A Study on Public Acceptance of Self-Driving Cars in China via Surveys and Serious Games

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Abstract

Google Trends showed that public interest in “driverless cars” has increased ten times compared to a decade ago. At the same time, people may have concerns about this disruptive technology. In this study, we studied the public acceptance of autonomous vehicles in China, conducted surveys, and developed a game for participants to better understand automated driving technology, including its regulations, safety, efficiency, and related economic and environmental issues. Our research showed that Chinese generally have positive attitudes and an overall higher acceptance rate about self-driving cars. We also demonstrated games can be a somewhat useful tool to improve public acceptance of self-driving cars.

Acknowledgment

First and foremost, we would like to express our deepest appreciation to professor Xinming Huang of the Worcester Polytechnic Institute. He provided us with valuable advice and guided us through the completion of this Interactive Qualifying Project. He had a profound belief in our works. The game development would not have been possible without the support and nurturing of professor Huang.

We would also like to thank professor Jianyu Liang of the Worcester Polytechnic Institute. She played a decisive role in helping us with the initial project proposal. We were grateful to take ID2050 with the instructor, professor Jermoh Kamara of the Worcester Polytechnic Institute. She provided us with insights and encouragement throughout the duration of this project.

We would also like to extend our deepest gratitude to the project sponsor, Jumbo Chen of TuSimple. He was instrumental in our game design process, and he never wavered in his support to help us understand the point of view of engineers from autonomous driving companies and people's concerns.

We would like to extend our sincere thanks to the Institutional Review Board of the Worcester Polytechnic Institute. They assisted us to develop a formal consent process and approved our survey and game to smoothly complete the project. Their patience and dedication could not be underestimated. They maintained strict ethical standards to guarantee the rights of participants.

We were deeply indebted to all the people who gave consent to participate in the project. Their contributions allowed us to explore significant findings in data analysis. Special thanks to our friends and families who advertised and introduced our project and game to others.

Executive Summary

In this study, the research team completed three main stages: benchmark surveying, game simulation, and a comparison of participants' attitudes before and after playing the game.

The benchmark survey consisted of twenty-three questions, and it collected participants' basic preferences and general acceptance rate on self-driving cars. The first few questions of the survey asked about demographic information of the participants. Following the demographic questions, the survey continued to ask participants if their decision on whether to adopt or accept automated driving technology will be affected by the four factors: governmental policies, safety, efficiency, and economic and environmental impact. For instance, Question 6 asked about participants' attitudes towards governmental regulations and policies related to autonomous vehicles. When analyzing the result of this question with respect to the demographic information collected, the research team generated pie charts for each age group to represent the distribution of different answers.

After the first half of the benchmark survey which focused mainly on participants' basic preferences regarding autonomous driving, the later half investigated the opinions and acceptance rates of participants towards this technology. The first few questions asked participants to express their thoughts on ethical problems caused by the existence of autonomous vehicles while the remaining questions directly asked participants whether they would accept and use the automated driving technology. Answering these questions, participants needed to think thoroughly about the social impacts of deploying autonomous vehicles, as well as to what extent they would like autonomous driving to be involved in their everyday lives. The results of these questions will not only indicate participants' personal attitude but their expectation of other people's willingness to adopt autonomous driving. Considering that some participants might be uncomfortable with answering certain ethical questions, "unable to answer" is offered as a choice in those questions. Other than the multiple choice questions, there was an optional open-ended question, which enabled participants to express their views freely at the end of the survey. Participants were given enough space to talk about any topics related to autonomous driving, or they could simply skip this question.

Data analysis was the last procedure in stage 1. The analysis process followed the one-week-long data collection, with Tencent Survey being the main data collecting method. Tencent Survey could generate a csv file to present the survey results. The data enabled us to create pie charts and tables representing the distribution of answers from each question. Through the pie charts, tables, and further data analysis, participants' attitudes regarding autonomous driving became easier to understand and summarize. With small variations across age groups, participants generally gave positive feedback on the acceptance of autonomous vehicles, while being vigilant toward the potential safety hazards. Participants were not yet ready for large-scale deployment of autonomous vehicles, but they were looking forward to future advancement of the technology.

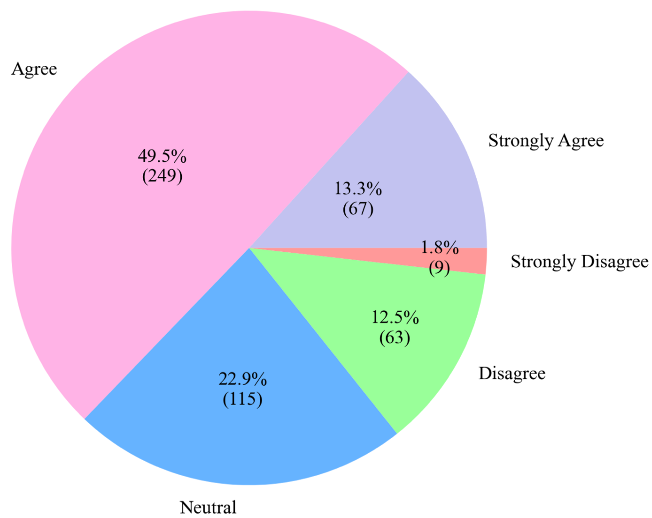

Figure 1: Pie chart representing the public acceptance rate

Game simulation stage was to invite participants to use a self-design game simulator. After playing the games, participants needed to answer three questions from the original survey. The simulation included two scenarios: Safety and Efficiency. The implementation of the two scenarios was decided by the result of data analysis from stage 1. Since participants showed great interests in the safety aspect of autonomous driving, the research team decided to design a safety scenario. In this scenario, the simulation showed participants that autonomous vehicles had huge advantages over conventional cars since they would not violate traffic laws. The research team built a mock city block with nine intersections. Conventional cars broke traffic rules in this city block while autonomous vehicles would not. Percentages of conventional cars breaking rules can be controlled by participants. During the simulation process, participants inspected the city from a top-down view, and they were notified about the total number of car crashes that happened to automated and human-driving cars, respectively.

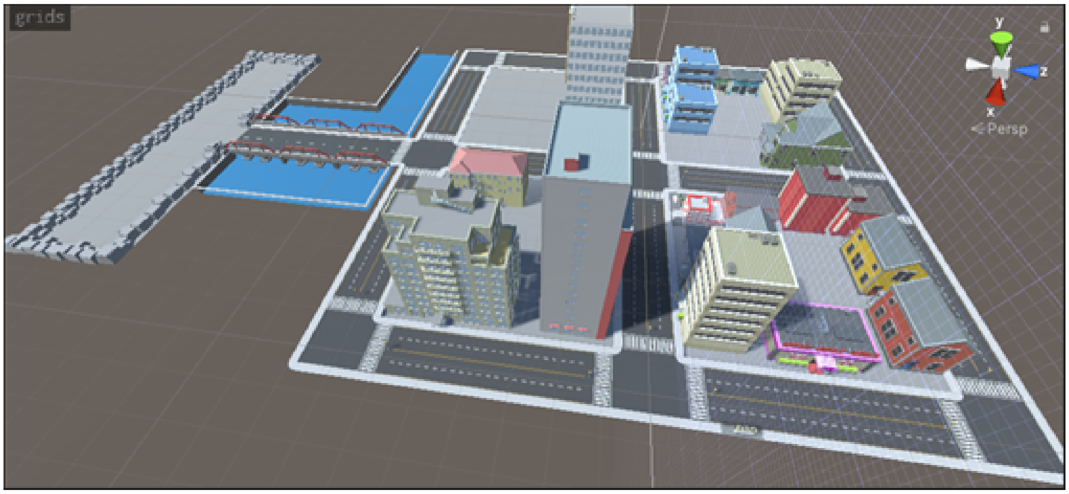

Figure 2: Screenshot of the city block in safety scenario

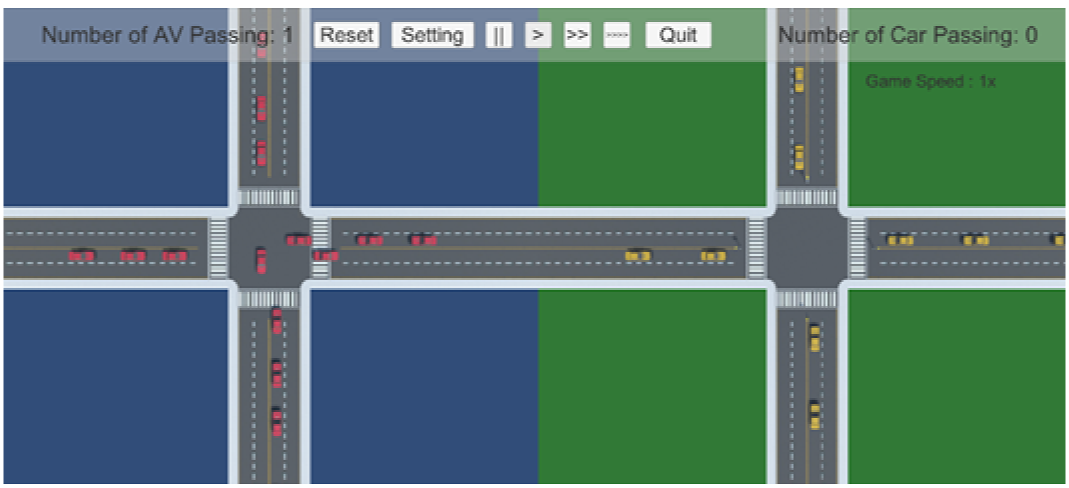

Figure 3: Screenshot of the efficiency scenario from the project team's simulation

In addition to the safety scenario, the research team also created an efficiency scenario. During the data analysis process, researchers noticed that fewer participants paid attention to the efficiency aspect of autonomous vehicles than to the safety aspects. A potential explanation was that participants were unaware of the potentially incredibly high efficiency with widely deployed autonomous vehicles. By presenting them the high potential of fully autonomous traffic, the game simulation might possibly change participants' views on the importance of autonomous driving. In this scenario, the game simulation was restricted on two congruent intersections, with one running conventional vehicles and the other running fully automated vehicles. At the intersection with conventional vehicles, cars needed to obey traffic rules and wait for the traffic lights. At the other intersection, there were no traffic lights. Autonomous vehicles were all connected, and they could drive through the intersection whenever they could assure safety among each other. On the side of the screen, two numbers were displayed to represent the number of cars that passed the crossroad. Participants can change parameters of vehicles, such as the speed limit. The game simulation shows that for all automated vehicles, the traffic through an intersection is about twice much faster, which could inform participants that autonomous driving could make a huge difference on traffic efficiency. After playing these two game scenarios, participants were asked three questions that were to evaluate whether participants have changed their views after playing the games.

Participants had to choose whether they "strongly disagree", "disagree", "neutral", "agree", or "strongly agree" with the following three statements: (1)The safety aspect of autonomous vehicles will influence your acceptance of autonomous driving. (2) The efficiency aspect of autonomous vehicles will influence your acceptance of autonomous driving. (3) Will you buy or drive an autonomous car? These questions covered two of the four determinant factors of autonomous driving in the study. Most participants also provided the last four digits of their phone numbers as usernames. The research team then evaluated changes in individual opinions by matching their responses using the four digits.

Stage 3 was to compare the answers of two surveys to check if the responses of participants were consistent before and after playing our game. The game simulation has made a positive change to participants' acceptance of autonomous driving. Overall, our research produced significant results: Chinese participants largely accept the newly automated driving technology.

Details of this study are all listed in this report. After the abstract, acknowledgement, and executive summary, the main part of the report begins with an introduction of autonomous vehicles. The next section is the background information about four aspects of automated driving technology we categorized. Subsequently, the methodology section explains how the survey is generated, how the data collection and analysis are completed, and how the game simulation is designed. Then, following the concrete data analysis, conclusion and future recommendation are provided at the end of this report. For references, the survey questions are listed in the appendices.

Authorship

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1: Introduction

People define autonomous vehicles from different perspectives. In 1973, Stephen King published a short story *Trucks*, which described a world where humans were enslaved by trucks with intelligence, to depict the struggles of blue-collar workers under the Industrial Revolution. The fiction might leave a negative impression on autonomous trucks for Millenials. On the contrary, starting from 2007, the film series *Transformers* imposed the idea of heroic intelligent robots in the form of autonomous trucks for Generation Z. Scenes of self-driving cars have become more positive and prevalent in movies and TV series. Increasing online posts start to describe a near future with driverless vehicles and expect more autonomous cars cruising on highways across the globe.

The Union of Concerned Scientists gave a well-known technical definition on self-driving cars: "cars or trucks in which human drivers are never required to take control to safely operate the vehicle. Also known as autonomous or 'driverless' cars, they combine sensors and software to control, navigate, and drive the vehicle."

Waymo founded by Google, Argo AI invested by Ford, and all other famous high-tech or car companies in the United States are competing against each other to take the lead in the field of autonomous driving. Similarly, in China, the Beijing local government has published its own autonomous vehicle testing reports since 2019, based on the data gathered from 14 Chinese start-up companies. Therefore, large amounts of investments rush into this promising market. People's concerns start to arise with this irreversible trend of evolving into a highly automated society with driverless cars.

One of the most prevalent concerns is safety. Accidents often generate worldwide discussion on the topic. In 2018, when Uber performed road-testing, even with a driver inside, a self-driving car killed a pedestrian, Elaine Herzberg, who was crossing the road with a bicycle in Tempe, Arizona. Although people regarded the incident as the first fatal accident caused by automated driving technology, in 2016, Tesla self-driving mode was considered causing a car crash and the death of car driver, Yaning Gao, in Hebei, China. Both the United States and China initiated road-testings for autonomous vehicles with safety concerns remaining unsolved.

Long before the actual road-testing of autonomous vehicles, the general public was thinking about other important societal issues. One of the WPI IQP teams in 2007 analyzed the socio-economic effects and the technical sides of autonomous vehicles. Another IQP team in 2013 surveyed on public acceptance of autonomous cars. With abundant innovation before 2021, recent research papers calculated energy preserved by managing an autonomous traffic network, along with rapid mobility. Besides these benefits, the negative sides of automated driving technology, including job loss and moral decisions, are still controversial.

The public recognizes that autonomous vehicles will make a revolutionary change in the traffic system, with further impacts on modern society. It has been envisioned to increase vehicle safety via the reduction of accidents. It contains hundreds of undiscovered possibilities towards social, economic, environmental, and technological advancement.

In particular, TuSimple, the sponsor of our project, is a leading company focused on implementing autonomous trucks in real life. TuSimple has already completed hundreds of testing trials on the highways in the southwestern part of the United States. TuSimple raised more than $1 billion in an I.P.O. that valued the company at nearly $8.5 billion, with the symbol TSP on the Nasdaq (Chokshi, 2021). This project will contribute to the sponsor by helping them to predict future acceptance rates and develop potential solutions for their concerns, which will draw the public's awareness and possibly educate people to think critically about the fast-growing technology.

The purpose of this project is to investigate, identify, and address four main aspects of autonomous vehicles and analyze how they influence the public acceptance rate and opinions toward the technology. At the end of our project, our sponsor will glean information on the change in the acceptance rate, or even possibly how individual opinions can be altered, toward self-driving cars. Such information will assist society to become more aware of existing technologies related to autonomous vehicles.

2: Background

This background presents a literature review of social and ethical implications of autonomous vehicles. Topics are categorized into four sections. The first section introduces the definition of autonomous vehicles and compares government regulations in the United States and China. The second section covers safety concerns involved with drivers, passengers, and pedestrians. The third section discusses the pros and cons of autonomous vehicles in traffic management. The fourth section delves into the long-term impact on the economy, environment, and employment. The last section summarizes the public acceptance rate estimated by previous studies.

2.1: Autonomous Vehicles: General Information and Law Enforcement

An autonomous vehicle is essentially a vehicle with the ability to collect information about its environment and navigate through it without human involvement. The Society of Automotive Engineers (SAE) recommended using the term “automated driving systems (ADS)” to refer to autonomous vehicles. SAE uses the word “automated” other than “autonomous” or “autonomy” to avoid ambiguous meanings. A fully “autonomous” car would have the self-awareness and the ability to make choices itself but an “automated” car should only be able to follow orders and drive itself. The Society of Automotive Engineers (SAE) also introduced the definition for six levels of automation from Level 0 (fully manual) to Level 5 (fully automated) in 2014 (“What is an autonomous car?”, 2020). In 2016, the U.S. Department of Transportation formally adopted these definitions. However, China hasn’t released any formal notification to adopt any international standard for autonomous vehicles, like the one(s) issued by SAE. Until 9 March 2020, the China Ministry of Industry and Information Technology released a draft *National Standards on Taxonomy of Driving Automation for Vehicles*, with content that clarifies autonomous driving in levels similar to SAE levels.

Nevada is the first state in the U.S that approved regulations regarding autonomous vehicle operation on designated roads. Google, a company which hopes to legally conduct further testing for their driverless car project on public streets, is partly responsible for the approval of those regulations. Before that, Google could only conduct the test on public roads in California, getting around the state’s reckless driving law, with two attentive researchers who could take over control at any time. But a human driver is still required during the testing of autonomous vehicles according to the regulations passed in Nevada. In 2012, Florida and California passed their own bill to start adopting rules and regulations for the safe operation of autonomous vehicles on public roads, similar to those in Nevada. In 2013, driverless cars were able to be tested on public roads in the United Kingdom. Before that, the tests could only be conducted within private lands in the U.K. In China, the Beijing local government published the first autonomous vehicles related law in 2017. The law included regulations for conducting road tests for self-driving vehicles, but those tests are limited to streets in Beijing. The legislators learned from the leading countries, including the United States, Germany, and Australia when drafting the law. Baidu's test on its autonomous vehicle in 2017 might be the cause of the publication of this law, which caused many controversies because the test itself is totally unregulated.

Even though automated driving technology itself is not a mature industry yet, many countries including China and America are working on completing the law systems regarding autonomous driving to prepare for the incoming era of autonomous vehicles. In January 2021, the U.S. Department of Transportation published a comprehensive plan of automated vehicles to facilitate transportation innovation and safety and to ensure the country remains a leader in automation. In April 2020, China announced a more standardized guidance, which includes the ban of road-testing conducted by foreign companies due to national security issues. There were 11 companies conducting road-tests in Beijing in the same year but TuSimple is not one of them, possibly because it's an American company.

2.2: Autonomous Vehicles: Safety, Cybersecurity, and the Moral Dilemma

According to the Association for Safe International Road Travel (n.d.), car accidents happen every day and everywhere. Over 3800 people died on American roadways each year, with a fatality rate of 12.4 deaths per 10,000 inhabitants. Moreover, there are 4.4 million people injured due to road crashes (Association for Safe International Road Travel, n.d.). In China, 244,937 cases of car accidents happened in the year of 2018 causing 63,194 deaths (Zhang, 2020). Fortunately, there may be a chance to ensure driving safety or zero fatalities.

