

On Ethical Considerations Concerning Autonomous Vehicles

Konstantina Marra^a, Ilias Panagiotopoulos^b and George Dimitrakopoulos^c

Department of Informatics and Telematics, Harokopio University, Athens, Greece

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Abstract: Autonomous vehicles are studied in terms of technology and economics, but there is also a social component to be discussed. Whereas technical challenges are being resolved and great progress is being made in their design, social and ethical issues arise, with legal and philosophical aspects, which must be addressed. Following this trend, the present study focuses on exploring peoples' views concerning ethical dilemmas related to the behaviour of autonomous vehicles in road accidents. In addition, liability issues in cases of such accidents are examined. On this basis, a questionnaire based survey is conducted, aiming at investigating the views of future owners of autonomous vehicles on liability and on the decisions, which such vehicles should make in the event of an unavoidable road accident. The above is achieved through a series of thought experiments, which reveal how potential consumers solve different versions of the Trolley-problem in two cases: with and without the option of equal treatment. The present analysis treats the risk of accidents as inevitable and tries to prevent public reactions which could stall the adoption of autonomous vehicles, by revealing peoples' perceptions of morality, which in the future could contribute to creating more ethical and trustworthy autonomous vehicles.

1 INTRODUCTION

Autonomous vehicles will become a reality on the highways in the near future, and it is expected that by 2040 the highways will have lanes specially designed for them (Yang and Coughlin, 2014). This prospect is generally considered to be positive, since autonomous vehicles are expected to improve our quality of life and to be able to prevent road accidents. Schoettle and Sivak (2015), Gless et al. (2016), Lohmann (2016) and Luzuriaga et al. (2019) have pointed out the many advantages of using autonomous vehicles.

However, one should not think that such vehicles never make mistakes or that they are completely safe. Accidents can be prevented, provided that errors and imperfections of the vehicle software remain as limited as possible (Luzuriaga et al., 2019). Otherwise, an autonomous vehicle may not respond appropriately to an unforeseen critical situation, which could result in vehicle damage, human injury or even loss of life (Gless et al., 2016)

Technical failures are not the only risk. Autonomous vehicles are also vulnerable to hacking. A person with malicious intent could, for example, gain illegal access to the vehicle and disrupt the operation of its sensors, in order to cause an accident (Lohmann, 2016; Holstein et al., 2018). Therefore, the scientists and engineers involved in the design of these vehicles must overcome significant technological challenges, particularly those related to the safe interaction of vehicles with their environment (drivers of conventional vehicles, pedestrians, cyclists and other autonomous vehicles).

Although autonomous vehicles are a topic of discussion from a technological and economic point of view, there is also a social side to be considered. While significant progress is being made in their design, as technical issues are gradually being resolved, social and ethical issues arise with legal and philosophical implications that need to be addressed (Holstein and Dodig-Crnkovic, 2018). The experts voice concerns related to the behavior of autonomous vehicles in cases when accidents are unavoidable. One example of a moral issue, from

^a <https://orcid.org/0000-0001-6858-2914>

^b <https://orcid.org/0000-0003-4366-6470>

^c <https://orcid.org/0000-0002-7424-8557>

which significant ethical dilemmas arise, is whether the aim of the vehicle should be to protect its passengers at all costs or to act in a way that minimizes the total number of losses (Luzuriaga et al., 2019). Except for that, in the event of an accident, it is certain that liability issues will emerge. One can easily imagine that the attribution of responsibilities becomes more complex, since autonomous vehicles can operate completely without a driver (Gless et al., 2016).

In light of the above, the purpose of the present study is: (a) to investigate peoples' views concerning which behaviours of autonomous vehicles in critical situations and road accidents should be deemed acceptable, (b) to highlight possible universal preferences of future buyers of autonomous vehicles, which could provide a solution to the problem of choosing ethical rules, based on which autonomous vehicles could be programmed in the future. This is achieved through a series of thought experiments, in which participants are asked to make decisions on behalf of the autonomous vehicle during the road accident.

The paper is structured as follows: Section 2 contains an overview of past studies and presents the ethical problems of driverless vehicles to which the present study refers. The methods used to conduct the present research are explained in section 3. Results as well as conclusions and final remarks are mentioned in sections 4 and 5 of the paper, respectively.

