Human-Computer Interactions in Autonomous Vehicles

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ABSTRACT

As the technological world continues its boom with advances in all areas, a feature that has found itself to be a critical topic of discussion often has been autonomous driving vehicles. Self-driving has brought about many safety advantages while presenting its fair share of ethical and real-world challenges. Understanding how human-computer interaction truly comes into play for this technology will be the key to a successful and safe adoption into society.

INTRODUCTION

As the world continues to develop into a hyper-technological one where machines are involved in almost every aspect of humanity, it becomes critical to understand what these developments entail and how they are impacting society. One such example of a change that could bring about a whirlwind of shifts in one of the most habituated activities of driving could be vehicle autonomy. The integration of autonomous vehicles into the global vehicle market has already begun and it has already reached a scale that can no longer be ignored. The number of vehicles with an autonomous driving feature was around 39 million in 2021, a number that is expected to grow up to almost 55 million by 2024 [1]. As this self-driving feature within vehicles is improving rapidly, it does not come without a cost. The inherent benefits of proposing vehicle driving autonomy lie in its benefits to take away human error, allow for reduced fatigue in long-distance travel, and ultimately create a safer environment on the road for everyone. However, these advancements would only be able to provide their promised benefits when the global or even the local infrastructure is ready to support them. In addition, vehicle manufacturers have not quite reached a level of driving autonomy that could be deemed entirely safe for drivers to pay no attention to the road. However, there have been several instances where users are putting more faith in their self-driving vehicle features than justified. These challenges also share a path with the rise of electric vehicles in the world, namely because EVs almost always tend to have an autonomous driving feature inbuilt. This jump in technology undoubtedly presents a compelling argument for widespread acceptance into society, but users must be aware of its capabilities before they allow blind faith adoption.

AUTONOMOUS DRIVING

Although some of the earliest occurrences of autonomous driving vehicles began appearing in the 1900s, the technology did not quite grow to a considerable potential until the 2000s. However, with the turn of the millennium, the funding, and the efforts to advance this feature even reached some of the U.S. government departments [2]. One of the most famous of these contributors to self-driving, as well as the EV space, is Tesla. To understand more about how autonomy is classified within vehicles, it is imperative to comprehend the Road Automation Levels as described by the National Highway Traffic Safety Administration. There are a total of 6 levels from 0 to 5 [3].

- Level 0 (Momentary Driver Assistance): This would include warnings or alerts that would assist the driver. However, the car will still need to be fully controlled and steered by the driver.

- Level 1 (Driver Assistance): This would aid the driver with acceleration or brakes through systems like adaptive cruise control.
- Level 2 (Additional Assistance): This would provide all the features from Levels 0 and 1 with additional support for steering. However, the driver must remain engaged and attentive when using this system.
- Level 3 (Conditional Automation): Although currently unavailable in U.S.-based vehicles, this system would be able to take over driving entirely from the driver. However, it would need a driver to resume control if necessary.
- Level 4 (High Automation): Although currently unavailable in U.S.-based vehicles, this system will be able to fully control the car with the driver only acting as a passenger. The only limitation would be the serviceable area.
- Level 5 (Full Automation): Although currently unavailable in U.S.-based vehicles, this would be the ultimate level of automation. The vehicle would be fully equipped to handle all circumstances on the road. The driver will only be a passenger with no required involvement.