According to data collected by Ingle & Phute (2016), 94 percent of serious car crashes are due to human errors. If people can widely adopt autonomous driving, safety on the road would drastically increase (Ingle & Phute, 2016). They believed that the new generation of autonomous driving, the Tesla Autopilot, could change the way people navigate and transport by incorporating state-of-the-art current artificial intelligence and hardware technology. Tesla Autopilot, according to Ingle and Phute, would also “relieve drivers of the most tedious and potentially dangerous aspects of road travel,” because of Tesla’s next-generation autonomous driving experience with real-time driving updates. They had high assessments on this technology of Tesla, referring to it as how an airplane autopilot does when conditions are clear.

No matter how well the Tesla autopilot system seemed to be, it was still not a perfect system. Endsley (2017) conducted a naturalistic driving study on the autonomous driving systems of the Tesla Model S. He found out that there are quite a few challenges on “dealing with new autonomous automobiles in realistic driving conditions.” Tesla’s current semi-autonomous driving systems could increase the variability in situation awareness that deserved consideration.

There are also accidents caused by Tesla’s autonomous driving that would further decrease its reputation. Recently, according to the New York Times, a Tesla “crashed and burst into flames, killing two men” while it was auto-piloting. An official said the men in the car were testing the driverless features of Tesla before the accident (Pietsch, 2021).

While there has not been a perfect autonomous driving system yet, a lot more researchers are putting their efforts into how to make autonomous vehicles safer, with high traffic flow stability. Kim (2021) came out with “decision-making and control procedures for realizing autonomous lane change.” After they performed simulation experiments on 12 different scenarios, they believed that their controller design can ensure vehicle motion stability as well as the overall safety.

Researchers did not just collect data from the road to enhance autonomous driving systems. In a study conveyed by Jiang (2018), he was trying to monitor the intent of human passengers to respond to the dynamic changes in desired destinations. Jiang and his colleagues conducted a human study to investigate if there are benefits of using a copilot system instead of merely manual or autonomous driving. Researchers also tried to make image classifications more precise using deep learning technology that could help autonomous vehicles to better identify pedestrians, animals, and other unusual scenarios. Such studies often provide successful outcomes, but they also raised a question: will autonomous vehicles only take and record photos to aid driving? People need to know if autonomous vehicles will upload these photos to car companies, if autonomous vehicles will also record audio data aside from images, and if hackers can crack these data.

By widely adopting autonomous driving, there may be fewer accidents and deaths related to human errors like drunk driving, but there are accidents that are hard to avoid even for autonomous vehicles. MIT conveyed a moral machine test asking people to choose in the case when the car brake is broken (Scalable Cooperation). Participants are to choose from prioritizing the lives of passengers or the lives of innocent civilians crossing the road. How engineers program autonomous vehicles to act in emergencies like that has become a moral controversy.

2.3: Autonomous Vehicles: Efficiency and Traffic Management

The first step humans learn how to drive is through some simple tasks. Everyone may encounter a situation of drivers putting their toes on the gas pedals and ready to be the first one rushing through a crosswalk before the green light. Autonomous cars are capable of winning this match. Researchers built a mathematical model for testing the traffic efficiency of autonomous vehicles under high traffic lights and generated a positive result (Cheng, 2021). Besides the basic driving task, parking tasks even became more efficient for autonomous cars than for human drivers (Jiang, 2018).

Not only being able to accomplish individual driving tasks, autonomous cars can also contribute to traffic management. Researchers built a hybrid traffic system consisting of both autonomous and traditional cars to achieve greater efficiency. Researchers showed that Multiagent driving policies outperform traffic with only human drivers (Cui, 2021). Especially autonomous vehicles can contribute to traffic congestion reduction (Chen, 2017). Scientists proved that flow control will be possible via a few autonomous vehicles, less than 5 percent of the total number of cars on road can help to avoid bulk traffic flow (Stern, 2018).

More surprisingly, traffic waves can be dampened by only controlling the velocity of a single vehicle in the flow (Stern, 2018). Does this feature require the exchange of information between autonomous vehicles? Some scientists believe there is no need to develop a new communication method between autonomous vehicles (Cui, 2021). This may result in fewer privacy concerns since these vehicles are not connected through the internet.

Indeed, many research papers conclude that autonomous vehicles can increase traffic efficiency and mobility. Similar to the process of transforming from riding horses to driving automobiles, the adoption of autonomous cars may even create a faster lifestyle. People generally believe fast-paced modern society is one of the causes for anxiety and depression (Brown, 2014). Although there is a lack of scientific evidence between fast-paced lifestyles and human's negative feelings, some articles suggest that increased efficiency means fewer interactions between people, while daily interaction has a positive correlation with happiness and feeling of belonging. Therefore, some people believe that increased efficiency will make humans lonely, sad, and miserable.

Another concern is that efficiency sometimes is equivalent to higher speed, which is correlated with a greater extent of vehicle damages and a higher death rate if an accident happens(High-speed vs. low-speed collisions, 2018). An optimistic view on this problem is that autonomous vehicles may be able to avoid any car crash with a shorter time to react and adjust direction than human drivers.

2.4: Autonomous Vehicles: Economic and Environmental Implications

From a city-wide perspective, autonomous vehicles can add another layer to green life. Private transport vehicles and heavy-duty trucks are contributing greatly to the pollution that impacts nearly one half of the citizens in the United States (Union of Concerned Scientists, 2014), but an electronic autonomous vehicle (EAV) system can alleviate and eventually solve this issue by maintaining and hosting vehicles without any emission.

Private cars are parked 23 hours per day on average and constantly occupy 25 percent of urban surface space (Gardner, 2011). Years ago, people may have swayed to choose to use public transportation, like buses, to alleviate traffic, environmental, and space pressures. However, since public transits are hosted in fixed routes and schedules, people may choose private transits for personal travels (both in short-distance and long-distance) when services are not supported. Car-sharing, a new transportation mode that bridges between public and private transit, can hold the environmental and economic benefits from public transportation mode while providing flexibility and privacy to passengers.

Autonomous vehicles can help the car-sharing systems to be even more efficient and greener. The traditional car-sharing system still faces environmental and management issues.

Due to the need for human-involving to relocate shared-cars and lack of workers, balanced distribution of cars is another big difficulty. EAV can be the saver of these issues – it does not generate any pollution, and it can relocate itself automatically. Researchers in China had used the Monte Carlo simulation model to evaluate the total system cost for a given location and vehicle deployment design and tested its effectiveness with a field test in Yantai City, China (Zhao, 2019). The result cheerfully proved the environmental, traffic, space, and economic friendliness of EAV systems at the city level.

In terms of another major pollution contributor - heavy-duty trucks - EAV systems can not just only help to reduce emissions but improve maintenance cost. EAV solves the driver shortage problem and saves the labor cost in this part. Further, the system can dynamically monitor and control the fleets to make the whole system more efficient, which will make the whole system more lucrative.

Considering putting the EAV system for passenger transportation and heavy-duty delivery together at the city level, the city can even benefit more since the majority of vehicles will be in operation at any time, which will save lots of parking space for the city, though specifically designed infrastructures.

Furthermore, multiple studies show that autonomous vehicles may bring irreversible impact to employment. Research shows that there could be as many as 15.5 million U.S. workers, which means one in every nine workers, to be impacted by the deployment of autonomous vehicles (Beede, et al. 2017).

While autonomous vehicles may bring irreversible negative impacts to the economy - especially to employment - they may also contribute greatly to the economy. Researchers expect that the widespread adoption of autonomous vehicles can lead to nearly $800 billion of economic benefits by 2050. It is achieved by reducing the dependence on oil and providing environmental benefits, along with the benefits from reducing the costs from vehicle crashes and gaining from boosted transportation efficiency (SAFE, 2018).

Thus, it will be hard to say whether autonomous vehicles will bring net economic and environmental benefits or harms, they will certainly have dramatic impacts on both.

2.5: Autonomous Vehicles: Public Acceptance Rate

One IQP team conducted a research on public acceptance of autonomous cars in 2013. They collected 467 responses from participants with ages ranging from below 16 to above 61. We only recruited participants whose ages are over 18, since the legal age for driving is 18 in China. Their IQP project focused on identifying the major factors that influenced people's desires to purchase autonomous cars. In addition to understanding how safety, law, cost, productivity, efficiency, and environmental concerns might affect the adoption of autonomous vehicles, our research hopes to find the exact percentages in a broader context, which revealed how likely people will be willing to accept, use, or even buy a self-driving car.

Among the research institutions that were trying to gather statistics of public acceptance rates, most of their reports concluded that, rather than expressing optimistics and enthusiasm toward the technology, most Americans were feeling skeptical and worried about the widespread adoption of driverless cars.

In 2014, a survey from Pew Research Center showed that, given the opportunity to ride in a driverless vehicle, 56 percent of Americans gave negative feedback, while 44 percent replied they would take the chance (Smith & Anderson, 2019). According to a 2019 Reuters/Ipsos opinion poll, 64 percent of Americans responded they would not buy a self-driving car (Lienert & Caspani, 2019). More recently, in an annual survey conducted in January 2021 by American Automobile Association (AAA), only 14 percent of drivers trusted riding in autonomous cars, but 86 percent of them were either afraid (54 percent) or unsure (32 percent) (Mohn, 2021).

Surprisingly, Chinese people express the opposite feeling: they were mainly confident in automated driving technology. Continental AG, a German multinational automotive parts manufacturing company, conducted a 2018 Mobility Study. According to the report, 89 percent of Chinese participants agreed with the statement: "automated driving is a sensible advancement". Compared to the other three countries, 68 percent of Japanese participants, 53 percent of German participants, and only 50 percent of American participants acknowledged the assertion (The 2018 Mobility Study, 2021). Not only the car manufacturers were curious about people's perceptions, KPMG, one of the four largest international firms providing audit, tax, and advisory services, also took a consumer survey on acceptance of autonomous vehicles across 25 countries. The survey summarized that non-Western countries had the highest acceptance, while

English-speaking Western countries had the lowest levels of acceptance. The United States ranked the 24th, conversely, China ranked the 5th (Miles, Lavery, & Shott, 2021).

Unlike these quantitative research that concentrated on estimating numbers and rankings, most papers tended to investigate the demographic factors behind people's decisions.

Public acceptance varies significantly among different socio-demographic groups. A study anticipated the early adopters of self-driving cars were likely to be highly educated young males, who live in a denser neighborhood with higher incomes and larger households. Other deciding factors included knowledge of autonomous vehicles, technology savviness, privacy concerns, and positive perceptions about safety (Golbabaei, Yigitcanlar, Paz, & Bunker, 2020). We will also analyze the public acceptance rate across different genders and age groups in this study.

3: Methodology

The goal of this project is to investigate general attitudes and public acceptance rates towards autonomous vehicles in China. Also, the project team will implement a game simulation to help people think critically about the technology. The research will be splitted into three stages: stage 1 is benchmark research for general background on public opinion, stage 2 is game simulation for knowledge informing and potential attitude change, and stage 3 is data comparison for studying the impact of game simulation on attitudes. Each stage has a specific objective:

1. Evaluate current public acceptance rate and general attitudes towards automated driving technology
2. Design game simulation to inform autonomous vehicle related knowledge using engaging scenarios and bring potential attitude changes
3. Compare data collected after game simulation and data collected in stage 1 to investigate the impact of game simulation

3.1: Evaluate Current Public Acceptance Rate and General Attitudes towards Automated Driving Technology

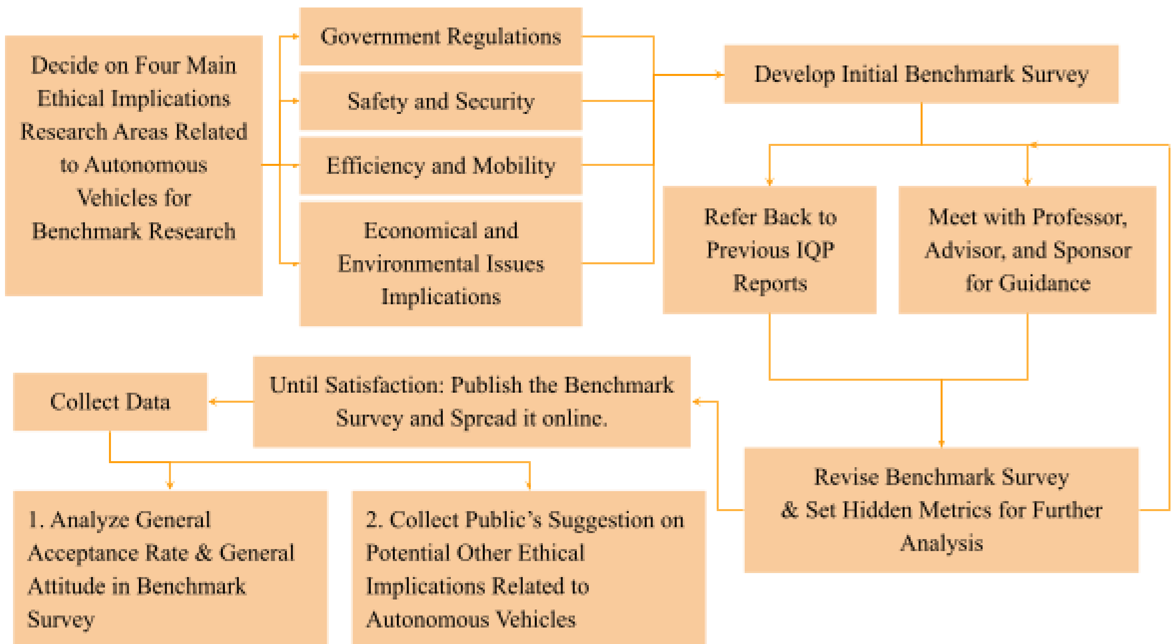


Figure 4: Flowchart of the first objective

In this stage, we will develop and distribute an online survey with questions that focus on the four research interests discussed in the background section. The objective of this stage is to understand the current public's general attitude and acceptance rate towards automated driving technology. Also, we will consult participants about their potential concerns about autonomous vehicles.

3.1.1: Survey Design Plan

First, we will focus on each of the four main ethical implication areas related to autonomous vehicles: government regulations, safety and security, efficiency and mobility, and economical and environmental issues. These areas will be used as the Four Main Research Interests for the rest of the proposal. Then, we will develop an initial online benchmark survey and recruit 3-5 people from ID 2050, a social science course for the IQP at WPI, to get feedback on the first design. Later, we will move on to revise the online benchmark survey based on guidance from the advisors and ID2050 professor. Meanwhile, we will refer back to previous IQP reports for further help. Until every member of the project team is satisfied with the online benchmark survey, the survey will be released to the public via chosen mediums, including Google Forms and Tencent Questionnaire. After a week, we are going to close the survey and start to analyze and record down the benchmark acceptance rate towards autonomous vehicles, benchmark general public attitude towards autonomous vehicles, and public's suggestions to potential ethical issues for further analysis.

Online benchmark survey will be conducted as the main medium to get benchmark data for the whole research in stage 1. An initial design will include survey contents consisting of questions from previous IQP and newly created questions. The intention is to craft a survey that focuses on the Four Main Research Interests. There will be 20 questions in the survey, with 2 optional open-end questions and 18 mandatory close-ended questions. It will take roughly about 3 minutes for participants to fill in. The first four questions will determine whether participants are from the target age group. Question number 5 to 8 will gather information about people's overall attitude toward automated driving technology. The rest of the questions are about the Four Main Research Interests. Data gathered in those questions will help us to understand how participants value each ethical concern and design the game simulation.

3.1.2: Data Collection Procedure

We aim to collect data from 100 participants, and they will be recruited by snowball sampling, a recruitment technique in which participants help identify potential subjects for the project team to contact (Kirchherr and Charles, 2018). We will encourage the participants to assist with recruiting, by sharing a link with a brief summary of the research to people who might be interested in participation. Surveys will be distributed on WeChat along with the consent form. Since the research focuses on the public acceptance rate in China, reaching out to WPI international students who come from China will be the first step to recruit project participants.

The eligibility of the sample population will be individuals aged beyond 18 and below 60, who have a driver's license or a car. The aforementioned is the eligibility criteria, will have "yes" or "no" before moving on in the survey. All those with the answer "no" will automatically be prevented from taking the survey.

Online surveys will be distributed via WeChat. The first advantage of using WeChat is that it is a very popular social application used by Chinese people, who are the main target audience. With WeChat, it's easy to spread the survey to as many people as possible. The second advantage is that it also allows us to share website links easily to project team members' friends. Thus, we will be able to receive timely feedback.

3.1.3: Data Analysis

Answers gathered through the initial online survey will be carefully placed into designed scenarios such that participants have to make informed decisions, which will essentially force them to indicate their own preference under certain conditions. For instance, the MIT Moral Machine test provides two options in each ethical problem: when a self-driving car encounters sudden brake failure, participants have to choose between saving three female pedestrians or three female passengers. We will summarize the survey responses to construct detailed ethical problems. For closed-ended questions, which explore general attitudes toward automated driving technology, we can sample those answers with frequency to get a better understanding of how the overall attitude is since the data are quantitative. Also, the survey will contain multiple open-ended questions to invite participants to nominate potential research areas. Moreover, to analyze the data across different groups of populations based on age, gender, or other important characteristics like income level, we will use Python for data visualizations to generate line charts or distribution plots.

There are two major advantages with this data analysis method: it is quick and easy to implement, so it will be a good starting point. However, there are also disadvantages. First, the survey will produce misleading outcomes if badly worded questions exist. Second, the question-based data collection will limit the range of data for ethical questions collected.