2 ETHICS AND DRIVERLESS VEHICLES

There are a number of ethical issues related to driverless vehicles, such as issues concerning safety, software security, privacy, trust, transparency, reliability, accountability (Holstein et al., 2018).

First of all, in this section, the term "Driverless Dilemma" is explained. Furthermore, an overview of recent studies is given, related to how people perceive crashes involving driverless vehicles, what their varying responses to the driverless dilemma are and what approaches have been proposed for the morality problem.

2.1 Definition of the "Driverless Dilemma"

There are three main methods of programming autonomous vehicles (Luzuriaga et al., 2019): (1) By

using pre-existing ethical rules based on philosophy. This approach is problematic, as there is no unanimity among moral philosophers as to what is moral. (2) Using rules that the general public considers appropriate and acceptable, in order to avoid social outcry in the event of a road accident. (3) Using rules that result from observing the behaviour of car drivers.

A good way to start investigating peoples' opinions concerning the behaviour of autonomous vehicles during an accident, is by extending the thought experiment of the so-called "Trolley Problem" in philosophy to smart vehicles, which will sooner or later have to deal with similar situations. The emerging "Driverless Dilemma" according to Holstein and Dodig-Crnkovic (2018), can be formulated as follows: *"A self-driving vehicle drives on a street at a high speed. In front of the vehicle, a group of people suddenly blocks the street. The vehicle is too fast to stop before it reaches the group. If the vehicle does not react immediately, the whole group will be killed. The car could however evade the group by entering the pedestrian way and consequently kill a previously not involved pedestrian"*.

In these mental experiments, participants are asked to make a decision on behalf of the autonomous vehicle as to who should be saved in the accident. In this way, universal views emerge, which could provide a solution to the problem of ethical rules, on the basis of which autonomous vehicles could be programmed in the future.

However, objections have been raised regarding the effectiveness of such dilemmas. These objections include the view that in real life conditions, vehicles seldom have to deal with only two alternatives. The possible actions are various and more complicated. Moreover, these dilemmas are not considered realistic. It is argued that it isn't possible for autonomous vehicles to have enough control to choose who to rescue, but at the same time not have enough control to completely avoid the accident. Dilemmas are also treated as simplistic, as they ignore factors such as legal aspects and liability issues. (De Freitas et al., 2020).

In addition to the above, the questions posed by the dilemmas include a limited number of possible solutions, all of which are morally questionable. It can be perceived as wrong to force people to make such decisions through these mental experiments. The driverless dilemma is often considered to be a misguided approach that focuses attention on the wrong side of the issue of autonomous vehicle accidents. The research should not focus on who will

lose their lives, but on the complete avoidance of the accident. Indeed, perhaps the most serious concern against these dilemmas is the fact that they involve the assumption that one will survive and one will be killed, based on criteria which ignore that all people are equal. In the simplest case a comparison is made between different sizes of groups of people, but many scenarios suggest making decisions based on age, gender or social class of people. After all, if decision-making on autonomous vehicles required personal data to be taken into account, there would arise an additional problem of privacy and personal data protection, as a vehicle would require access to all personal data (Holstein and Dodig-Crnkovic, 2018).

Even if the driverless dilemma could be solved, another factor which nevertheless renders it ineffective is the fact that there is no overall established infrastructure that allows autonomous vehicles to function properly yet. Whereas in a smart city the autonomous vehicle will be able to obtain detailed information about its environment and choose the solution with the best result that maximizes the benefit and/ or minimizes the damage, one must consider that, until all cities become smart cities, autonomous vehicles involved in traffic will have to interact with human drivers. However, the current mixed environment of vehicles (smart and not) or locations (with and without smart infrastructure) means that the decision-making of the autonomous vehicle cannot be well-founded, due to the fact that there is insufficient data. Therefore, the inequality problem would include even more aspects than it would have if there were already established smart cities (Holstein and Dodig-Crnkovic, 2018).