ELECTRIC VEHICLES WITH AUTOMATION

Even though all-electric vehicles may not have a self-driving feature of some capacity available to them, proportionally, the majority of EVs are equipped with some ability to assist the driver. There can be two reasons for this. First and foremost, EV vehicles are much newer when compared to their internal combustion engine (ICE) counterparts. Moreover, in a vehicle system that is already heavily electrical and battery-operated, EVs are essentially moving computers on wheels. Adding software to a computer is far easier than adding it to a mechanical system with only a few computerized parts like most traditional ICE vehicles. One of the primary reasons as suggested by General Motors stated that the ability to provide stable power through the inherent EV design system becomes a big reason for EVs to be equipped with an autonomous driving ability [4]. GM also explained that is powered by a battery and having more electrical systems compared to mechanical ones only improves the use case for EVs through reduced latency. One way to look at the future of autonomous driving can be observed through the viewpoint that its success depends heavily on an immense amount of road condition data, minimal system reaction times, and a plethora of real-world situations with solutions. One of the modern advanced autonomous driving assistance systems offered by any car manufacturer is seen in Tesla’s vehicles. Tesla currently offers its buyers three possible driving assistance features: Autopilot, Enhanced Autopilot, and Full Self-Driving Capability [5]. Autopilot offers the driver some adaptable cruise control features along with a level of steering abilities to ensure that the car remains within roadway lines when driving. Enhanced Autopilot enables navigation, lane changing, automatic parking, and some basic levels of car movement without the driver being seated inside. The Full Self-Driving Capability adds to all the previous levels with a level of a stop sign and traffic signal detection (still a Beta feature). Tesla also claims to bring about an automatic steering capability in city driving within this package. Advancements made by Tesla in this automated driving technology have allowed current as well as potential future users to understand where this feature stands today. Even though all the systems still require the driver’s undivided attention, they are a testament to progress.

HCI PRINCIPLES FOR VEHICLE AUTONOMY

The entire autonomous driving technology can be appropriately viewed through several principles of human-computer interaction. After all, even the current early stages of progress are only made possible through the successful interactions between computers and humans, both within as well as outside the vehicle. In the field of study about HCI, three primary intersecting components can be classified as humans, computers, and the interactions that are carried out between them [6]. The human can be recognized as any user who will be interacting with the system. The computer will be any computing system that will handle the input being provided by the human. The interactions are the effective harmony of requests/responses from the users to the computers and vice versa. Humans and computers have different ways of carrying out their input/output processes. However, the most important part of the human and the computer input/output means are those that intersect between the two. The intersecting features are of paramount interest to anyone who wishes to analyze how an HCI system functions. Diving deeper into principles, one of the backbones of human-computer interaction study has been Norman's Seven Stages of Action. Each of these stages, as illustrated in the figure below, map out a generally assumed psychological path taken by a human when deciding to interact with a computer system [7].