3.2: Design Game Simulation to Inform Autonomous Vehicle related Knowledge Using Engaging Scenarios and Bring Potential Attitude Changes

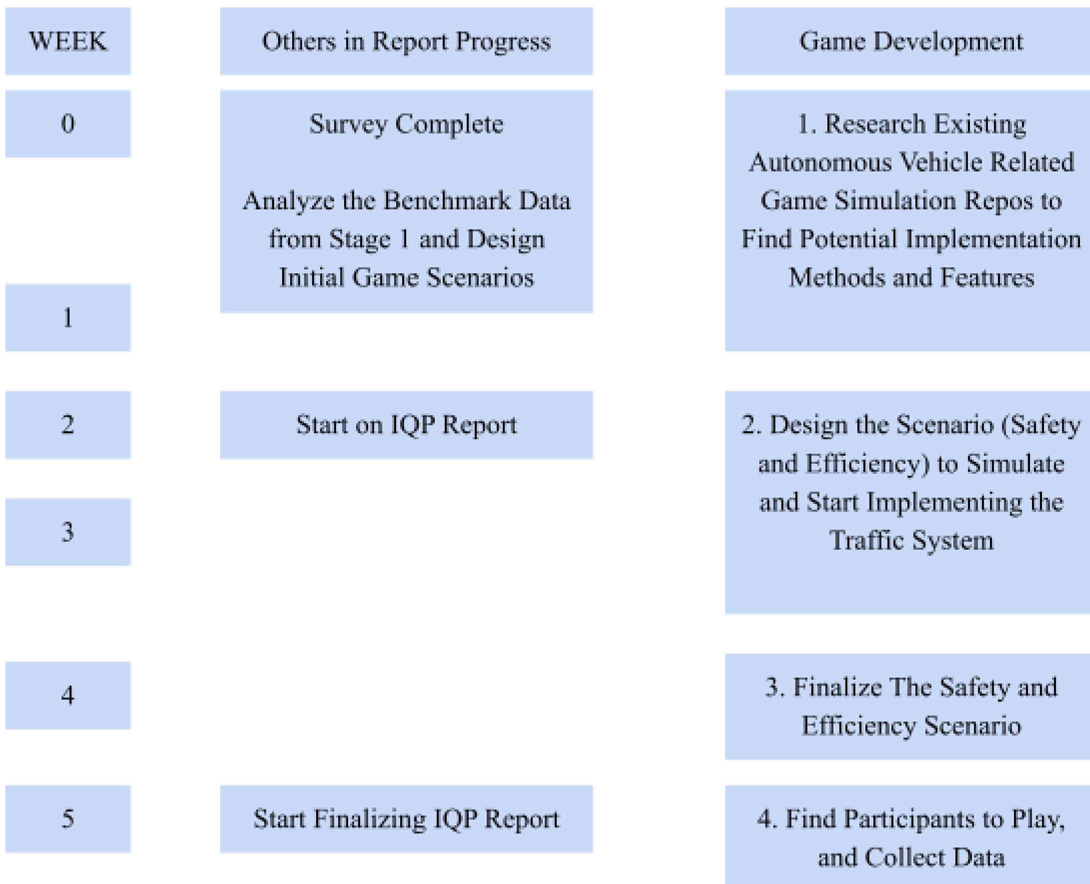


Figure 5: Flow chart of the second objective

3.2.1 Game as a Data Collection Medium

In the research stage, we found that some researchers had tried to use games to collect quantitative data in their studies. Marketing researchers are typical ones among them. Specifically, Cechanowicz intentionally gamified three chosen market surveys and showed that participants are way more willing to respond to gamified questions, regardless of age, gender, length of panelist's tenure, and game experience (Cechanowicz, 2013). The motivational benefit of games is the key factor to this. With the additional interactive mechanics and the intrinsic challenge-reward systems, games outperformed by dragging more attention from participants.

Also, Loh has shown in his research the possibility of conducting scientific research with serious games within the social study paradigm (Loh, 2007). In the same work, Loh showed that with deliberate designs, researchers will be able to capture player's actions without a video camcorder.

Therefore, the project team has decided to construct a simple game simulation to visually display how autonomous vehicles might work in cities. Participants should be able to engage in ethical situations immersively and see the difference between human-operated vehicles and autonomous vehicles. The first objective of this stage is to bring potential attitude change to participants with games. We hope that participants will have a clearer understanding of what automated driving technology is and how it would impact our life with visual simulations. We then further expect that participants will have a generally greater acceptance rate towards autonomous vehicles after playing the game.

Additionally, we plan to form additional recommendations to sponsors and other researchers with the collected data from the game. With the additional immersive and subjective visual experience, we hope that the team could collect more meaningful subjective answers from participants. At the end of this stage, we will analyze those subjective answers and extract key findings.

3.2.2 Game Development Timeline

Preparation (Week 0 - 2):

Proposal: In the proposal, we planned to continue the research on potential solutions for the Four Main Research Interests while waiting for enough data to be gathered in the first stage. Also, we planned to initialize the preparation for the game simulation for Stage 2.

Actual: In Week 0-2, we successfully delivered surveys and collected abundant data. Hearing such success, game developers in the team then started their research on Autonomous Vehicle Simulation. Majorly, developers had examined code segments in open-source traffic simulator repositories. Also, they had tried to read published papers on Autonomous Agent Simulation Algorithms. The developers tried to find useful segments in researched sources for the implementation and the potential design thoughts.

Design (Week 3):

Proposal: In the proposal, we planned to craft carefully designed levels (like the moral machine: passenger or pedestrian dilemma) that participants must choose one out of two to four hard-to-choose ethical choices that are greatly related to Four Main Research Interests to gather quantitative data.

Actual: During Week 3, the design of the game has dramatically changed compared to the proposal, majorly due to the consideration of feasibility. In the end, we decided to go with "simulations", which will present simulated autonomous vehicle scenarios to participants. Those scenarios will come with no interactive components at first. It is merely a visual experience for participants. Then, developers will gradually add interesting features to crafted scenarios. More details of the final design will be discussed in *Section 3.2.3* in the report.

Implementation (Week 4-5):

Proposal: In the proposal, we dreamed that the team would complete several versions in a sequence. The game release should start with a survey-based game, which is a gamified version of the initial benchmark survey. Then, more complex features will be added to the releases throughout the timeline.

Actual: In the actual implementation time, the developers followed strictly with the design of a "simulation-oriented game", majorly for the consideration of feasibility. The developers did encounter many unexpected obstacles during the implementation, including but not limited to asset discovery and retrieval, unconventional coding bugs, or framework errors, etc. Fortunately, under the guidance and suggestions from the project advisor, the development team followed the rule that they must report their progression each three to four days. Such rules ensured enough progression of the simulation development that the final product could be used for the research.

Finalization, Delivery, and Data Collection (Week 6-7):

Proposal: In the proposal, we expected that they could hire half of the participants who answered the initial survey to play the game simulator. We had planned to use WPI email, friend connections, and WeChat to deliver the simulator. Meanwhile, automatic in-game data collection was nominated for data collection.

Actual: With over 500 answers from the initial survey, we only succeeded in finding 20~30 participants who are willing to experience the game simulation. It is relatively a small portion of the sample pool of the initial benchmark survey.

In terms of the playable delivery, we packed a zip file with the executable simulation inside it, along with instructions to download and run. Although it is easy to distribute the packed package via WeChat, we would lose data from those participants who do not have direct contact. Thus, we had intentionally asked participants to leave the final 4 digits of their phone number as their unique identifier in the initial survey to solve this problem. As such, the researchers were also able to compare the results in the initial survey and the data collected after playing the game.

Finally, we designed an additional survey that only has a few questions to gather follow-up data from participants who had played the game. More details of the analysis of those data will be discussed in *Section 4.2* in the report.

3.2.3 Final Game Design and Simulation Implementation

3.2.3.1 Game Design Introduction

At first, the autonomous vehicle experience simulation tool developers (will be abbreviated as developers for the following) envisioned four game scenarios in which each one corresponds to one of the Four Main Research Interests about automated driving technology: law enforcement, safety, efficiency, and economics. However, considering time constraints, the development team decided to only focus on implementing two out of four scenarios: safety and efficiency. Our objective is to find out whether there is a change in participants' views about automated driving technology after showing them these simulation scenarios. We were interested to investigate whether an interactive visual simulation would bring new knowledge to people that might change their opinion eventually. Also, we tried to answer whether game simulation is a good medium for data collection.

3.2.3.2 Design & Implementation of Scenario: Efficiency

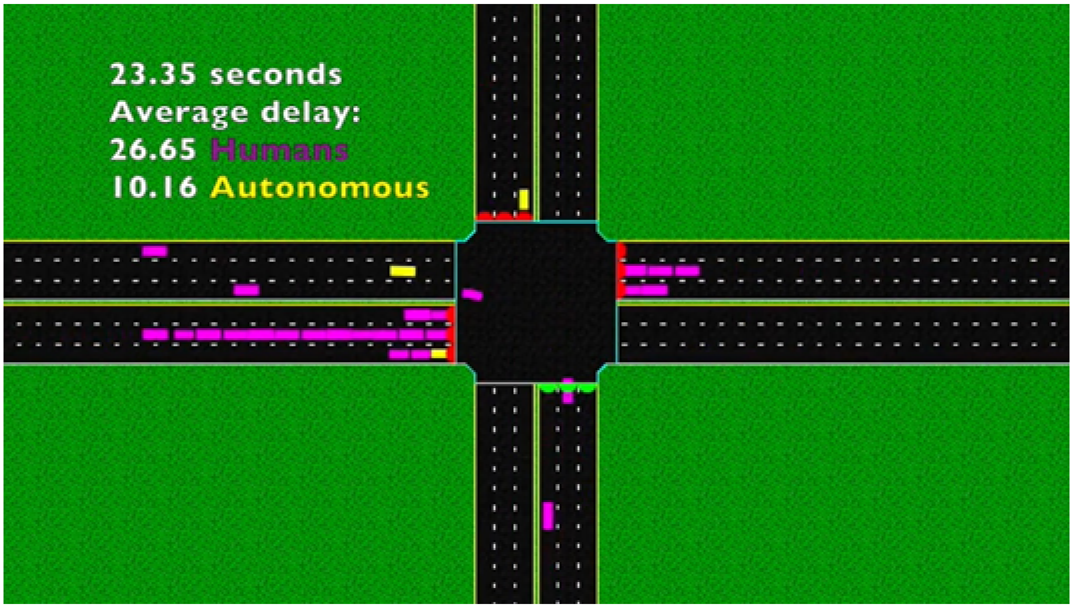


Figure 6: Screenshot from the presentation video of the AIM project (Guni, 2018)

After research, the development team chose to implement a straightforward Autonomous Intersection Management (AIM) scenario for the efficiency scenario. AIM is a special technique that manages fully automated vehicles at intersections without traffic lights.

The developers were enlightened by the AIM project conducted by researchers from the University of Texas at Austin (Guni, n.d.). The basic idea of this technique is to have the autonomous car calculate and predict when reaching an intersection, the driving paths of other vehicles that are also crossing the intersection. Then, the calculating vehicle would use calculated information to decide movements like whether it should just go ahead without any considerations or wait for other cars to cross the intersection. In a fully automated community, it is relatively easy for autonomous vehicles to retrieve that information from other vehicles as they are all connected with the internet and thus all vehicles will be sharing their positions, future paths, etc. It would be a more complex scenario in a hybrid community where autonomous cars and human-operated cars exist at the same time. Rather than retrieving information online, autonomous vehicles must use their sensors to gather offline-only information, like the locations of human-operated cars or the status of the traffic lights to calculate the predicted paths of human-operated cars.

The ultimate goal of the AIM project conducted by the AI laboratory of the University of Texas at Austin is to figure out the usage of AIM in a hybrid community. In that study, human-operated cars are regulated by traffic lights, while autonomous cars can decide whether they can cross at red lights without causing any car accidents. The study shows that increases in the ratio of autonomous vehicles will decrease the average reaction time for each car to successfully pass the intersection.

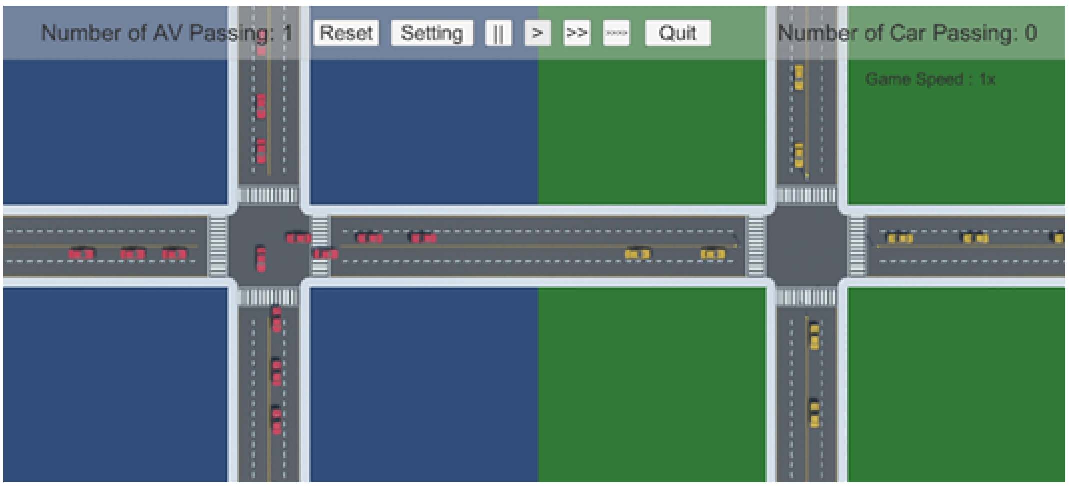


Figure 7: Screenshot of the efficiency scenario from the project team's simulation

In the simulation, the developers built two congruent crossing intersections for direct comparisons. We hoped that participants could see the difference in the crossing efficiency of an autonomous crossing and a non-autonomous crossing.

The scene on the left contains autonomous vehicles, while the scene on the right does not contain any autonomous vehicles. Since autonomous vehicles do not need traffic lights for regulation, traffic lights do not exist on the left scene while they do exist on the right scene since human-operated vehicles need regulations and guidance from traffic lights.

In the autonomous scene, instead of checking for signals from the traffic lights, an autonomous vehicle that approaches the intersection would consult whether it can pass or not from an in-game AI agent that developers intentionally put in the game for macro-management. The AI agent would then put it into a queue of cars waiting to cross and calculate its future path using its current speed and acceleration speed. After that, the AI agent would continue to test the calculated future path with other calculated future paths of the other vehicles in the waiting queue to check if they would collide with each other. If there would be no collision, the AI agent would allow the car to proceed freely. If not, the AI agent would signal the car with lower priority (usually the car that came later in time) to slow down and wait.

Instead of calculating the reaction time, developers chose the counting number of passing cars in each intersection as the metric to show the huge difference in efficiency between a fully automated community and a human-operated community. To bring more interaction and fun, the developer also introduced some adjustable parameters like speed limits, acceleration speed, and minimum distance between each car when crossing (only for autonomous vehicles). The sample result of the simulation with runs by developers showed that most of the time, the autonomous community would have about twice the number of cars passing in the human community. We hoped that such visual results would make participants who do not have much knowledge about automated driving technology see its advantage from an efficiency perspective.

Due to the time constraints, the development team was only able to finish a simplified version in which the cars could only go straight. With abundant time, the developers would optimize the current algorithm for calculating possible collisions, which is bulky right now. Also, the developers would try to build a much more realistic scenario that includes cars turning at intersections. Even further, the developers would extend the single crossroad to city-level blocks. We believed that participants could be more persuaded with the benefits of autonomous vehicles, in terms of efficiency, with those additional visually appealing simulation features.

All the mentioned additional features here were under development in the implementation period. However, there were some unsolved bugs or obstacles that blocked them from becoming available. Therefore, the development team chose to discuss those planned yet not finished and other designed features in *Section 6.2* to give some insights for future researchers.

3.2.3.3 Design & Implementation of Scenario: Safety

For the safety scenario in the simulation, the development team decided to show participants the one key advantage of autonomous vehicles: no rule-breaking. The development team built a small city block that includes nine intersections as a closed-loop in the virtual city.

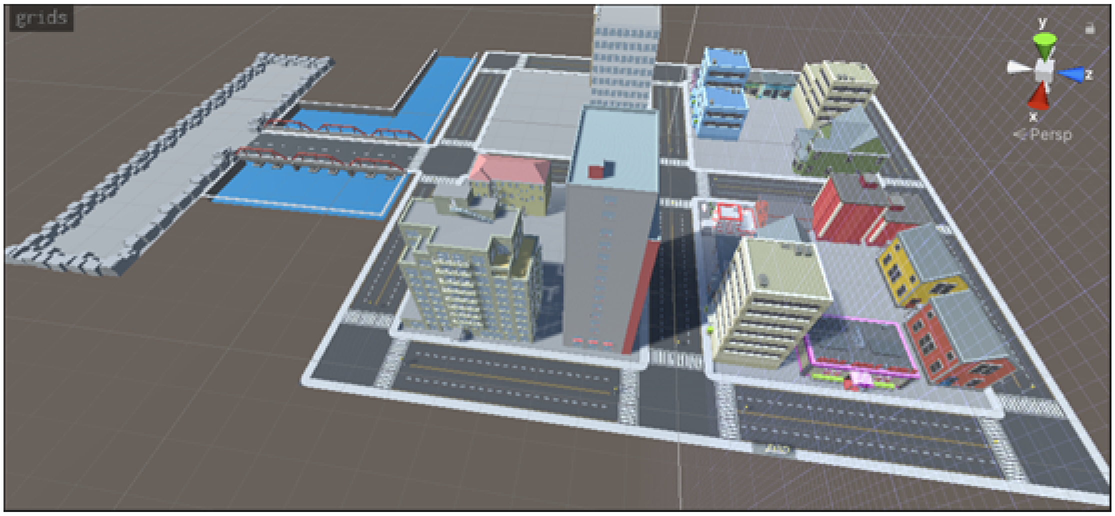


Figure 8: Screenshot of the city block in safety scenario

To better show the advantages of the rule-obeying driving scenario, the development team intentionally makes human-operated cars consecutively breaking traffic laws, including Overspeed, crossing red lights, drunk driving, etc. Maybe those driving habits will not lead to a 100 percent accident, but they will certainly breed the possibility.

The development team put 10 autonomous cars (red cars) and 10 human-operated cars (yellow cars) into the simulation city and let them wander around randomly. The participants would get a bird view (top-down view) of the city in the simulation such that they could better see the whole city. There are also zoom-in and zoom-out features that enable participants to adjust the levels of detail they want to examine the city. They could see more vehicles in a larger area in a fully zoomed-out scenario, though the vehicles would be smaller, and less detail could be examined.