In any case, these mental experiments are not really intended to examine every aspect of a road accident, but to focus only on ethical aspects in order to investigate which extreme behaviours of a vehicle would be accepted by the general public. This goal is best achieved if the dilemmas are more simply formulated, even if that means they become less realistic. It should be borne in mind that non-experts in artificial intelligence or ethical philosophy are the majority and are the future buyers of autonomous vehicles. Therefore, it is important to find a way of communication between scientists and the general public, which makes the simplicity of these mental experiments a positive element. In addition, the dilemmas manage to draw the public's attention to the ethics of autonomous vehicles, which is desirable, since progress in a field can only take place if a corresponding interest exists. (De Freitas et al., 2020).

2.2 Responses to the “Driverless Dilemma”

Ethics of autonomous vehicles have attracted the attention of many researchers, who seek to define how such a vehicle should be designed. In theory this subject has been approached among others by studies such as Shariff et al. (2017) and Bissell et al. (2018).

The study by Liu et al. (2019) shows that, although the consequences of the crashes involving an autonomous vehicle and a conventional vehicle were identical, the crash involving the autonomous vehicle was perceived as more severe, regardless of whether it was caused by the autonomous vehicle or by others and whether it resulted in an injury or a fatality. The research by De Freitas and Cikara (2020) revealed more negative reactions towards the manufacturer of the autonomous vehicle, when a vehicle caused damage deliberately.

According to the study by Gao et al. (2020), most of the participants wanted to minimize the total number of people who would be injured in a road accident. It has also been concluded that most drivers consider not only their own safety, but also the safety of pedestrians, as they chose to hit an obstacle rather than hit pedestrians. Choosing a course with obstacles in order to protect a pedestrian could also be considered as a way to minimize the overall damage caused. Bonnefon et al. (2016) have also noted that participants strongly agreed it would be more moral for autonomous vehicles to sacrifice their own passengers when this sacrifice would result in minimizing the number of casualties on the road. However, the same participants showed an inclination to ride in autonomous vehicles that will protect them at all costs. According to Liu and Liu (2021) participants perceived more benefits from selfish autonomous vehicles which protect the passenger rather than the pedestrian, showing a higher intention to use and greater willingness to pay extra money for these autonomous vehicles.

The results of the research by Tripat (2020) showed that, due to the shift in accountability, autonomous vehicles seem to have also shifted people's moral principles towards self-interest. In the case of an autonomous vehicle, the control of the actions of the vehicle by the human driver is limited, so the responsibility for any harmful consequences can be attributed to the autonomous vehicle. As a result, it is possible for the passenger to ensure their self-protection while exempting themselves from the moral cost of causing damage to a pedestrian. Therefore, it is expected that most people would be

willing to choose to cause harm to the pedestrian when it comes to an autonomous vehicle.

The research of Bigman and Gray (2020) showed that people would prefer to save a woman over a man, a younger person over an older one, a person with good physical health over a person with poor physical health, a person of a higher social status over a person of lower social status, a law-abiding person over a delinquent person. Also, the participants in the research would choose to save the largest possible number of people, and they would rather save the pedestrians than the passengers of the vehicle. With the addition of a third option, which allowed the two parties partaking of the dilemma to be treated equally, it was observed that the vast majority chose this option, revealing that the general public wants autonomous vehicles to treat people equally.

The paper by Li et al. (2019) presents three principles that could serve as solutions to the ethical problems of autonomous vehicles: the principle of consciousness transformation, the principle of responsibility distribution, and the principle of law making. The principle of consciousness involves teaching and giving the correct amount and type of information to the people. The level of responsibility distribution concerns both ethical and legal aspects. Small disputes of responsibility can be resolved through ethics, but complex and difficult judgment disputes must be resolved through legal means, which is why the law-making principle is needed.

3 METHODOLOGY

Although researchers have studied the moral dilemmas of autonomous vehicles both theoretically and practically, ethical issues have not yet been resolved, since we can reach no definite conclusion as to which actions of a vehicle would constitute moral behaviour. The present analysis does not aim to provide any recommendations regarding particular principles on which the programming of autonomous vehicles can be based. It focuses on investigating the opinions of the public about autonomous vehicles with different crash behaviours, and how these opinions could be considered before attempting to design any crash algorithms.

On this basis, the main research questions on which the present analysis is focused are the following:

- Who is considered responsible in case of an accident with an autonomous vehicle?

- How do people react to different scenarios of the driverless dilemma?