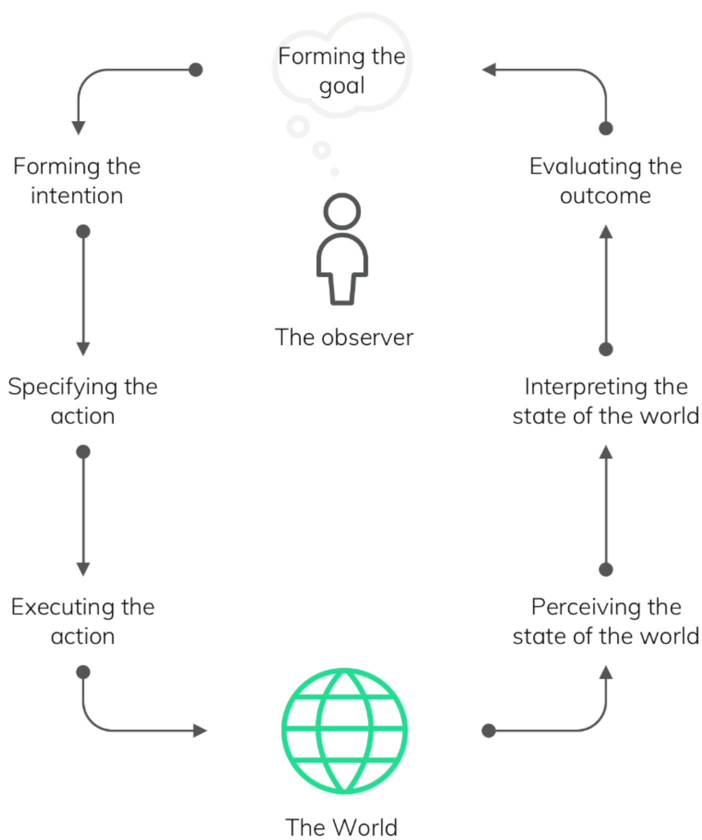

Figure 1: Norman's Seven Stages of Action

Using these principles as a basis for HCI knowledge, one can understand how critical the connections between these components are to the success of artificially intelligent autonomous driving vehicles. In the realm of vehicle autonomy, a car must be able to properly recognize and differentiate between humans or objects being detected on the road ahead. The results of its detections should be appropriately conveyed to the human user seated within. Based on the interaction between the computer and the human, the user would provide instructions on the next steps which would be carried out by the system. A process as such will ultimately continue until the user stops providing necessary input for the computer to continue its commands. Such would be the human-computer interaction cycle, on a basic level, for autonomous vehicles. Observing where innovation stands in this technology, it is relatively fair to state that these interactions are at a positive stage of progress as far as the users seated inside the car are concerned. The major limiting factors preventing enormous leaps in this domain of autonomy are the interactions happening between the vehicle's computer and the environment (objects or other humans) on the exterior.

