of public thought may prove useful in discussions with automobile manufacturers, who are one of the main sponsors and collaborators of vehicle safety research.

Conclusion

The very first automobiles ever created were absolutely marvelous feats of engineering. The idea to harness the power of a petroleum or diesel engine and transmit it to rotate the wheels of a carriage revolutionized personal transportation forever. This trailblazing technology was not without its flaws, however. Due to the disregard and thus absence of safety features in early models, widespread use of motor vehicles resulted in heavy casualties, involving both pedestrian and passengers. In recent times, there have been vast advancements in passenger safety, such as the introductions of the seat belt and air bag. Unfortunately, pedestrian safety has not received such attention. With the advent of a society-wide autonomous vehicle system, it is likely that passenger injury risk decreases, as artificial intelligence will be able to make accurate, split-second decisions to minimize bodily harm. Therefore, it is imperative that more attention go towards improving aspects of pedestrian safety. From this research paper, it is evident that even with the rapid development of autonomous vehicle technology, drastic changes to occupant safety are not on the immediate horizon. As such, efforts to mitigate pedestrian harm should be encouraged and funded. Moreover, perfection of autonomous vehicle algorithms is imperative to the development of the technology, both in terms of public adoption and safety mitigation.

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