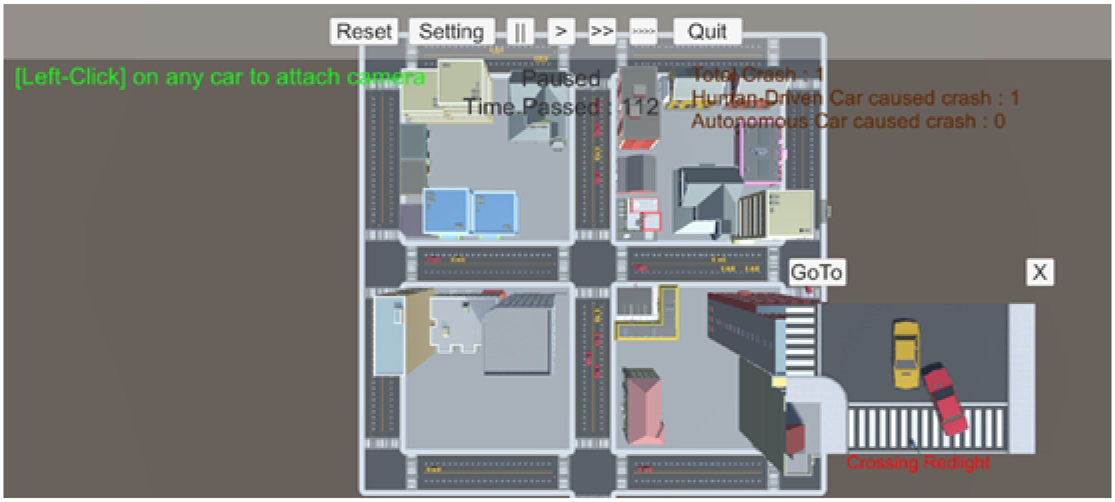


Figure 9: Screenshot of game play in safety scenario

There will be a side camera that displays the scene if a car accident happened (as shown in *Figure 8*). The player could also click on the button to move the main camera to the position of the accident to examine the scene. Also, the cause of the accident would be notified under the camera. The system would also keep macro statistics about the accidents-the count of the total number of accidents and number of car accidents caused by both types of car-to show participants that autonomous vehicles are safer.

Although the player could not directly operate any cars, they were allowed to switch to a third-person view of the selected vehicle by clicking on the car to attach the camera. The development team believes that it would bring more immersion to participants.

Same as the efficiency scenario, there are a few parameters that the player can adjust with, like the disobedience chance (chances of human-operated cars to break traffic laws). If the chance is set to 0 percent, then those human-operated cars will act normally. However, participants will certainly witness chaos if the chance is raised up to 100 percent.

Figure 10: Screenshot of camera attach mode in safety scenario

During the implementation, a city with special types of cars (corresponds to the initial benchmark survey, including buses, taxis, and trucks, etc.) was under development. However, due to the time constraint, the development team was not able to solve all the unseen bugs, especially in the task system. The development team will discuss those unfinished designs in detail in *Section 6.2*.

3.3 Compare Collected Data Before and After Game Playing to Investigate Impacts of the Game Simulation

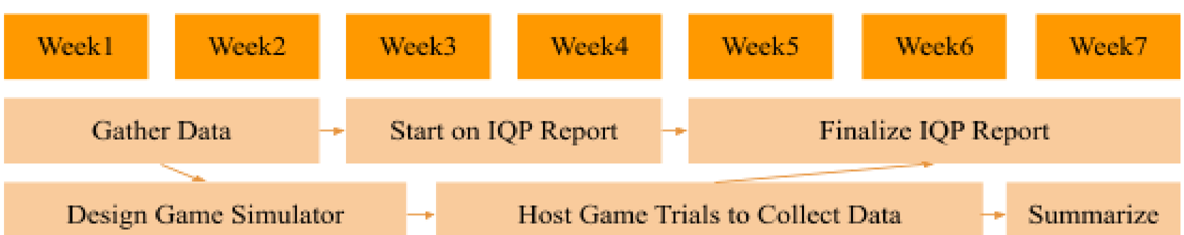


Figure 11: Flow chart of project timeline

Upon the completion of the second stage by successfully collecting over 90 percent of expected data from participants, we will step into the third stage to summarize and therefore analyze all collected data so far. Project timeline in Appendix D presents a more detailed plan based on Figure 4 and 10.

We will compare the results gathered in the game with participants' first time responses. We expect that there will be changes in opinions, possibly becoming more neutral, yet we can't predict the public acceptance rate will increase or decrease. We will first try to detect any changes in individual opinions, then calculate differences in overall acceptance rate. After that, we will discuss future improvements. At the end, we will investigate whether there are some surprising discoveries related to people's responses and conclude a general pattern that may apply to social studies of other technologies.

3.3.1 Individual Opinions Assessment

During stage 2, Participants' decisions will be formed as quantitative data, represented by numbers from 1 up to 5, based on the number of options in each scenario. Thus, results will be displayed using frequency. Data visualization tools such as frequency tables, pie charts, and other visual data analysis designs will be used to highlight the differences between before and after playing the game simulation.

Above measurements will refer back to participant's responses on question 10 and 11 in the initial online survey: how much will the safety aspect and efficiency aspect of autonomous vehicles influence you when considering whether to purchase or use an autonomous car? (1-5, with 5 being the greatest). The third question would simply be question 15: How likely would you accept automated driving technology? We will match their responses using

3.3.2 Acceptance Rate Calculation

When waiting for their individual reports to come out at the end of each game session, participants are required to answer question 15 to question 17 again:

- How likely would you accept automated driving technology?
- Are you willing to travel by autonomous car? (as passenger)
- Will you buy and drive an autonomous car?

It will take less than 1 minute for the participant to indicate one's preferences. If there is a noticeable difference on any of the attitude questions compared to his or her initial response (like from negative(1) to neutral(3), or from neutral(3) to positive(5)), then we will count this as a case of "changing views after playing the game".

We will calculate the mean value of numbers getting from the above three questions in the initial benchmark survey. Then, comparing the mean value across all participants after the game simulation and concluding whether the overall acceptance rate increases, decreases, or remains relatively the same.

If there is a significant change in the mean value (difference greater than 0.5), we will use distribution plots to identify which gender or age group shows the greatest changes in attitudes and explore the reasons behind such an attitude shift.

3.3.3: Future Improvements

If no obvious changes are detected in any of the previous two steps, we will then examine the effectiveness of implementing a game simulation. We will also make recommendations for future IQP groups on how to better incorporate technical skills into social science research. Otherwise, we will generate a set of recommendations for future research on the acceptance of autonomous vehicles and ways to create a better game simulation.

Advisors have pointed out an important challenge to the research: we will need to decide on the amount of data that they will gather and analyze to create useful and statistically significant results. We should prepare for the worst case scenario if only 5 participants are willing to play the game simulation.

3.4: Ethical Implications

There is minimal or no risk for the involved participants. All participants will need to sign a consent form in Appendix B, before participating in the survey. We will educate all participants to consent before being involved in the game simulation. All answers generated from the survey will be anonymous and confidential, only accessible by the research project team members. Participants can skip any questions that they feel uncomfortable answering. We will never use data retrieved from participants and participants' information for commercial purposes. The only exception is that in special circumstances, the research project team will share results with Worcester Polytechnic Institute Institutional Review Board (IRB).

4: Findings

4.1: Findings from the Initial Survey

We recruited 503 participants during one week in June 2021. All survey results are represented by pie charts and tables. Section 4.1.1 is about the demographic information of participants, as the first five questions asked about their gender, age, license, and car ownership, and whether they have experienced a car accident. These questions are the basis of precise data analysis. Starting in Section 4.1.2, there is data analysis about the basic preferences of participants on the four factors of autonomous vehicles: government policy, safety, efficiency, and economic/environmental impact. Section 4.1.3 is the analysis of ethical decisions. It includes questions of who should be responsible if an autonomous vehicle gets into a car crash and should autonomous vehicles prioritize pedestrians or passengers. Next, section 4.1.4 talks about questions asking what kind of autonomous vehicles participants can accept. This section is about participants' acceptance of autonomous vehicles. It also includes answer distributions of questions asking participants if they will buy an autonomous vehicle in the future, and whether they would like a driver inside of an automated car. Lastly in section 4.1.5, we analyzed the open-ended question.

4.1.1: Analysis of Demographic Information

Gender Distribution

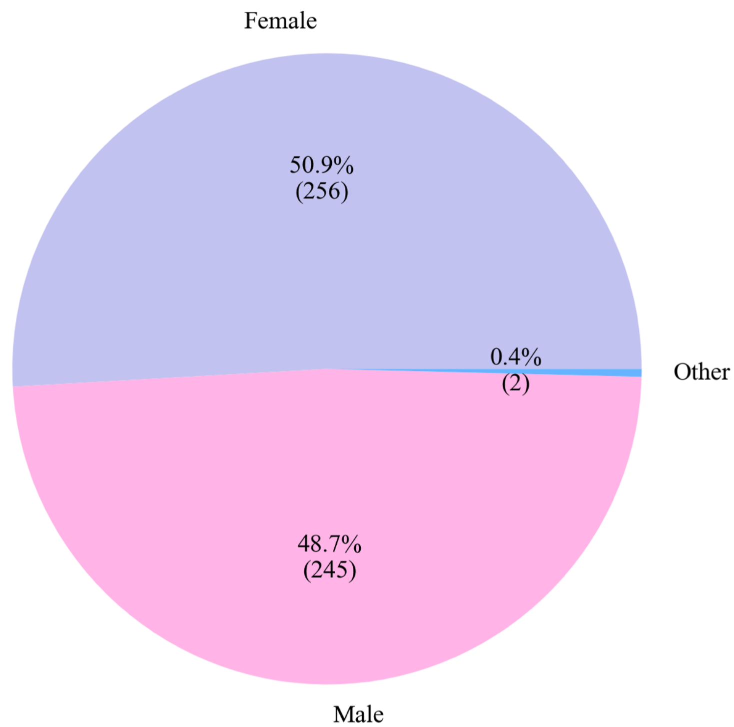


Figure 12: Survey participants were asked to identify their genders

Figure 12 corresponds with question 1 on the initial survey: What is your gender? Among all participants of this survey, 50.9 percent of them are female, with 48.7 percent of them being male and 0.4 percent choosing "other" as their gender.

Participants need to identify their genders in this study because their data will be sorted into various groups based on the genders. According to Golbabaei, Yigitcanlar, Paz, & Bunker's study in 2020, males tend to be the early adopters of autonomous vehicles. To eliminate this potential gender bias, researchers will analyze data from participants within different gender groups pursuing a more precise result. During the participants' recruiting process, we paid additional attention to the overall ratio between genders. We would recruit more female participants if we noticed male participants were much more, and vice versa. This is the only factor we manipulated when recruiting participants. All other participants are recruited randomly.

Age Group Distribution

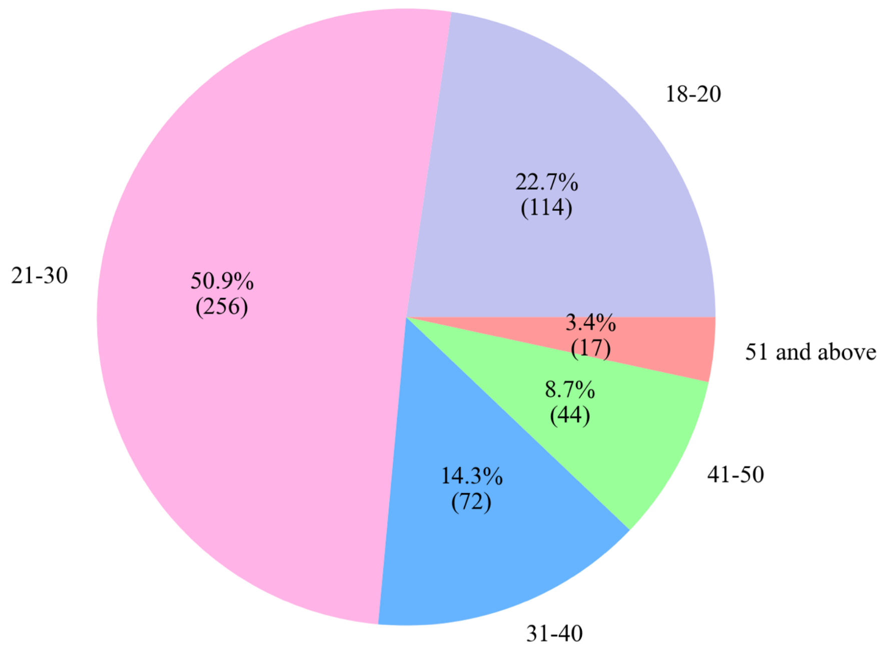


Figure 13: Survey Participants were asked to identify their age groups

Figure 13 illustrates the results of question 2 from the original survey: What is your age group? 22.7 percent are from 18 to 20 years old, and 50.9 percent are from 21 to 30. From 31 to 40, there is 14.3 percent, and from 41 to 50, there is 8.7 percent. The remaining 3.4 percentages 51 or above. Different age groups may indicate different tendencies to accept automated driving technology. As a result, same as question 1, this question was designated to divide participants into different groups.

Because the participants recruited in the study are acquaintances of researchers, most of the participants are from 18 to 30 years old. However, such an imbalance in number will not become a major concern since people of these age groups are more likely to purchase a new car in China, which makes them the focus of the analysis.

License Distribution

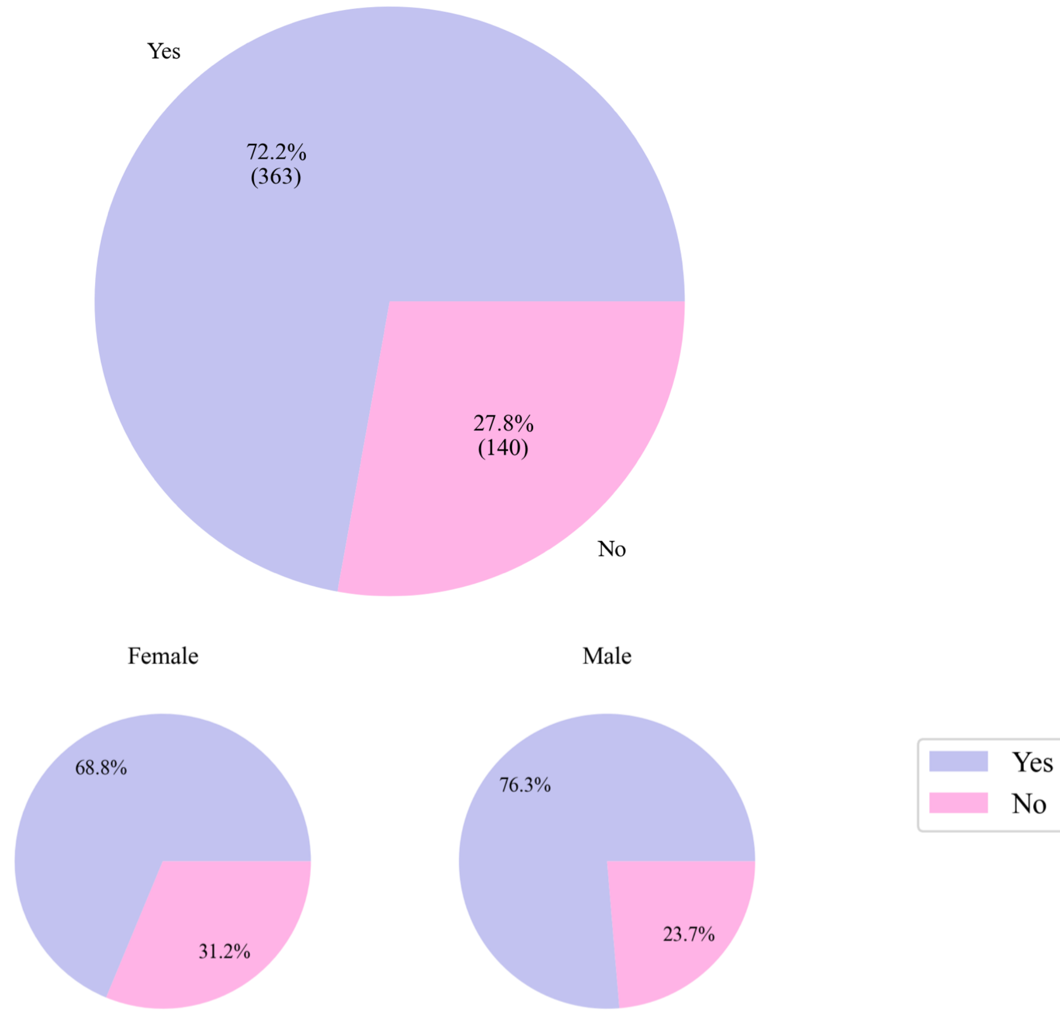


Figure 14: Survey Participants were asked to report whether they have driver licenses

These pie charts represent the percentage of participants who have a driver's license, and the ratio of license possession separately among female and male participants. Among all the participants, 72.2 percent claim that they have a driver's license while the other 27.8 percent do not. 68.8 percent of female participants said that they have a license, with 31.2 percent say no. On the other hand, 76.3 percent of male participants say that they have a license, while 23.7 percent claim they do not. Like the two preceding questions, this question will also help with differentiating participants and cooperate with data analysis of other questions to generate a more precise result. The reason for differentiating participants based on license possession is that those who are possessing a driver's license are more likely to purchase a new car and thus to be the potential owners of autonomous vehicles. They may choose the answers that favor the drivers of autonomous vehicles, or answers that favor those with driver's licenses.

Car Ownership Distribution

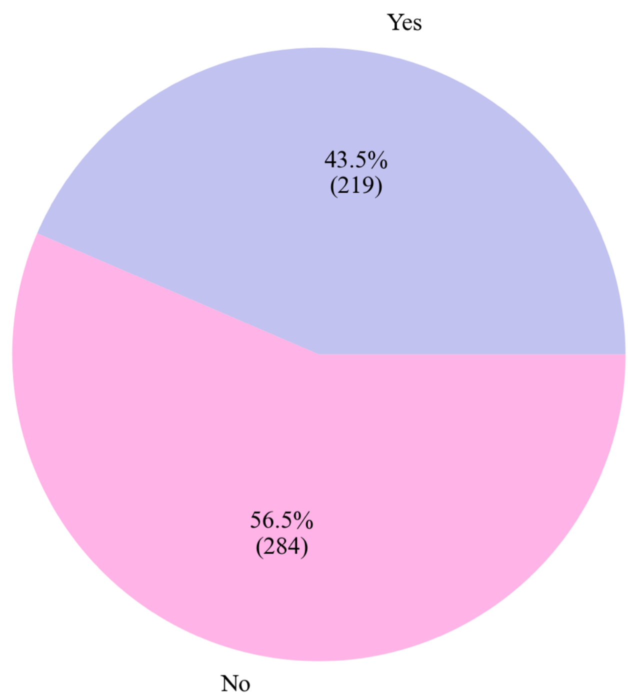


Figure 15: Survey Participants were asked to report whether they own cars

Figure 15 corresponds with question 4 of the survey, which asks participants if they own a car. 43.5 percent of them said they own at least one, while 56.7 percent said they do not own one. Similarly, we ask this question because we need to consider each case separately. Participants who own a car may think differently from those who do not own a car. Those who own a car may consider more about the efficiency of traffic as the number of autonomous vehicles increases since they will be driving alongside them on the streets. Also, they may choose answers that favor the drivers, support policies that protect car owners' rights, value cars that guarantee drivers and passengers' safety, and with the autonomous driving system to consider more for the benefits of owners or drivers. On the other hand, those who do not own a car might expect more regulations on autonomous vehicles. When the ownership of autonomous vehicles increases, they may start to consider if autonomous driving can protect the safety of pedestrians like them. Fortunately, the survey questions cover all these aspects.