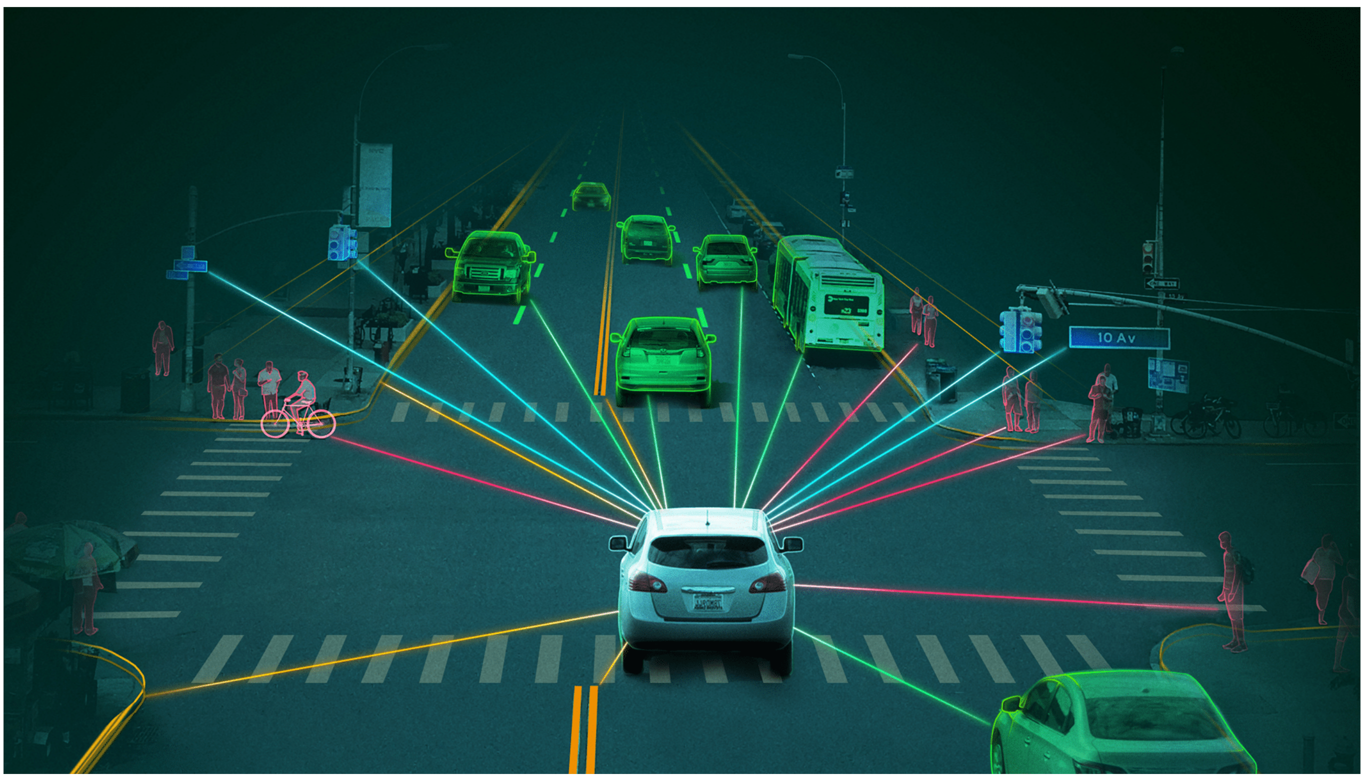

Figure 2: Human-Computer Interactions in Autonomy

BENEFITS OF AUTONOMOUS DRIVING

One may wonder to question why major automakers are making autonomy in vehicles such a big part of their Research and Development spending lately. This may not necessarily relate to autonomy on a full self-driving ability, but rather even on a driving assist level through smaller and vastly useful features. The first and unarguably the most important reason for vehicle autonomy is safety. According to reports by the United States Department of Transportation

(USDOT), in the number of deaths that occurred in 2017 (37,133), a staggering 94% of the crashes came down to human error [8]. In the best-case scenario, if all cars were able to interact seamlessly with each other, it would be possible to save as many as over 37,000 lives every year. Given that one cannot reasonably put a cost on human life, even a single life being saved through such a technology would be incredible. Another benefit that could greatly aid the average American could be efficiency and convenience. Americans are thought to spend almost 7 billion hours in traffic delays annually [3]. This was a number calculated in 2014. Considering that the number of vehicles on the road has only grown, this number of wasted hours would have only increased significantly. A major reason to consider autonomous driving would also be for greater independence for the disabled [9]. People who are blind or physically disabled may not be able to drive and this may be causing a huge deal of mobility issues. If cars can drive themselves in any capacity, these barriers to travel are almost eradicated. These are just some of the major benefits that can be obtained through advancement in autonomous driving. There are several other advantages such as a drop in carbon emissions from the most efficient road decision-making, an increase in lane capacity uses, and all these benefits leading to savings in money and time [8].

ISSUES WITH AUTONOMOUS DRIVING

The known benefits of autonomy are many, but it is important to consider the other side of the coin in terms of disadvantages. One of the biggest limitations preventing autonomous vehicle (AV) technology from truly flourishing is the current premature infrastructure [10]. As is the case with electric vehicles, full AV technology is still several milestones away from becoming practically feasible. There are several requirements for AV to function effectively on roads. These include clearly marked road lane lines and a better charging network. From a big-picture perspective, there simply need to be far more AV vehicles on the road; as a matter of fact, AV technology can only be considered effective when most of the vehicles on the road are equipped with autonomy. The reason behind such a mammoth requirement lies in the fact that if there are only a few AVs on the road surrounded by many human-driven vehicles, the sheer number of possibilities caused by human error is endless. It is computationally infeasible to program every case and a solution to handle it for any car or computer system. In an ideal, utopian driving environment, AVs can reach their peak performance only when they can communicate with each other and predict each other's behavior to anticipate movements and appropriate reactions.