In order to answer the above questions, a quantitative survey was carried out through a questionnaire of 24 closed-ended questions. The survey was conducted between July and October 2021. Questionnaires were distributed electronically via mailing lists and social media, and the filling out was done by individuals residing in Greece. The sample of individuals was random, so that they do not have common characteristics and can represent the general population of the country. Answers were recorded from 266 participants.

Concerning the questionnaire's structure, it includes the following categories:

- Demographic attributes (5 questions)
- Autonomous vehicle liability issues (2 questions)
- Thought experiments (17 questions), which contains "Driverless dilemma - Possible solutions" (5 questions), "Thought experiment with forced choice" (6 questions), and "Thought experiment with equal treatment option" (6 questions).

More precisely, in order to discover the participants' views on liability issues, participants were asked if they would hold responsible for an accident the owner of the vehicle, the vehicle itself or rather the manufacturer of the vehicle. In addition, they were asked if they would be willing to take collective action against an autonomous vehicle manufacturer, in the event of a road accident caused by an autonomous vehicle.

With respect to the driverless dilemma, questions were asked on whether the participants would actively change the vehicle's course or prefer to remain inactive, whether the participants would prefer a larger rather than a smaller group of people to be saved, which group they would save, if one group could be saved only with a violation of the highway code, while the other could be saved without violating the highway code and whether they would prefer the vehicle to save its passengers or the pedestrians. Questions relating to the thought experiments also include scenarios of autonomous vehicle accidents, in which the participants have to decide who to save between two options: younger or older, male or female, fit or in a bad physical condition, law-abiding or demonstrating delinquent behaviour, higher or lower social status person or animal. In these choices, equal treatment is allowed at first, but then the participants are presented with the same questions with forced inequality.

Furthermore, the questionnaire in its introduction section included a definition of the term “autonomous vehicle” as well as detailed descriptions for each case of the thought experiments. The above were introduced in order to solve the problem of participants’ unfamiliarity with the subject of the present analysis, assuming that they have no previous knowledge of autonomous vehicles.

4 RESULTS AND DISCUSSION

This section presents the results of the research. Table 1 shows the demographic data of the respondents. Regarding the gender, the participant sample is almost divided in half. The majority of the participants are under 29 years of age and live in a big city/ capital. Most of the participants are secondary education graduates and single.

Concerning liability issues, more participants consider the owner of the vehicle responsible (50.7%) rather than the manufacturer (44.4%). Very few consider the vehicle itself responsible (4.9%), probably because they realize that the vehicle is making the decisions it has been programmed to make. Results also have shown that people would be willing to take collective action against an autonomous vehicle manufacturer in the event of an autonomous vehicle causing a road accident (60%).

Regarding the autonomous vehicle dilemma, action and change of course were preferred, when participants were faced with the choice to maintain the vehicle’s course or change it (80.5%). Saving the larger number of lives was also preferred (91.4%), as well as observing the Highway Code, if one group can be protected without violating it (75.6%).

The number of people who would prefer to save the passenger in an accident is exactly the same as the number of people who would prefer to save the pedestrian. Not all people who prefer the pedestrian being saved were consistent with their choice, however most would indeed be willing to be passengers to an autonomous vehicle which sacrifices the passengers (54.1%). If most people who would like to protect the pedestrian from the passenger were reluctant to drive vehicles programmed to sacrifice the passenger, then that would reveal a possible obstacle to the adoption of autonomous vehicles that are programmed with such ethical rules.

Furthermore, 92.9% of the participants chose to save the younger person while 7.1% chose to save the older when faced with forced inequality. With equality allowed, 37.2% chose to save the younger

Table 1: Demographic attributes of respondents.

| Gender | Frequency | Percentage (%) |
|--|-----------|----------------|
| Male | 133 | 50.0 |
| Female | 131 | 49.2 |
| Other | 2 | 0.8 |
| Age | Frequency | Percentage (%) |
| ≤ 20 | 88 | 33.1 |
| 21-29 | 91 | 34.2 |
| 30-39 | 33 | 12.4 |
| 40-49 | 37 | 13.9 |
| 50-59 | 15 | 5.6 |
| ≥ 60 | 2 | 0.8 |
| Place of residence | Frequency | Percentage (%) |
| Big city / capital > 100000 inhabitants | 160 | 60.2 |
| Suburb | 48 | 18.0 |
| Small town < 100000 inhabitants | 24 | 9.0 |
| Province < 30000 inhabitants | 34 | 12.8 |
| Marital Status | Frequency | Percentage (%) |
| Single | 205 | 77.0 |
| Married | 54 | 20.3 |
| Divorced / Separated | 6 | 2.3 |
| Widow/er | 1 | 0.4 |
| Education | Frequency | Percentage (%) |
| Primary school graduate | 6 | 2.3 |
| Secondary school graduate | 146 | 54.9 |
| Trade / technical / vocational training graduate | 7 | 2.6 |
| Bachelor’s degree | 71 | 26.7 |
| Mastert’s degree | 34 | 12.8 |
| Doctoral diploma | 2 | 0.7 |