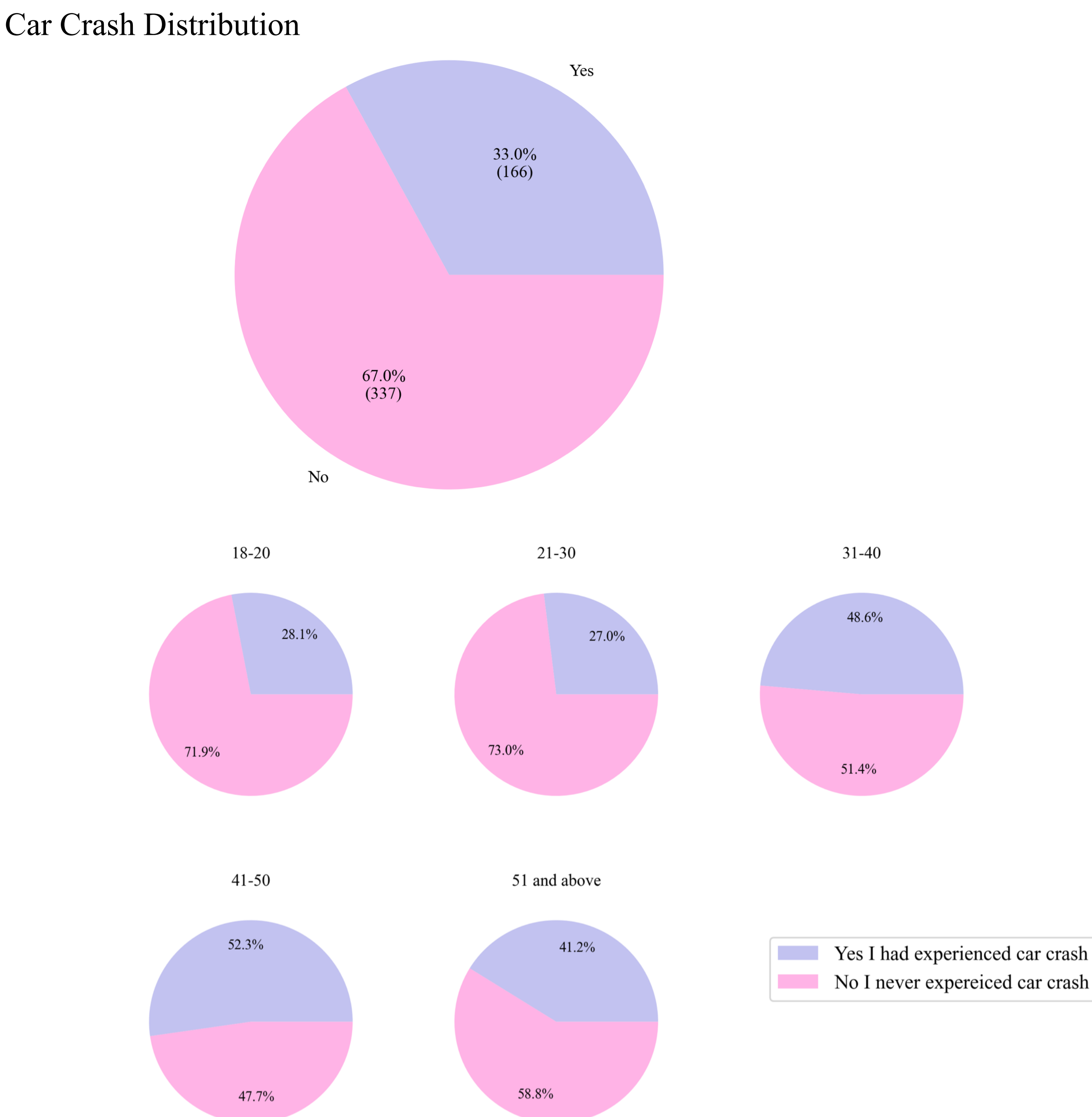


Figure 16: Survey Participants were asked to report whether they experienced car crash

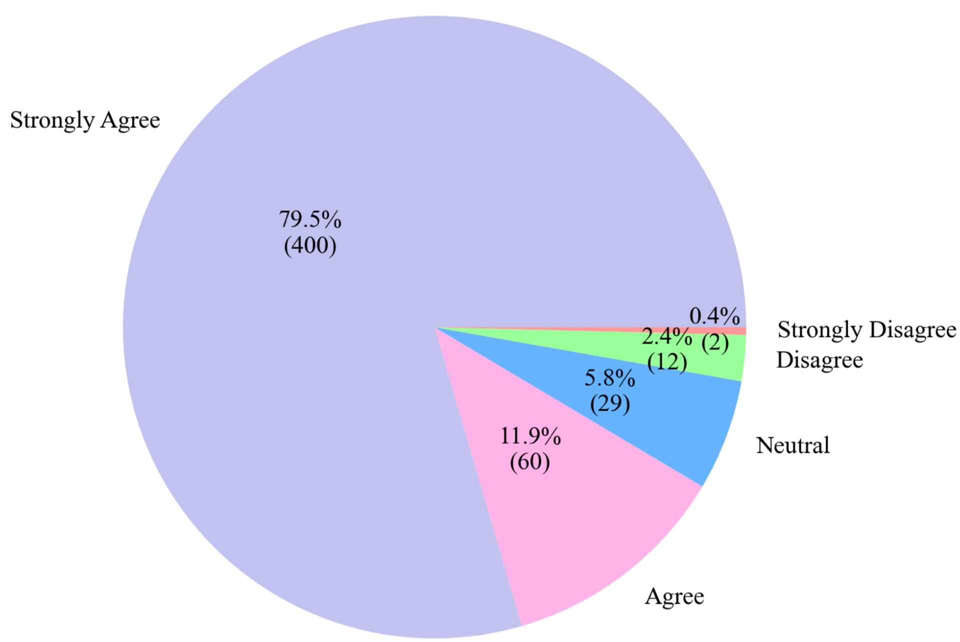
Question 5 reflects the number of participants who experienced car crashes before. The portions of participants who experienced car crashes are different across age groups, with an overall percentage of 33.0. According to the Courtesy of Roads Alliance, in the United States, 43 percent of first-year drivers and 37 percent of second-year drivers are involved in car crashes. This statistic is very different compared to the data collected in this survey since the percentage of first and second-year drivers who reported car crashes in this survey is only 28.1 percent.

However, because the legal age to drive in China is 18 which is two years older than the legal age in America, first-year drivers in China may be more mature. This could explain the difference in the ratio of car crashes. Participants between the age of 41 to 50 reported the most car crashes. This may not be closely related to their driving habits or patterns. Instead, a more possible explanation is that participants of this age group spent the longest time behind wheels, which exposed them to the risk of car crashes for a longer period of time.

This question is another one of those designed to differentiate participants. Those who experienced car crashes may tend to prioritize the safety aspect of autonomous vehicles. Furthermore, they might tend to choose answers that protect the drivers. Thus, analyzing them separately with other participants is necessary.

4.1.2: Analysis of Basic Preference

Regulation Distribution



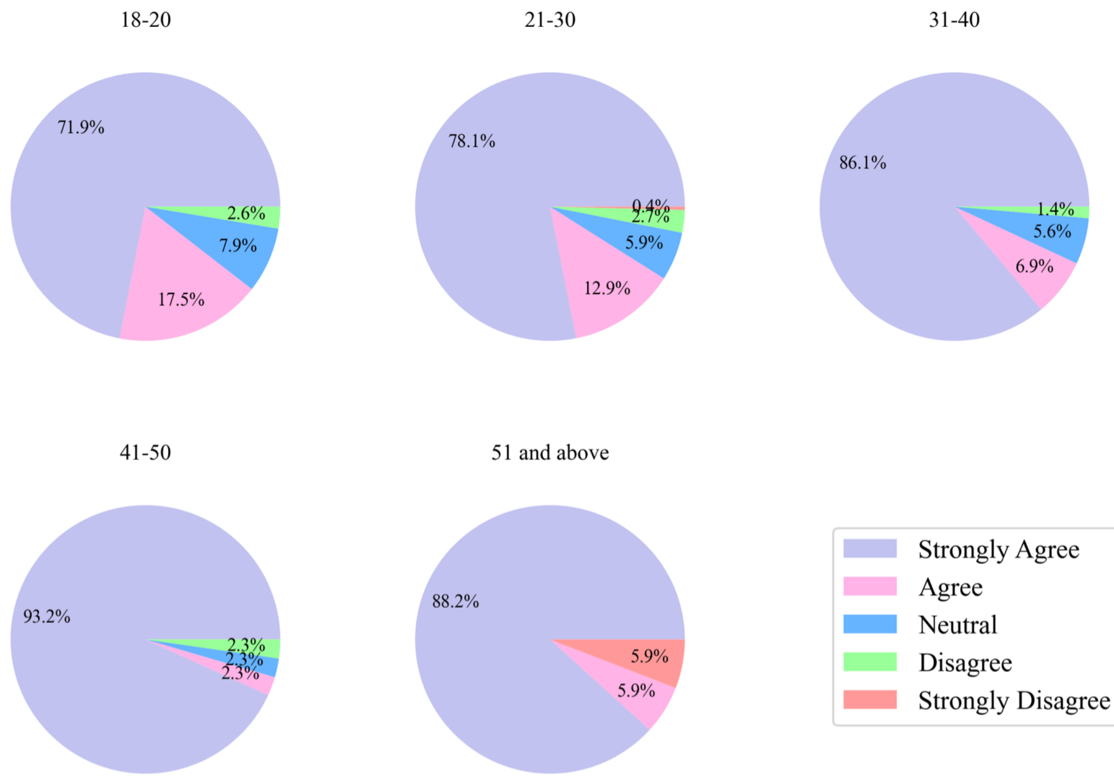


Figure 17: Pie chart representing participants attitudes on government regulation

The following four questions are related to the four factors of autonomous driving in this study. Figure 17 is about the influence of governmental regulations. Figure 17 reflects the answer distribution of question 6 which asks participants to what extent they will consider governmental policy and regulations when considering if they will adopt or use automated driving technology. Among all the participants, 79.5 percent strongly agree that governmental regulations will sway their decisions, with an additional 11.9 percent also on the same side. 5.8 percent of participants chose neutral, and a total of 2.8 percent said governmental policy or regulations will not change their mind when deciding if they are going to accept or adopt autonomous vehicles.

Governmental regulation and policies will influence participants' decisions from all ages. Participants from the age of 41 to 50 have the highest ratio of picking "strongly agree" among all age groups, while participants from 18 to 20 have the lowest ratio of picking so. Interestingly, only 2 participants choose to strongly disagree with the impact of governmental policies and regulations. In fact, one of the two participants is very possible to be an outlier, since this participant picked the last option for every question in this survey.

The result of this question clearly indicates the impact of governmental regulations on new technology. For instance, in Chinese cities with a lot of traffic, the government tends to alleviate traffic by only allowing vehicles to drive on alternative days in a week according to their license plates, whereas the use of electric cars is not restricted since it is an environmentally friendly technology supported by the state. As a result, a possible assumption could be that more people will accept or adopt autonomous vehicles if governmental policies favor this technology.

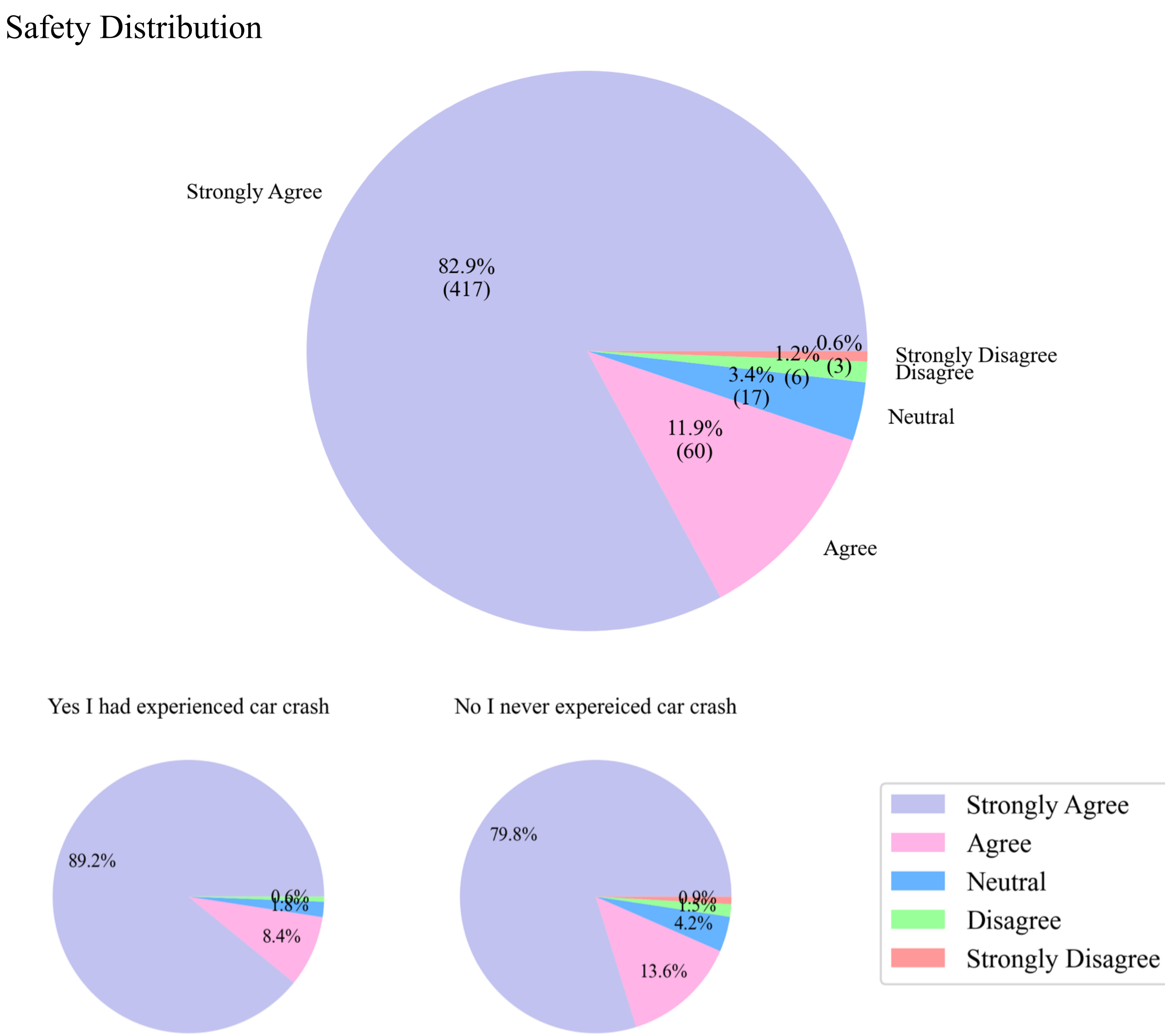


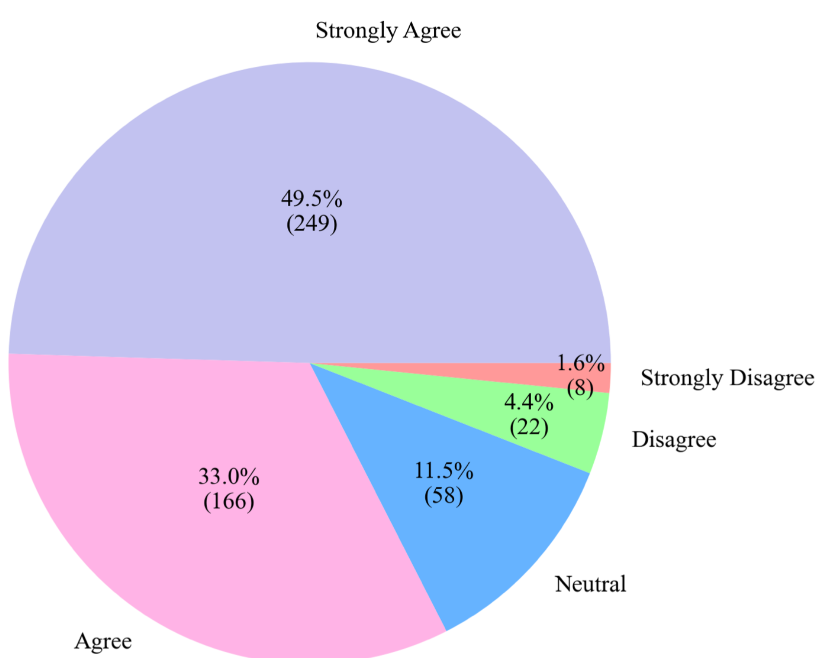
Figure 18: Pie chart representing participants attitudes on safety problem

Figure 18 illustrates the result of question 7 in the original survey which asks participants if safety is an influential factor while deciding if they are going to accept or adopt autonomous vehicles. Overall, the result of this question is very one-sided. 82.9 percent strongly agree that they will consider the safety factor, and an additional 11.9 percent agree on the importance of the safety aspect. 3.4 percent are neutral about safety while only 1.8 percent said they will not take the safety perspective into account when considering accepting autonomous vehicles.

Concerning the distribution of participants who had experienced car crashes before, the ratios are similar. 89.2 percent of participants who experienced a car crash before chose "strongly agree" while participants who never experienced a car crash made up 79.8 percent. This difference in distribution cannot be concluded as participants with car crash experience tend to prioritize the safety aspect of autonomous vehicles, since, according to figure 12, a lot of those participants who experienced car crashes are from 41 to 50 years old. Older participants, instead of participants who experienced car crashes, may tend to prioritize the safety aspect.

More and more people are losing faith in autonomous driving as Tesla is involved in an increasing number of car crashes (Hawkins, 2021). Consequently, doubts about the safety of autonomous driving are omnipresent.