The other major concern with AVs and their autonomy will be regarding insurance liability and law enforcement for accidents. This issue can be viewed from quite a basic perspective. Humans are deemed responsible for car accidents. However, when humans are not responsible for the accident, someone must take the blame in their place. Vehicles or computers cannot be blamed because there is no possibility to recoup compensation. Drivers/passengers cannot be blamed because the accident would not be caused by their neglect. Vehicle manufacturers will likely have disclaimers mentioning that it is not their fault if accidents occur. Such ambiguity can cause great confusion and it could lead to serious problems for all parties involved. Some may argue that alerting emergency first responders could be a much faster process if AVs are involved. While this may be true, all the steps following this could leave the passengers in a whirlwind of trouble. This issue only becomes more critical when injuries or deaths are caused by AVs. There are several valid arguments to persuade users that the cost of insurance could drop significantly as the risk will be lower. However, insurance companies are expecting the opposite outcome. Progressive is expecting insurance premiums to increase to account for the higher price tag of AVs [11]. As the repairs for these vehicles will need to be handled by professionals in that domain, those costs will only justifiably rise. Ultimately, little can be confidently said about the direction that insurance companies will choose to take on this matter. However, they are certain to dynamically update their policies as new developments come to light in the automobile industry.

HCI LIMITATIONS IN TESLA'S AUTOPILOT

One of the most recent topics when it comes to the effectiveness of AVs has been Tesla's autopilot system. Even though it is well ahead of its competitors, Tesla's self-driving system comes under constant scrutiny. As more Tesla vehicles enter the market, the number of customers is growing proportionally. Unfortunately, so are the complaints with its human-computer interaction system. Several automobile experts and reviewers have carried out robust, comprehensive tests to understand the effectiveness of the autopilot system. Although Tesla does require its drivers to be attentive and touch the steering wheel periodically to keep autopilot engaged, the current system has issues of its own. There have been numerous instances where the computer has been tricked into believing that objects are humans and vice versa. There have been occurrences when the computer has been severely confused in its decision-making process when it comes across a horse chariot on the streets, an occurrence that the engineers did not anticipate. On one hand, it is feasible to argue that the engineers will eventually cover all cases because of the finite number of objects on the road. However, this is no excuse for the system to be sub-par by any measure, especially when it may impact the safety of those human lives within.