person, 1.1% chose to save the older and 61.7% chose the equal treatment (Figure 1a).

In the case of forced inequality, 89.5% of the respondents preferred to save the female pedestrian, whereas 10.5% preferred to save the male pedestrian. With equality allowed, 5.3% would save the female, 0.3% would save the male, while 94.4% would choose equal treatment (Figure 1b).

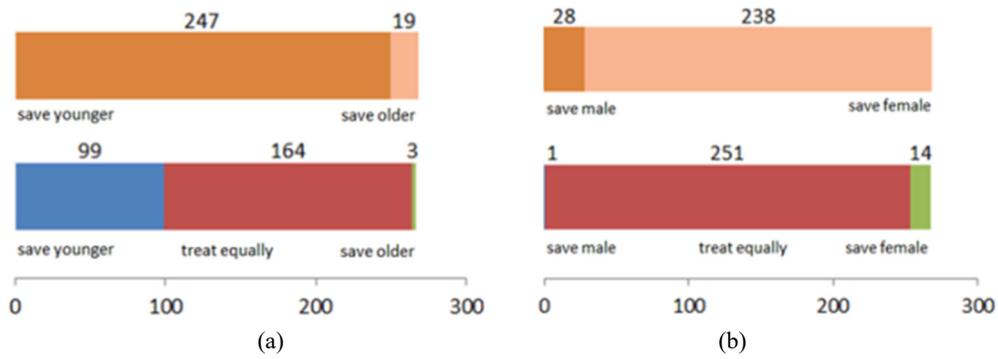


Figure 1: Number of responses regarding (a) the choice between a younger and an older pedestrian, (b) the choice between a male and a female pedestrian.



Figure 2: Number of responses regarding (a) the choice between a pedestrian in good physical condition and a pedestrian in a bad physical condition, (b) the choice between a law-abiding pedestrian and a pedestrian with delinquent behaviour.

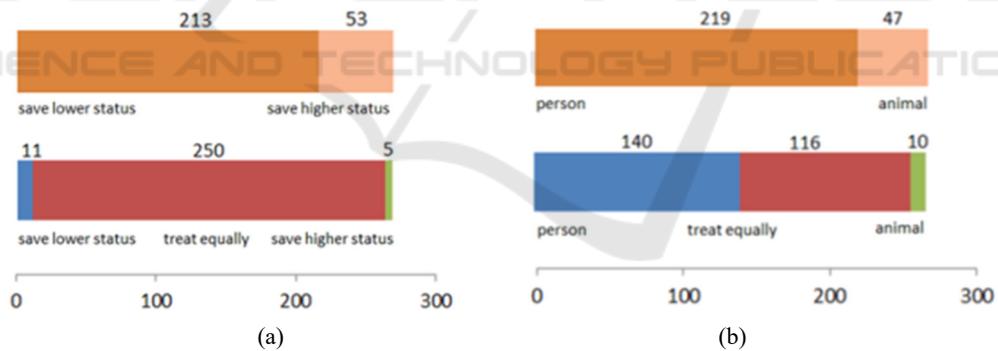


Figure 3: Number of responses regarding (a) the choice between a pedestrian of lower social status and a pedestrian of higher social status, (b) the choice between a person and an animal.

Moreover, 53% of the respondents find it preferable to protect a person with a good physical condition and 47% would choose in favour of a person with a bad physical condition, when no equality is allowed. If equality is allowed, 4.1% would save the fit person, 6% would save the unfit person and 89.9% would treat them equally (Figure 2a).