Efficiency Distribution



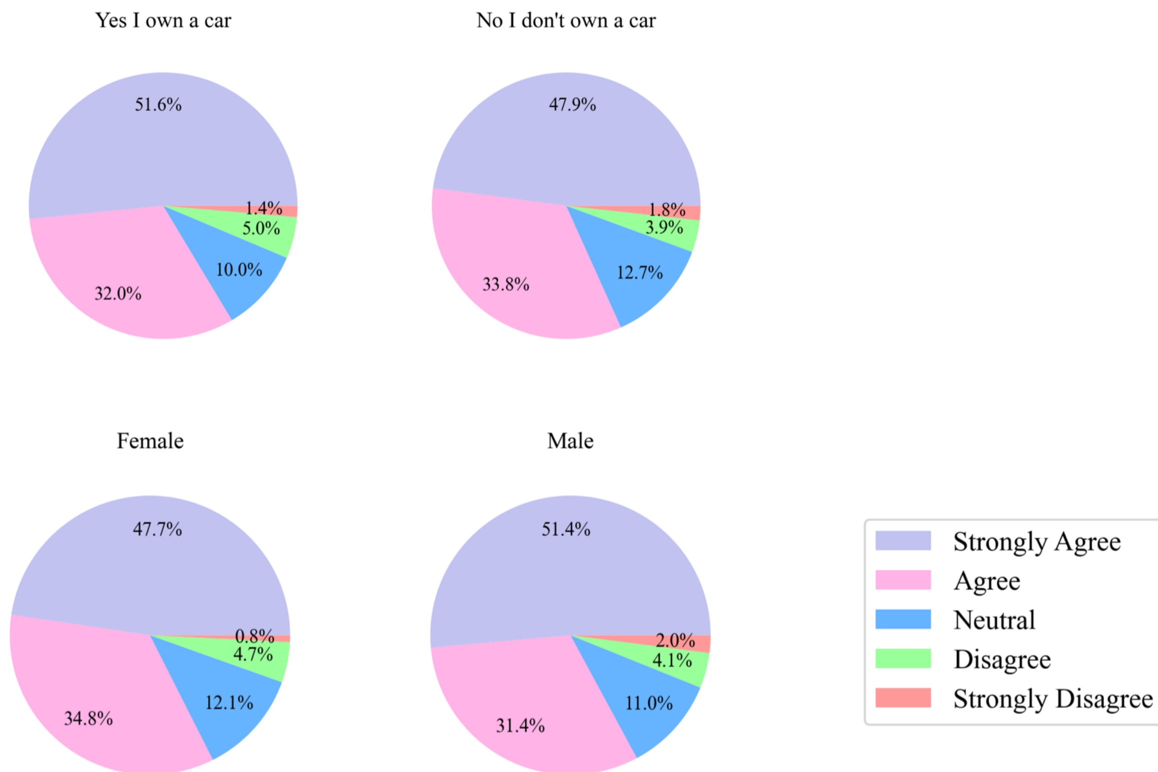


Figure 19: Pie chart representing attitudes on the efficiency aspect of autonomous vehicles

Figure 19 reflects the result of question 8 of the original survey: will the efficiency aspect influence participants' acceptance/adoption of autonomous vehicles. 49.5 percent strongly agree that this is an important factor. 33.0 percent agree that efficiency will make a difference. 11.5 percent choose neutral, and 4.4 percent do not think efficiency is influential, with an additional 1.6 percent strongly disagreeing that efficiency matters.

The ratios of participants prioritizing the efficiency aspect of autonomous vehicles did not vary much from those who own a car to those who do not. The ratios stayed nearly consistent for both genders, too. The earlier assumption that car owners might tend to favor the high efficiency of autonomous driving is not supported by our results.

The adoption of highly efficient autonomous trucks can drastically decrease the work time of truck drivers (Debusmann, 2021), though, compared to the last two questions, a lot fewer people choose the option of "strongly agree" for this question. The reason could be that their current or future career has nothing to do with transportation and the fact that the total ratio of "strongly agree" and "agree" does not drop suggests people still acknowledge efficiency as an influential feature. Participants may lack the knowledge of how much a difference autonomous vehicles can make to the efficiency of the public traffic system.

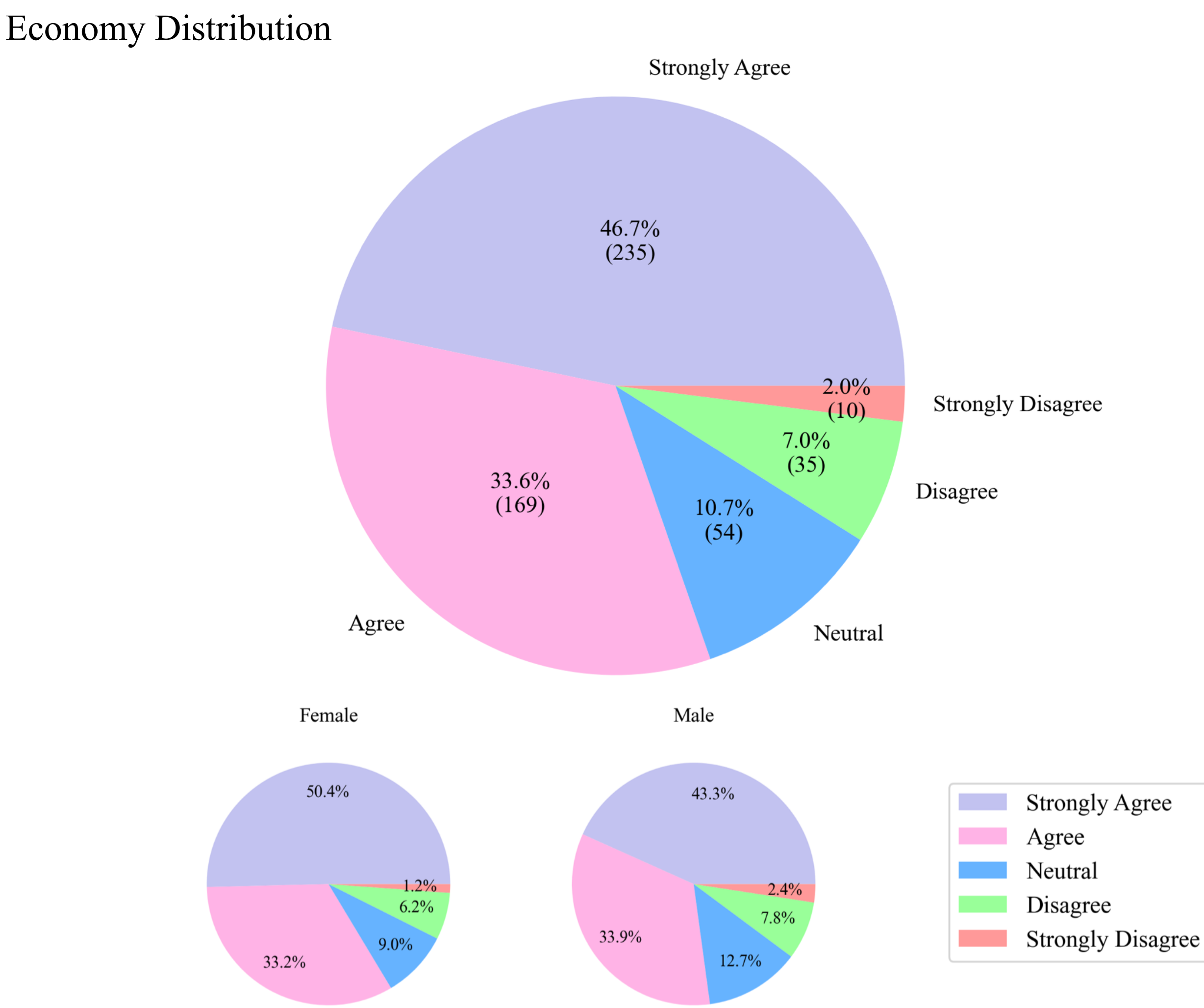


Figure 20: Pie chart representing participants attitudes on the economic and environmental impact of autonomous vehicles

Figure 20 illustrates the result of question 9: whether economic or environmental concerns will influence the acceptance or adoption rate of autonomous vehicles. The distribution of answers to this question is very similar to that of the last question. 46.7 percent chose “strongly agree”, 33.6 percent chose “agree”, 10.7 percent chose neutral, and 7.0 percent chose “disagree” with an additional 2.0 percent choosing “strongly disagree”.

Same as figure 19, fewer participants chose “strongly agree”, but the sum of participants who chose “strongly agree” and “agree” remains high. Participants may still consider economic and environmental concerns as relevant, but they may not think that such concerns are equally influential as the safety and governmental regulation aspects, since the ratio of “strongly agree” drops significantly.

Specific Law Distribution

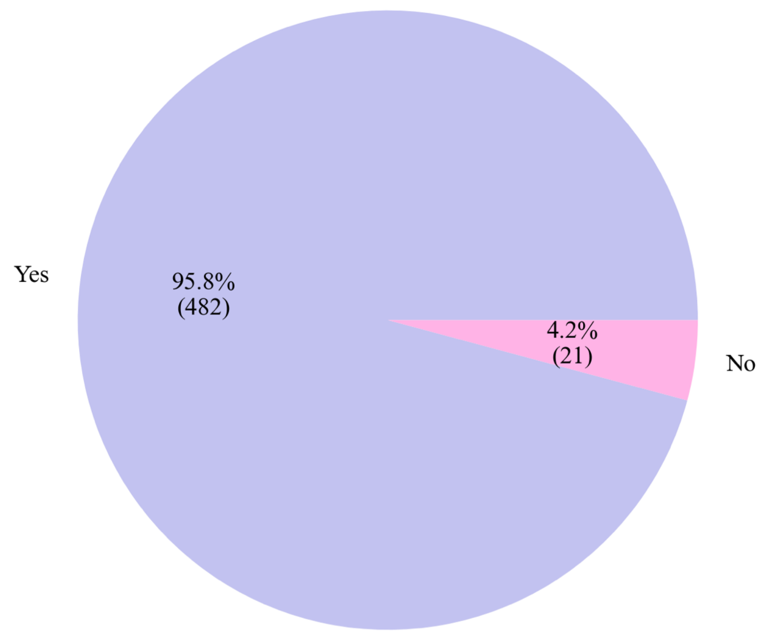


Figure 21: Pie chart representing participants attitudes on whether there should be specific law for autonomous vehicles

Figure 21 correlates with figure 17. Both two figures ask about the relationship between governmental laws and autonomous vehicles. Different from figure 13’s question that asks whether governmental regulation will influence participants’ acceptance or adoption of autonomous vehicles, question 10, the one related to figure 17, asks the participants if there should be specific traffic laws just for autonomous vehicles. 95.8 percent chose “yes” which clearly outweighs 4.2 percent, the ratio of participants who chose “no”. Comparing this result to that of figure 13 in which over 90 percent of participants gave positive answers, we can conclude that governmental regulation and traffic laws are critical aspects regarding autonomous driving.

License Requirement Distribution

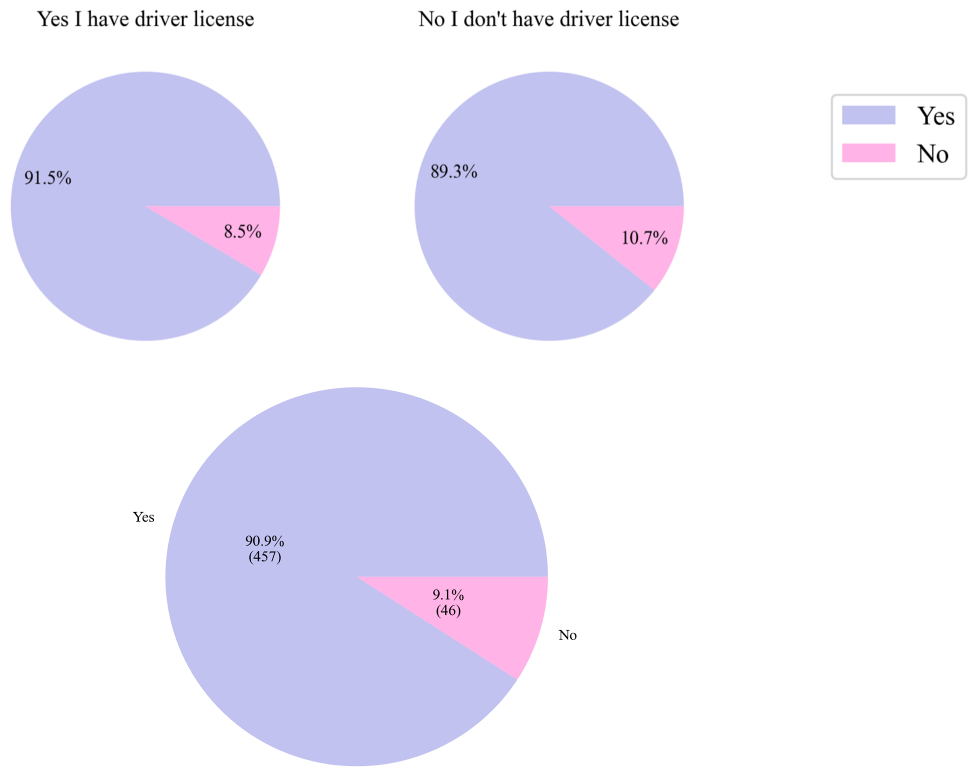


Figure 22: Pie chart representing whether driving autonomous vehicle requires a driver license

Figure 22 corresponds with question 11 which asks participants if utilizing a completely automated vehicle would still require a driver's license. 90.9 percent of participants chose "yes" while the rest 9.1 percent chose "no". The result implies people still believe that programs alone cannot autonomously drive vehicles, and the availability of a human driver in the car is essential. An earlier assumption made in this report was that participants with driver's licenses might tend to support the possession of a license when operating an autonomous vehicle compared to those without a license. From the distributions of this question, however, two groups of participants thought the same way. A possible explanation could be that a driver behind the wheel of autonomous vehicles can assure safety. Because even though participants without a license would not drive an automated car, they could still be pedestrians in an autonomous driving system. As shown in figure 14, 82.9 percent of participants chose "strongly agree" for the safety aspect of autonomous vehicles. Moreover, participants without a license might be those who failed the license test, so they know that people without a license may not be qualified to operate a car, even an automated one.

4.1.3: Analysis of Ethical Decision

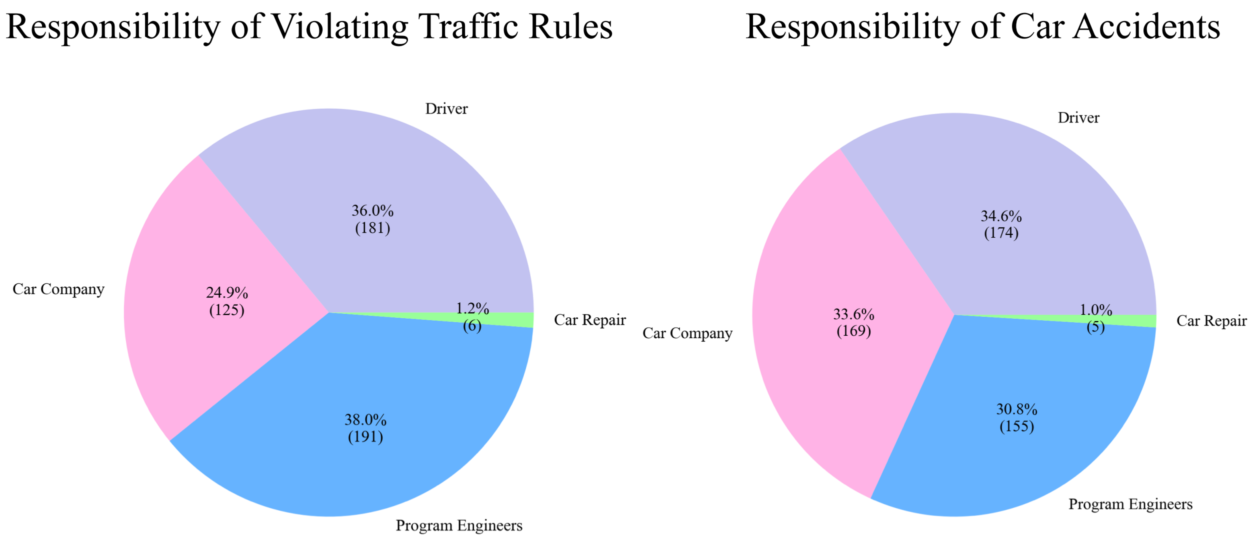


Figure 23: Pie chart representing participants attitudes on who should be responsible for traffic rules violation and who should be responsible for car accidents

The top left pie chart in figure 23 shows the results of question 12: If an autonomous vehicle violates traffic rules while it is driving completely autonomous, who should be responsible? 38 percent of participants believed program engineers should be responsible, 36 percent chose drivers, about 24.9 percent voted for car companies, and only about 1.2 percent agreed that car repairs should take the responsibility, proving car maintenance a trivial option.

Program engineers got the greatest number of votes, probably because people expected these engineers to consider all possible scenarios that might happen on roads, but these traffic rules were not consistent across states. Even the testing rules for self-driving cars were different across California, Texas, and Arizona (Lekach, 2019). Different areas have diverse restrictions, depending on weather, city layouts, population density, and other factors. When there was a lack of coherent framework for general traffic rules and regulations of autonomous vehicles, it might be challenging for programmers to put every specific road rule into the driving system.

The right pie chart of figure 23 illustrated the results of question 13: If an autonomous vehicle causes a car accident while it is driving completely autonomously, who should be responsible for the loss and be penalized? This question was slightly different from the previous one because it indicated a greater degree of impact and it highlighted potential penalties. 34.6 percent of participants chose drivers, higher than the 33.6 percent who voted for car manufacturers, then 30.8 percent of survey respondents thought programmers were in charge, with only 1 percent among all participants who blamed car repairs.

Compared to the results on the top right, the number of participants who selected car companies increased and the percentages of the other three options all decreased. Car repair remained insignificant. However, it was reasonable that drivers got the first place since, among the 25 leading causes of car accidents, 16 were related to drivers with improper behaviors, including distracted or drunk driving, 6 were about environmental factors, such as fog and snow, the rest of 3 factors were associated with defective parts of the automobile itself (Pines, 2021).

The greatest difference between the two pie charts is that “car company” got 44 more votes in question 13 than 12. This illustrated that humans tend to blame the brand. People criticized Uber for the death of pedestrian Elaine Herzberg but ignored the fact that she was transpassing highways. People accused Samsung of selling exploding phones but neglected that many buyers used or charged their phones improperly. Overall, they tend to find an entity to take legal responsibility, instead of prosecuting an individual. If we divided the results based on whether people had a car crash or not, among the 337 participants who replied “no”, they tended to blame the driver (33.7 percent) when an accident occurred. While the other 166 participants who experienced a car crash were more inclined to find fault with the car company (39.2 percent). In summary, people who experienced car crashes were apt to blame the car company.