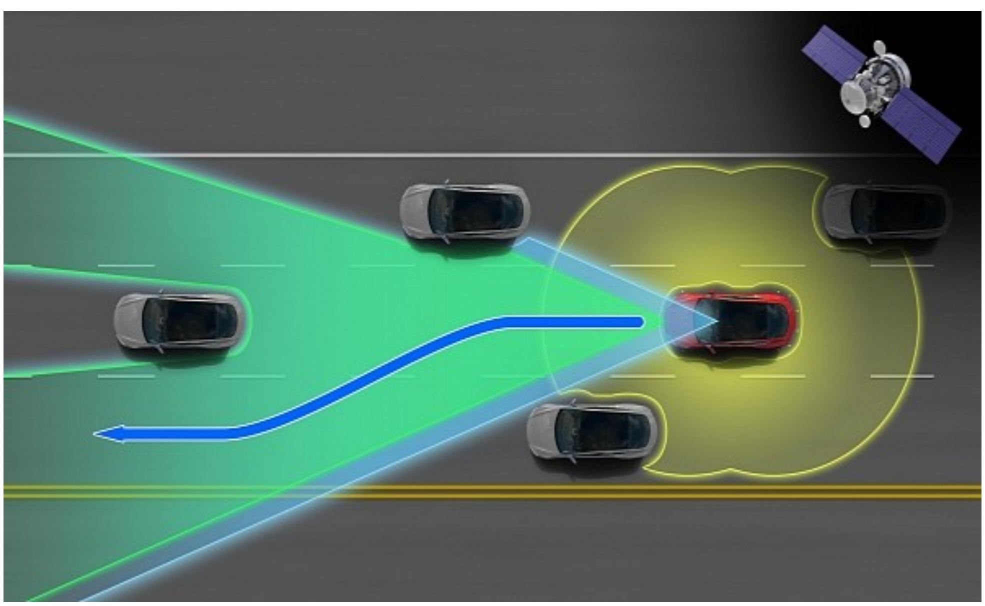

Figure 3: Tesla's Autopilot Mode

PASSENGERS VS. PEDESTRIANS IN ACCIDENTS

As the development of autonomous vehicle technology is no easy task by any stretch, it appears that the industry seems to be making notable strides in the right direction. Unfortunately, this does not mean that there will be no challenges on that path. One of the most critical challenges, both moral and well as decision-making, would be to decide who to save in an unavoidable accident situation. If the computer system can only save the passengers seated or the pedestrians walking on the road, this decision reached will certainly have severely detrimental consequences. This type of a scenario is not unrealistic or farfetched at all. Such an incident could occur in several different variations involving a vehicle versus vehicle, vehicle versus pedestrians, vehicle versus semi-truck, etc. In all of these instances, the computer system interacting with the humans within and on the exterior will need to rapidly weigh on the cost of its decision to minimize damage for all those involved. Not only is this situation fueled by the seriousness of morality, but it is also fueled by the decision-making powers of life and death being given to the logical thinking of a computer. The troubling aspect here would be that a human driving the vehicle may be able to make a more sound instinctual decision than a computer because it will employ emotions over pure mathematics or logic.

Take figure 4 for instance to discuss the possibilities of a computer's decision-making in a real-world scenario. The autonomous vehicle has two options: save the passengers within the vehicle in exchange for the lives of those on the road or save the pedestrians crossing the road in exchange for the lives of those within the vehicle. In both scenarios, the computer will be making a decision that will cost human lives. The ultimate decision made by the AV system in this scenario would solely be based on how the computer has been programmed. The computer may choose to give priority to the pedestrians on the road or to the passengers in the car. However, a human driving the vehicle may be able to consider a third possibility. There could be the possibility of the vehicle swerving off the road entirely to increase the odds of saving all the lives involved. There could be another potential solution where the driver may identify a softer target to utilize as a buffer in an attempt to reduce speed and save both the endangered parties. There could be several other creative ideas that could be used at the moment if a human has control of the vehicle based on the surroundings. Meanwhile, AV may only be able to decide based on its pre-programmed set of choices. This could result in regrettable decisions.

Following the rise of this critical question, PBS carried out a study that gathered responses from over two million people across 233 countries to identify who should be saved should a situation as such arise. The analysis of all responses confirmed that there was a notable variety of trends based on people's backgrounds, cultures, and other influencing factors. Based on a compilation of results, the trends showed that on average, people gave preference in the following order: saving human life over animals, saving as many lives as possible, and giving more importance to young lives over old ones [12]. Given that public surveys can occasionally be skewed, the outcomes yielded by these responses did not appear too shocking. Given that this system would be made by humans, it seems logical to prioritize human life over that of an animal. Furthermore, if an accident is unavoidable and the cost of human life is imminent, then saving the most number possible would be ideal. Choosing younger lives over older ones does seem to walk the line of reasoning. However, even in this case, there is precedent from prior disasters, and this seems to be the generally chosen approach. Overall, if these are the decision of the public who will ultimately be using this technology, it is fair to state that the results should carry some weight in the minds of automakers.