Faced with forced inequality, 92.9% of the participants chose to save the lawful person, whereas 7.1% chose to save the lawless one. With equality

allowed, 29.7% would save the lawful, 1.1% would save the lawless, while 69.2% would prefer equal treatment (Figure 2b).

In addition, 80.1% of the participants chose to save the pedestrian of lower social status, while 19.9% chose to save the pedestrian of higher social status in the case of forced inequality. With equal treatment allowed, 4.1% chose to save the pedestrian of lower social status, 1.9% chose to save the pedestrian of higher social status and 94% chose equality (Figure 3a).

Furthermore, 82.3% of the participants chose to save the human while 17.7% chose to save the animal when faced with forced inequality. With equality allowed, 52.6% chose to save the human, 3.8% chose to save the animal and 43.6% chose equal treatment (Figure 3b).

Overall, it has been observed that people show a preference for equal treatment of individuals. Equal treatment was not chosen by the majority only in the case of the human vs. animal dilemma, in which saving the person over animal was preferred. When there is no equal treatment option, the research has revealed a universally strong preference for saving younger people over older people, women over men, law-abiding people against offenders, people of lower social status over people of higher social status and humans over animals. It also seems that there are weaker preferences for saving people who are in better physical condition than those who have worse physical condition.

Chi-squared test shows that there is a correlation between one's gender and the gender one chooses to save when there is no choice of equal treatment ($p=0.004996927<0.05$). There is also a correlation between one's age and the age one chooses to save when there is no choice of equal treatment ($p=0.004225882<0.05$).

At this point, it would be of interest to explore the relation of the present research to previous studies. The present study combines the questions raised by Gao et al. (2020) with the dilemma cases presented in Bigman and Gray (2020) and adds questions of liability to them. Compared to the research by Bigman and Gray (2020), the reactions of the respondents participating in our research were similar concerning gender, age, fitness and lawfulness. However, our participants seem to deem saving people of lower social status as more favourable. Also, our participants prefer to take action during a critical situation on the road (choose actively whether to change course or remain on the same course instead of abstaining from making a decision), whereas the participants of the research by Bigman and Gray (2020) would choose to remain inactive. Our participants' responses also confirm what the study by Gao et al. (2020) has shown, namely that people generally choose to save the greater number of people and that they are concerned about the safety of the pedestrians, often choosing to protect the pedestrian instead of the passenger.

5 CONCLUSIONS

Autonomous vehicles have the potential to offer great advantages from a social, economic and environmental point of view as long as the ethical issues related to them are resolved. On this basis, the purpose of the present study was to investigate peoples' views concerning which behaviours of autonomous vehicles in critical situations and road accidents should be deemed acceptable.

According to the results of the present analysis, participants believe first the owner and next the manufacturer to be responsible for faults in the behaviour of the vehicle. That implies that people regard the owner as accountable for mistakes that result in a crash, and at the same time hold the manufacturer of the vehicle responsible for minimizing the unreliability of the software. In addition, most respondents thought that autonomous vehicles should make utilitarian decisions and behave in a way which ensures the greater good. Specifically, saving the greater number of people and sacrificing the passenger in favour of the pedestrian are actions which seem to be perceived as more acceptable. A particularly important finding concerns the strong preference for equal treatment. Results suggest that people consider unbiased behaviour on the part of the vehicle more justifiable.

Regarding the limitations of our research, only a few answers were recorded by participants over 50 years of age. Although that means that the participants may not be representative of the general population, they are considered to at least represent the first buyers of autonomous vehicles. However, it would be appropriate to repeat the research in a larger population, to examine whether the findings remain consistent. Furthermore, the majority of respondents are not familiar with the subject of the study, due to the fact that autonomous vehicles are not expected to become a reality by 2025, and therefore, it would be appropriate for future research to take into account the lack of information and experience of participants. Finally, the present work has addressed only a small range of ethical issues that are expected to arise with the introduction of autonomous vehicles.

Future research should be further extended to other contexts, such as the development of technology acceptance models related to ethics of autonomous vehicles, by revealing peoples' perceptions of morality. Some extra recommended questions, which future research could explore, is the authorities' role in making the owner and manufacturer of autonomous vehicles liable towards

their behaviour and the correlation between the dilemma responses and the willingness of the participants to own an autonomous vehicle.

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