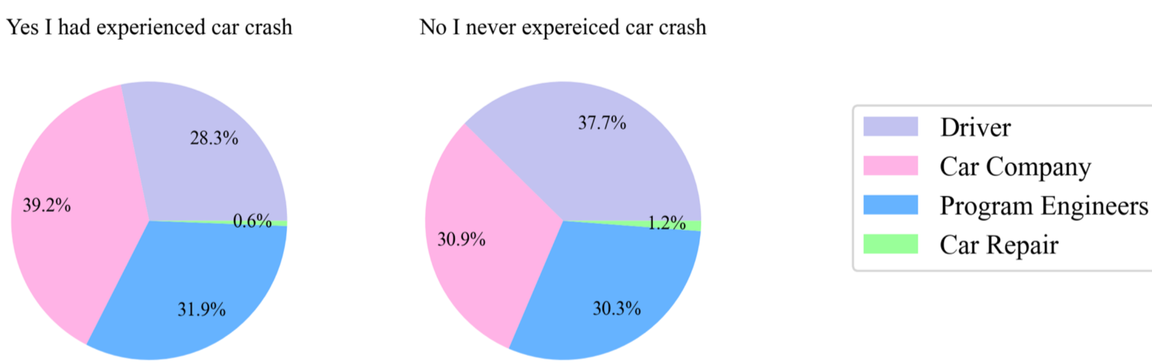


Figure 24: Pie chart representing participants attitudes on who should be responsible dividing whether they had car crash or not

Priority Distribution

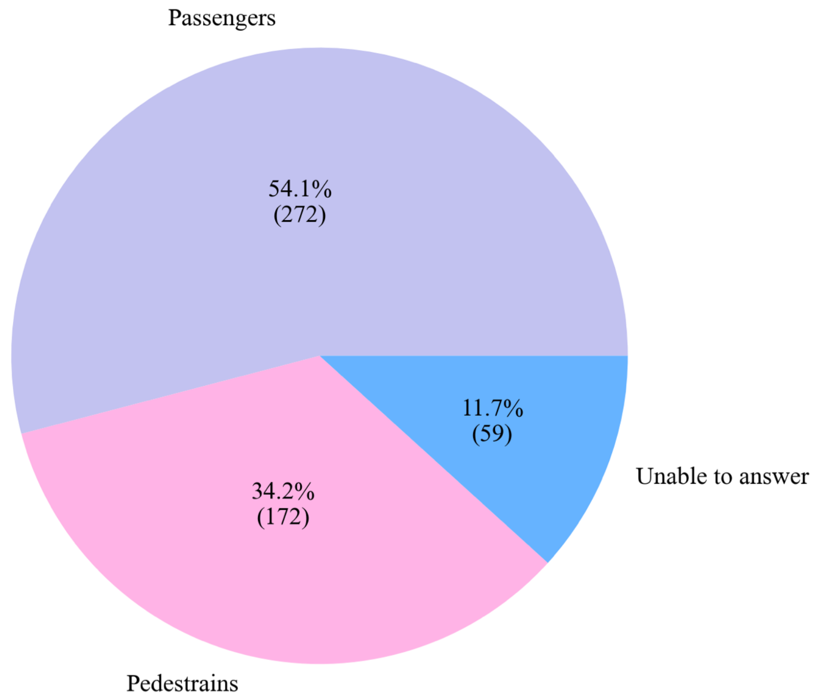


Figure 25: Pie chart representing participants attitudes on who should be prioritized by autonomous vehicles

Question 14 is: While driving autonomously, should the vehicle prioritize the safety of its passengers, or should it prioritize pedestrians around it? 54.1 percent of participants chose passengers, 34.2 percent of respondents overweight the safety of pedestrians over passengers, the rest of 11.7 percent were unable to make the ethical decision.

Based on the global preference published by the MIT Moral machine experiment, the probability of sparing pedestrians is about 10 percent greater than the probability of sparing passengers (Awad et al., 2018). The following BBC report pointed out from the research data, Chinese people placed the least emphasis on saving pedestrians (Fox, 2018). In another study, 76 percent of participants chose to save ten pedestrians over one passenger, but they preferred to ride with autonomous vehicles which protected passengers at all costs (Bonnefon, Shariff, and Rahwan, 2016). Researchers from different institutions were dedicated to finding an answer for building a moral algorithm. Besides the above three research projects, more surveys and games were distributed to people around the world, but there was neither a uniform answer nor a correct solution. Cultural, economic, and individual differences created ethical variations. This classical moral dilemma remained controversial.

4.1.4: Analysis of Public Acceptance Rate

Acceptance Distribution

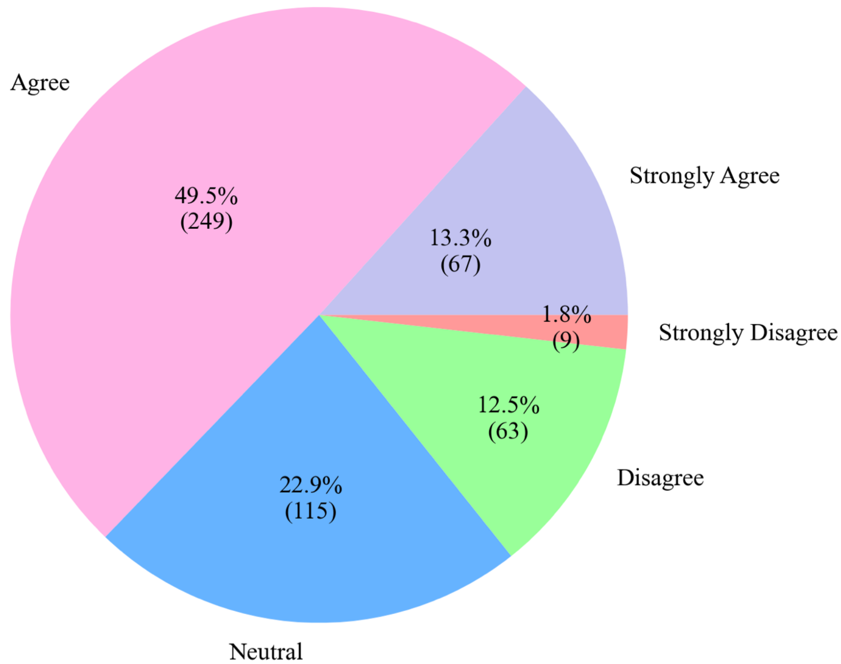


Figure 26: Pie chart representing general adoption rate

Question 15 was one of the most crucial problems we addressed: I would like to accept automated driving technology in the future. 13.3 percent of participants strongly agreed with the statement. About half of the population agreed, 22.9 percent remained neutral, 12.5 percent disagreed, and only 1.8 percent thought autonomous vehicles would be absolutely unacceptable. If answers from strongly disagree to strongly agree are represented by 1 to 5, then the mean number is approximately 3.59, with a standard deviation of 0.93. Since 3 represents a neutral attitude, 3.59 proved a generally positive perspective.

We could also aggregate the results into three groups, about 62.8 percent respondents were considered positive toward automated driving technology, 14.3 percent were negative responses, and the rest of 22.9 percent were marked as undecided. Compared to acceptance rates gathered in the past literature, participants in this study were more critical about the technology, in contrast with the 89 percent of positive Chinese respondents in the 2018 Mobility Study by Continental AG. 62.8 percent was still greatly higher than the 50 percent of American who were doubtful about automated driving technology. “Automated driving takes the fun out of driving” might be one of the reasons that explains the huge difference in people's perceptions.

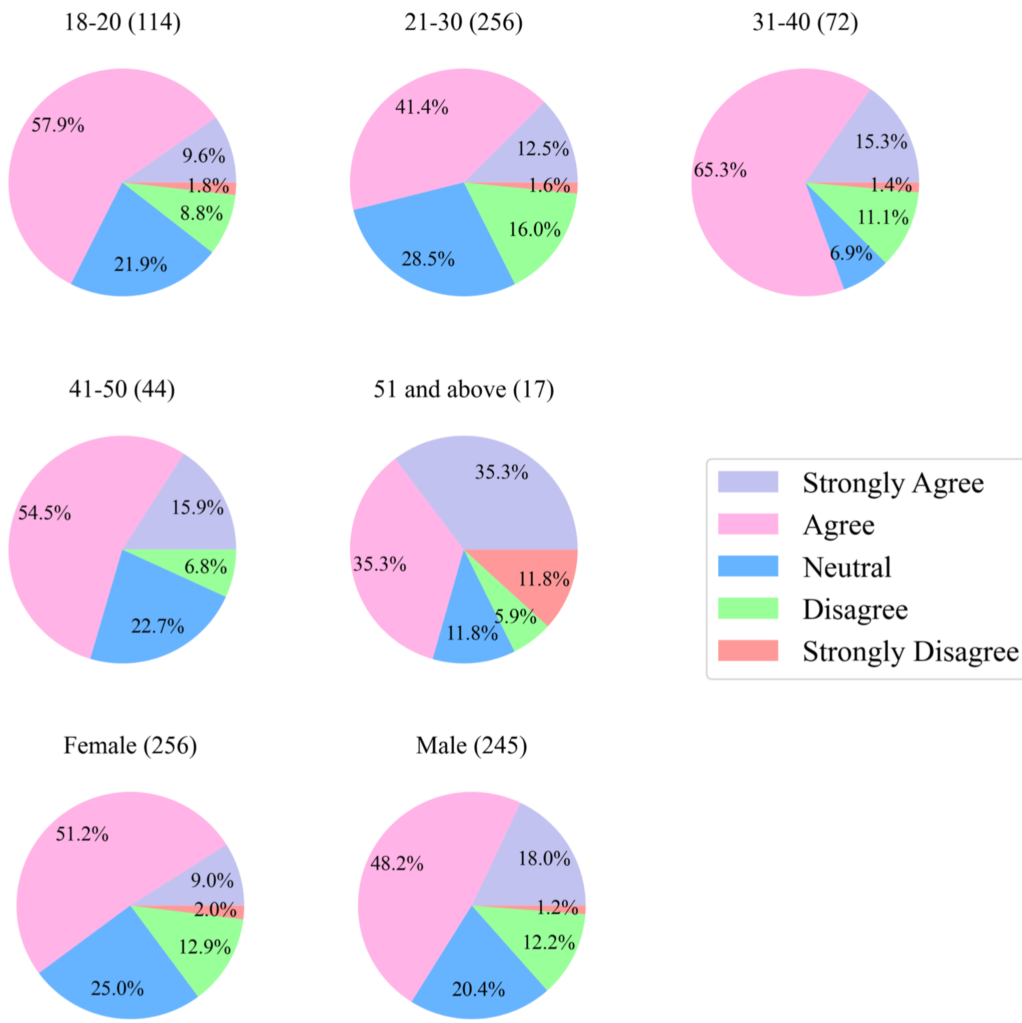


Figure 27: Pie chart representing general acceptance rate based on age groups and gender

Since more than half of the respondents were between age 21 to 30, they gave the most significant and representative results. Among people aged 41 to 50, none of them chose Strongly Disagreed. For those who are older than 50 years old, more than one-thirds chose Strongly Agreed. These unexpected outcomes showed that the sample sizes were too small, which means 44 and 17 participants could not represent the ideas of the entire populations who are 41 years old and above. Therefore, we recognized the first three pie charts as valid representatives of their corresponding age groups. People who are 31 to 40 years old had the greatest acceptance rate, 18 to 20 year-old participants ranked the second to accept autonomous vehicles, and respondents with age 21 to 30, the greatest sample in number, tend to be neutral compared to other age groups. Differences between genders were less obvious that males had slightly higher acceptance rate toward automated driving technology.

Travel Preference Distribution

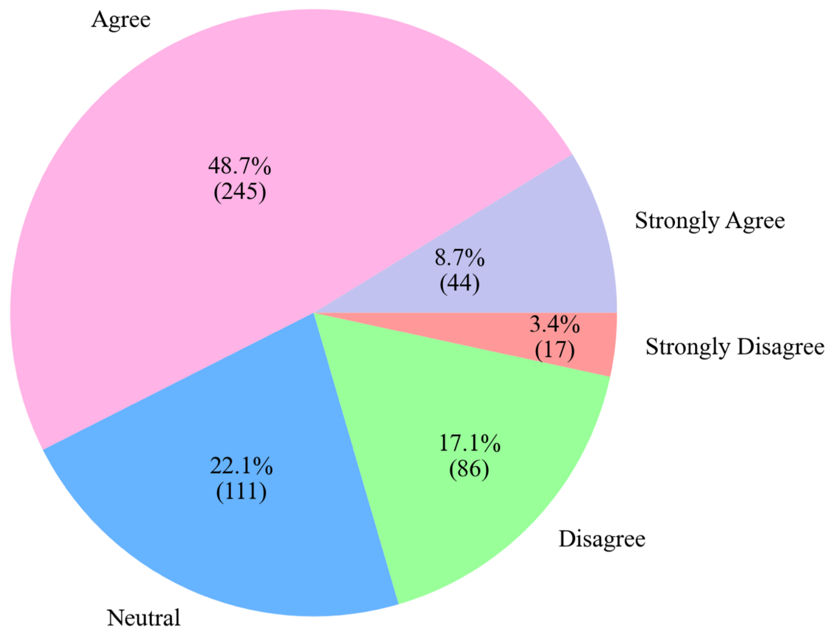


Figure 28: Pie chart representing acceptance rate of taking an autonomous vehicle

After asking the participants about their degree of acceptance, we hoped to know whether they are comfortable about using the technology themselves, so question 16 was: Are you willing to travel by autonomous car as a passenger? People who strongly agreed decreased by 4.6 percent, participants who agreed or were neutral both declined by 0.8 percent, disagreed population increased by 4.6 percent, and strongly disagreed respondents raised by 1.6 percent. Using the same scale, 1 to 5, to represent the distribution of all options, the mean number is approximately 3.42, with a standard deviation of 0.96. The mean number, 3.42, is still a generally positive perspective, but 0.17 lower than the previous graph. Therefore, participants are able to adopt the development of automated driving technology, not all of them will actually want to take self-driving cars.

Combining 5 options into 3 groups, 57.4 percent of answers were positive, 22.1 percent remained neutral, and 20.5 percent were regarded as negative. Assuming the population who chose to agree or strongly agree were consistent in question 15 and 16, then out of those who had faith in automated driving technology, approximately 91.4 percent were willing to ride in a driverless car. We should take a careful look at how the distribution shifted between these preferences.

Accept \Use	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Sum
Strongly Agree	42	16	6	2	1	67
Agree	2	198	32	15	2	249
Neutral	0	22	65	27	1	115
Disagree	0	7	8	40	8	63
Strongly Disagree	0	2	0	2	5	9
Sum	44	245	111	86	17	503

Table 1: Table representing correlations of accepting and using autonomous vehicles

The first column represents the options of general adoption and the first row corresponds with the preferences of actual intentions to use autonomous vehicles. To analyze the above chart horizontally, out of 67 participants who strongly agreed to adopt autonomous vehicles, 42 strongly agreed they would use the technology in the future, while 16 others agreed, 6 people were neutral about actually travel by autonomous vehicles, and 3 respondents would like to accept automated driving technology, but they were unwilling to use it themselves (2 disagreed and 1 strongly disagreed). Looking at the chart vertically, out of 44 participants who wanted to travel by autonomous vehicles, 42 were excited to adopt autonomous vehicles in the future, and the other 2 were less enthusiastic but still optimistic about the technology.

We shaded the table with different gradients using quantiles. Among the 25 numbers in the 5 by 5 table, the first quantile is 2, the second quantile is 6, the third quantile is 22. Numbers over 22 have the deepest blue, while numbers less than 2 are nearly transparent. Increasing frequencies have deeper colors.

The diagonal from the top left corner to the bottom right corner showed that most participants have the same attitudes across two questions, confirming the two results are strongly correlated. Votes are centralized at two options: “Agree” and “Neutral”.

Future Ownership

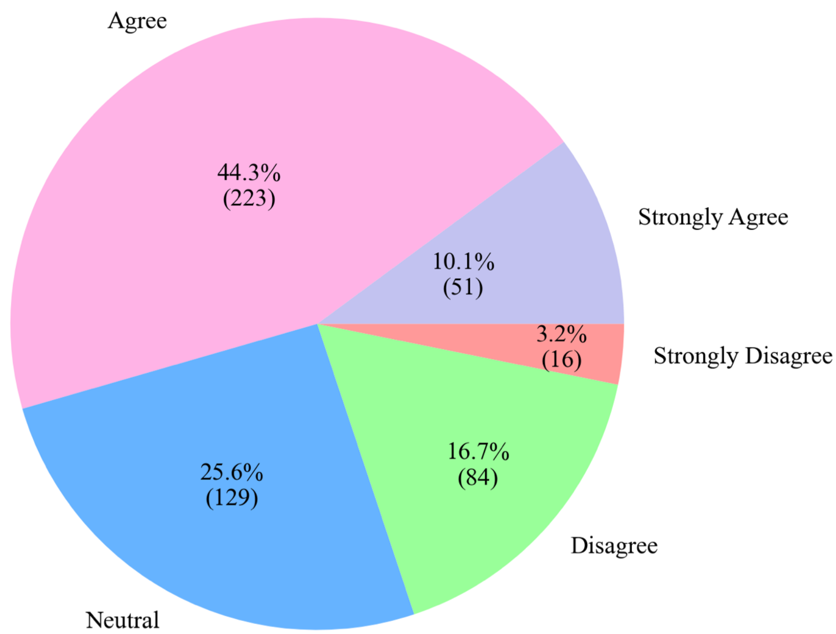


Figure 29: Pie chart representing acceptance rate of purchasing an autonomous vehicle

After asking the participants about their inclinations of taking self-driving cars as passengers, we hoped to know about their tendencies to drive and even purchase such vehicles, so question 17 was: Will you buy and drive an autonomous car? People who strongly agreed increased by 1.4 percent, participants who agreed decreased by 4.4 percent, respondents who were neutral increased by 3.5 percent, disagreed population lowered by 0.4 percent, and strongly disagreed respondents declined by 0.2 percent. Using the same scale, 1 to 5, to represent the distribution of five options, the mean number is approximately 3.41, with a standard deviation of 0.985. The degree of preference is close to the previous result, showing a positive general attitude, but still 0.18 lower than figure 22, which proved that not all believers of the technology will actually want to drive or buy autonomous cars.

54.4 percent of answers were categorized as positive, 25.6 percent were neutral, 19.9 percent would not consider owning an autonomous vehicle. We should also study how the distribution shifted between these preferences, compared to the previous 2 questions. We also need to split the results into two groups based on whether participants already owned a car.

Accept \Own	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Sum
Strongly Agree	45	17	3	1	1	67
Agree	4	183	44	18	0	249
Neutral	2	21	69	21	2	115
Disagree	0	1	13	41	8	63
Strongly Disagree	0	1	0	3	5	9
Sum	51	223	129	84	16	503

Table 2: Table representing correlations of accepting and owning autonomous vehicles

The first quantile is 1, the second quantile is 6, the third quantile is 20. We shaded the table using these three quantiles. Same as Table 1, the diagonal from the top left corner to the bottom right corner showed that most participants have the same attitudes across two questions, confirming the two results are strongly correlated. Votes are centralized at two options: "Agree" and "Neutral".

We also analyzed the results based on whether participants owned a car or not. The below pie chart showed that current car owners were more interested in purchasing autonomous vehicles.