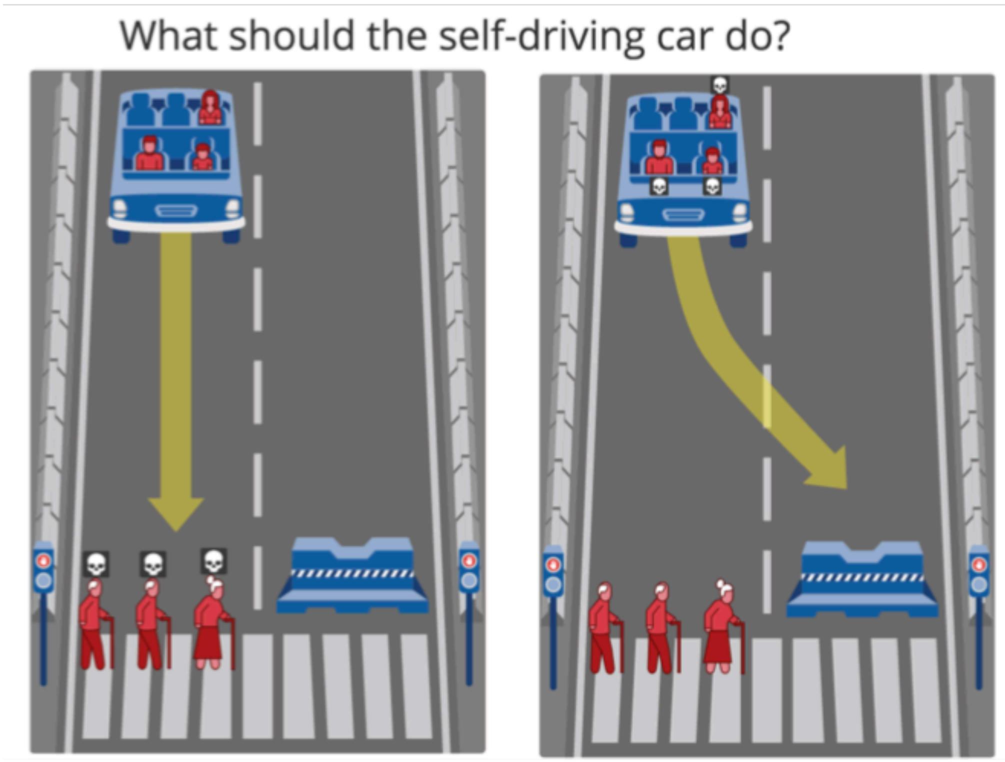

Figure 4: Passengers vs. Pedestrians

RISK ASSESSMENT FOR LANE CHANGING

Many known AV issues impact the safety of passengers and other drivers as a whole. However, with a fully equipped self-driving vehicle, there is another concern that could be valid and critical. When it comes to changing lanes, whether it may be to take an exit or to pass another car, the human-computer interaction aspect of any self-driving vehicle would be at its peak performance. To successfully change lanes and carry out the desired action, the driver needs to consider several factors such as the speed of neighboring cars, the speed of their car, the speed limit, blind spots, etc. In an autonomous driving vehicle, a computer will need to use its sensors to carry out the same checks before it can successfully execute its desired action. In the case of a human, most of these checks are almost instinctual. However, a computer will need to carry out these checks deliberately and undergo many calculations to succeed. There is a notable amount of risk involved in this maneuver as the speeds of any given interstate are nothing compared to city roads or residential areas. Although there is limited data in this domain, with the full expansion of AVs into society, this will become another major area of concern that will need to be addressed in due time. Another reason that makes this topic crucial is that even a minor miscalculation for quite a commonly used maneuver could result in not just one, but many accidents. A failure in the computer's ability to interact successfully with its surroundings and the people that it involves could cost lives.

CONCLUSION

There is no doubt that vehicle autonomy and all its related driving assist features point toward a hopeful future for drivers. Only looking at some of the benefits like safety, fuel efficiency, and travel independence is sufficient to convince most people about AV's potential. These are merely a handful of reasons why major car manufacturers have been rapidly investing in their research and development departments in the race for total autonomy. However, these advantages are not enough to entirely cover up the disadvantages and concerns that follow. Liability or insurance, lacking infrastructure, premature technology, and safety are only some of the factors that are holding back AV technology. Each of these categories brings about its own set of issues that require attention. That being said, solving these problems is not impossible by any means. Rather, it is just a matter of prioritization and time. Even as AV technology grows, new worries arise as a deterrent for manufacturers. But all aspects considered, a future with autonomy aiding societal growth does not appear to be too distant.

REFERENCES

[1] Placek, M. (2021, May 3). *Projected number of autonomous cars worldwide*. Statista. Retrieved March 1, 2023, from https://www.statista.com/statistics/1230664/projected-number-autonomous-cars-worldwide/

[2] Reiser, A. (2023, January 13). *History of autonomous cars*. TOMORROW'S WORLD TODAY®. Retrieved March 1, 2023, from https://www.tomorrowsworldtoday.com/2021/08/09/history-of-autonomous-cars/

[3] *Automated vehicles for safety*. NHTSA. (n.d.). Retrieved March 1, 2023, from https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

[4] *Why all AVs should be evs: General Motors*. Why All AVs Should be EVs | General Motors. (n.d.). Retrieved March 1, 2023, from https://www.gm.com/stories/all-avs-should-be-evs

[5] *Autopilot and full self-driving capability: Tesla Support*. Tesla. (n.d.). Retrieved March 1, 2023, from https://www.tesla.com/support/autopilot

[6] *Introduction to human-computer interaction & design principles*. Educative. (n.d.). Retrieved March 1, 2023, from https://www.educative.io/blog/intro-human-computer-interaction#components

[7] *The human action cycle by Don Norman – Simon Whatley*. Simon Whatley – Service designer, creative technologist and coach. (n.d.). Retrieved March 1, 2023, from https://www.simonwhatley.co.uk/writing/human-action-cycle-don-norman/

[8] *7 benefits of Autonomous Cars*. Thales Group. (2017, July 21). Retrieved March 1, 2023, from https://www.thalesgroup.com/en/markets/digital-identity-and-security/iot/magazine/7-benefits-autonomous-cars

[9] *Benefits of self-driving vehicles*. Coalition For Future Mobility. (n.d.). Retrieved March 1, 2023, from https://coalitionforfuturemobility.com/benefits-of-self-driving-vehicles/

[10] McCauley, R. (2021, April 30). *The 6 challenges of autonomous vehicles and how to overcome them*. GovTech. Retrieved March 1, 2023, from https://www.govtech.com/fs/the-6-challenges-of-autonomous-vehicles-and-how-to-overcome-them.html

[11] *Insurance coverage for self-driving cars*. Progressive. (n.d.). Retrieved March 1, 2023, from https://www.progressive.com/answers/insurance-for-driverless-cars/

[12] Leventhal, J. (2018, October 24). *In a crash, should self-driving cars save passengers or pedestrians? 2 million people weigh in*. PBS. Retrieved March 1, 2023, from https://www.pbs.org/newshour/science/in-a-crash-should-self-driving-cars-save-passengers-or-pedestrians-2-million-people-weigh-in

FIGURES/IMAGES

[1] *The human action cycle by Don Norman – Simon Whatley*. Simon Whatley – Service designer, creative technologist and coach. (n.d.). Retrieved March 1, 2023, from https://www.simonwhatley.co.uk/writing/human-action-cycle-don-norman/

[2] Boric, S., Schiebel, E., Schlögl, C., Hildebrandt, M., Hofer, C., & Macht, D. M. (2021, December 18). *Research in autonomous driving – a historic bibliometric view of the Research Development in autonomous driving*. Research leap. Retrieved March 1, 2023, from https://researchleap.com/research-in-autonomous-driving-a-historic-bibliometric-view-of-the-research-development-in-autonomous-driving/

[3] Agatie, C. (2023, January 19). *Tesla owners complaining to NHTSA more often than ever, and issues are well known*. autoevolution. Retrieved March 1, 2023, from https://www.autoevolution.com/news/tesla-owners-complain-to-nhtsa-more-often-than-ever-and-issues-are-well-known-208741.html

[4] Leventhal, J. (2018, October 24). *In a crash, should self-driving cars save passengers or pedestrians? 2 million people weigh in*. PBS. Retrieved March 1, 2023, from https://www.pbs.org/newshour/science/in-a-crash-should-self-driving-cars-save-passengers-or-pedestrians-2-million-people-weigh-in