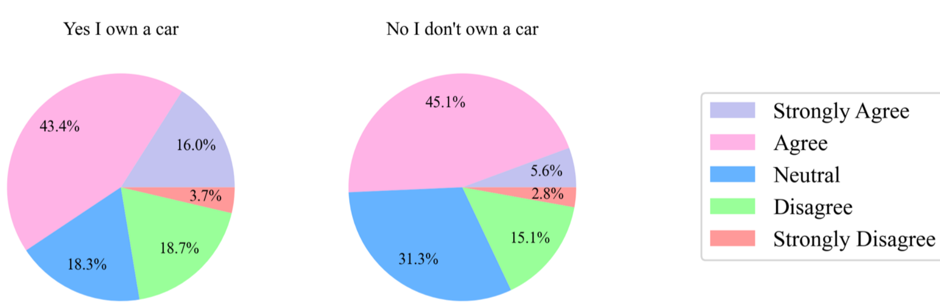


Figure 30: Pie charts representing preference to purchase an autonomous vehicle based on car ownership

Special Types of Vehicles

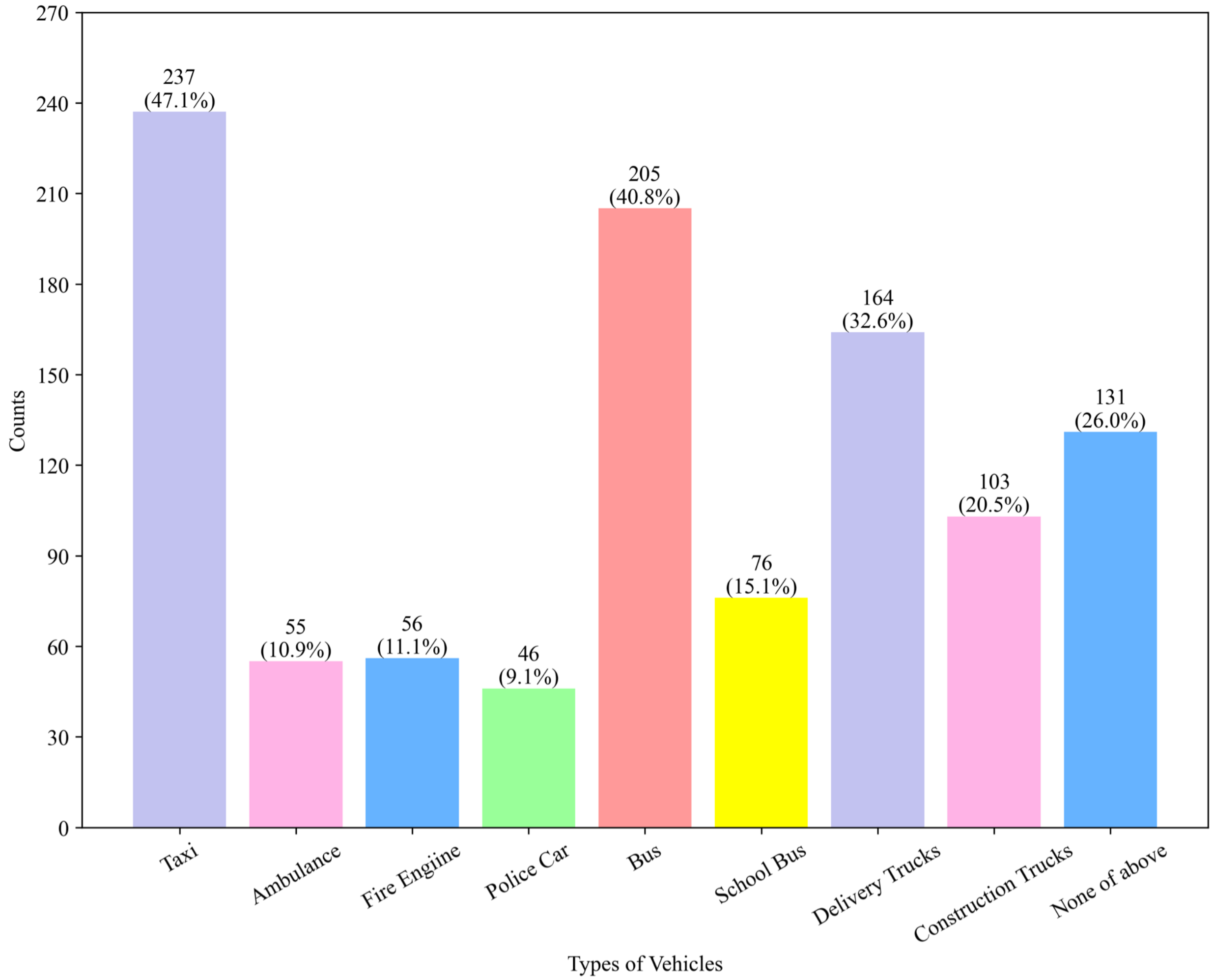


Figure 31: Bar graph representing the counts of participants who accept special types of vehicles to be autonomous

We explored how people perceive some special types of vehicles could also be autonomous, so question 18 was: Do you accept the following vehicles to be autonomous (check all that apply)? Ranked from the most votes to the lowest, taxi gained 47 percent of votes, buses were approved by 40.7 percent of participants, delivery trucks got 32.6 percent of acceptance, surprisingly, about 26 percent of respondents chose none of the above options, higher than the percentages of negative responses in previous 3 figures, proving more participants were expecting automobile to be autonomous, but they were less prepared for wide adoption in different types of transportations. The 4th place was construction trucks with 20.4 percent, school buses with 15 percent, fire engines with 11.1 percent, ambulances with 10.9 percent, and police cars received a minimum of 9.1 percent of votes.

Acceptance of Human Driver

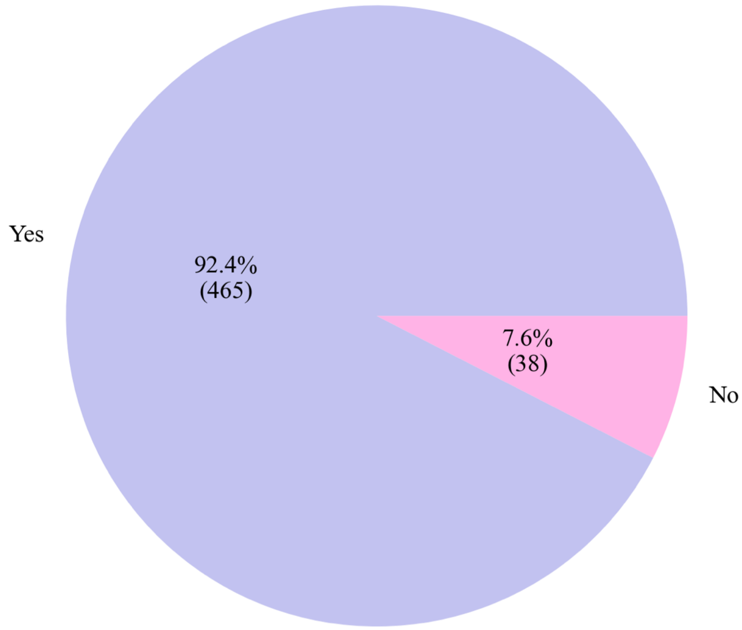


Figure 32: Pie chart representing acceptance rate of autonomous vehicle with a monitored driver

Question 19 is designed for people who are less likely to accept a completely autonomous driving system: Would you accept an autonomous vehicle if it's monitored by a driver? 92.4 percent chose yes and 7.6 percent of participants still could not accept autonomous vehicles. In contrast with the results shown in figure 18, negative feedback decreased by 6.7 percent.

Most road testing of autonomous vehicles still requires the involvement of human drivers. In the United States, The National Highway Traffic Safety Administration (NHTSA) specified that at level 3 of automation, human drivers must continue to pay full attention during actual road tests. For autonomous trucks companies, such as TuSimple, self-driving trucks that are already on the road also need backup drivers (Heilweil, 2020).

According to the 2020 Beijing City Autonomous Vehicles Testing Report, Baidu became the first company to get the approval to test 5 out of its 55 autonomous cars to be completely autonomous without the intervention of humans (Fan, 2020). The report also highlighted that, in August 2020, Robotaxi created by Baidu, even started online registration for the general public to volunteer for the autonomous taxi services. Based on the user feedback, human drivers were presented in Robotaxi to guarantee the safety of passengers.

Key Factor Distribution

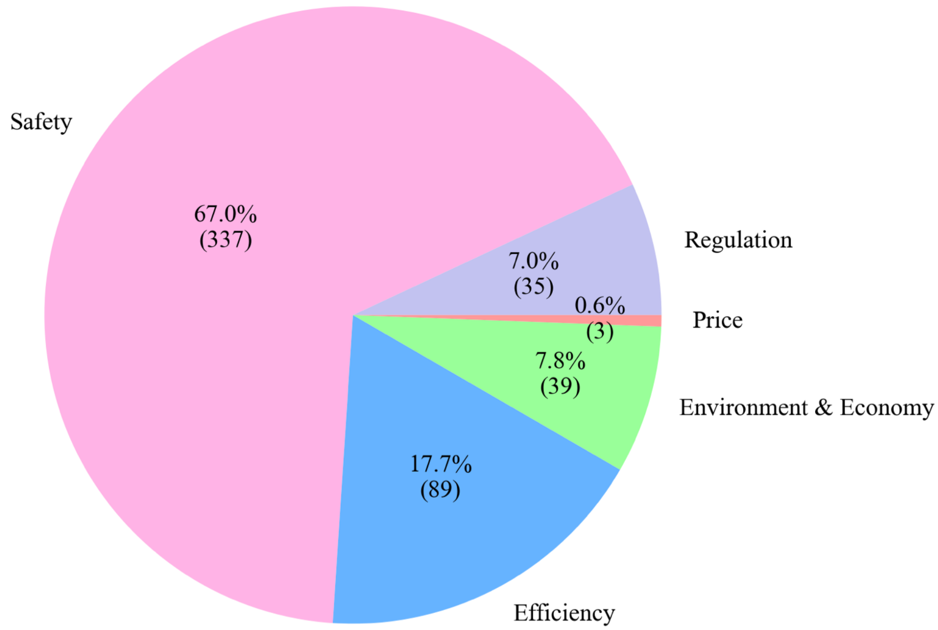


Figure 33: Pie chart representing the distribution of key factors for participants to consider using autonomous vehicles

Since questions 7 to 10 on the survey were asking about how participants value each factor we identified during the background research, and the IQP report published in 2013 determined that price was one of the primary factors, we investigated the most major aspect among all 5 options. Question 20 was: What is the most important factor that will change your mind on accepting/adopting autonomous vehicles? More than two-thirds of the population chose safety, 17.7 percent outweigh Efficiency over other determinants, 7.8 percent of participants cared more about environmental and economic influence, 7 percent of respondents were concerned with government regulation, and only 0.6 percent voted for price.

Out of the 94.8 percent of positive answers in question 8, 67 percent thought safety was the most significant criterion, then we could conclude that, among all the participants who agreed or strongly agreed safety issues mattered to them, about 70.7 percent of them emphasized safety as the decisive factor. To increase the safety index and eliminate accidents, there would still be a long way to go. A new study from the Insurance Institute for Highway Safety showed autonomous vehicles might prevent only a third of potential crashes if the driving systems were simply programmed to imitate human drivers (Baldwin, 2020).

Ideal Ratio

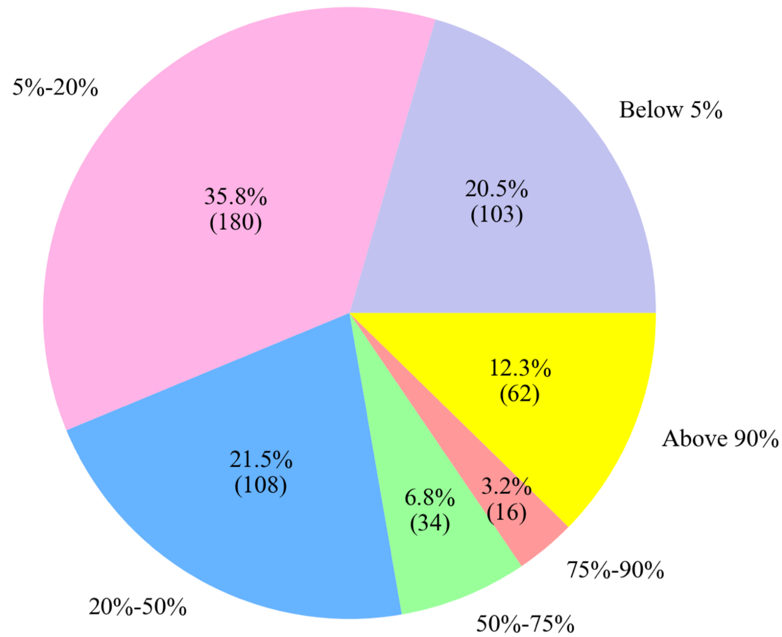


Figure 34: Pie chart representing the distribution of ideal ratios of autonomous vehicles in a city

Question 21 was aimed to help with game design: What number of portions do you think is an appropriate amount for autonomous cars in a city? 35.8 percent of participants believed 5 to 20 percent of autonomous vehicles would be suitable, 21.5 percent of respondents supported there should be 20 to 50 percent on roads, 20.5 percent upheld the idea of allowing less than 5 percent, 12.3 percent were enthusiastic about having more than 90 percent of driverless cars, and the last 10 percent thought numbers of such cars should be between 50 to 90 percent.

We hoped to collect people's current perceptions on what they believed was a proper degree of autonomy on the traffic system, then we could show that, with increasing percentages, the game could simulate real-life scenarios of boosting the efficiency of transportations, or even speeding up the modern lifestyle.

The Autonomous Intersection Management Project, conducted by researchers from the University of Texas at Austin, studied the hybrid system of human and autonomously operated vehicles. One of the important results was that self-driving cars suffer less delay compared to vehicles operated by humans. In the simulated video, the average delay time for a traditional traffic system was about 27.05 seconds. Allowing 90 percent of the vehicles to be autonomous, the average delay time declined to 3.66 seconds (*Autonomous Intersection Management project,* n.d.).

4.1.5 Analysis of Open-Ended Response

The last question on the survey was: Do you have any other concerns about automated driving technology? Out of 503 responses, 80 people clearly stated they did not have other concerns. 303 participants did not leave any comments. We calculated word frequencies and categorized the remaining120 responses into the following areas: safety issues, ethical problems, current limitations, and future impacts.

Safety concerns appeared 73 times. 34 participants simply wrote down "safety" in their answers. Many respondents were worried about autonomous vehicles' ability to deal with emergencies, including pop-up children, severe weather, complex traffic conditions, and driving system malfunction or sudden brake failure which makes self-driving cars lose control. Some were concerned about cybersecurity and their privacy. The other asserted that the technology is immature. 3 people believed autonomous vehicles were restricted because the driving system could not think or make decisions like humans. 1 person gave a technical answer that self-driving cars may encounter scenarios outside of their training data sets.

Ethical problems were highlighted in 34 responses. 14 people thought it would be difficult to decide who should be responsible for car crashes caused by autonomous vehicles. 7 participants referred back to the moral dilemma of choosing between pedestrians and passengers. 6 required more refined government regulations and industrial standards for autonomous vehicles to be legal. Some respondents were anxious about structural unemployment for human drivers. A few participants were pessimistic about making autonomous vehicles prevalent. Only 2 people were heartbroken that car cultures and the fun of driving will fade away.

Practical restrictions were mentioned by 12 participants. Some assumed self-driving cars would be hard to operate and difficult to switch their mode between human driver and autonomous system. The others were concerned about outdated hardware, like engine stalling and low battery storage. The rest of the respondents questioned the speed of sensors and Wi-Fi, the actual reaction time, and bad signals in rural areas. One person had concerns on a timely refreshed map and the accuracy of the actual environment identified by autonomous vehicles.

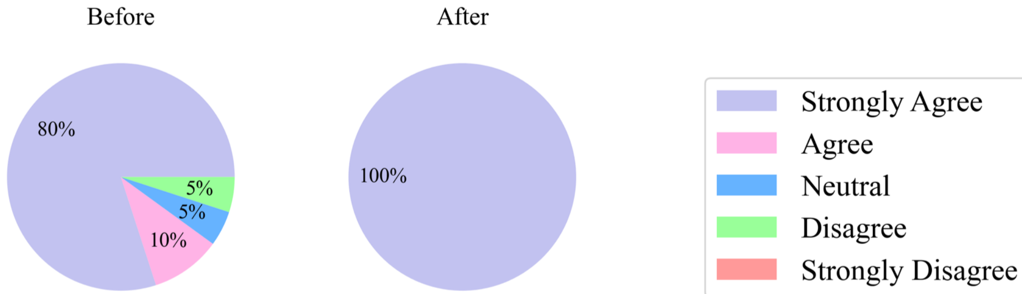
Future impacts were predicted by at least 20 participants. Many people expected that humans will rely too heavily on autonomous vehicles, therefore more accidents are likely to happen due to the dependency and unqualified drivers. Some required attentive human drivers behind the wheels of autonomous cars, but one person refuted that autonomous driving systems will replace humans, so it would be unnecessary to let driverless cars be monitored by humans. 2 participants were skeptical that autonomous vehicles would be more convenient for the general public and people with disabilities. The other 2 respondents hoped autonomous vehicles could have more detailed functions, including automatically searching for gasoline stations and cooperating with an intelligent transportation system (ITS) to build an intelligent vehicle infrastructure cooperative system (IVICS).

Among people's future expectations, the other 10 comments were more subjective. Some people worried autonomous vehicles may be too expensive to afford, resulting in a low acceptance rate, consequently, accidents beyond algorithms may happen due to the lack of real-life data, or the new technology might enlarge social inequality because rich people would support the regulations that favor autonomous vehicles and ignore the safety and rights of poor people. A few participants thought driverless cars were not cost-effective due to their high development cost and lower-than-expected efficiency, so it would be a waste of social resources. If autonomous cars were permitted to drive on roads, people would be perturbed about unpredicted human behaviors in a hybrid traffic system, including cutting in line and abrupt U-turns. Therefore, researchers are focusing on developing "streaming perception", a perception technology that involves careful integration of detection, tracking, forecasting, and dynamic scheduling (Li et al., 2020). People were afraid that autonomous vehicles will harm vulnerable people and animals since it may prioritize some lives over others. One person declared that it was unacceptable for autonomous vehicles to prioritize pedestrians. Another participant simply did not trust machines at all. One of the respondents challenged the idea that an intelligent driving system was not equivalent to a safer way of transportation. The last opinion was that, similar to Hollywood movies, autonomous vehicles and intelligent robots may lead to human annihilation.

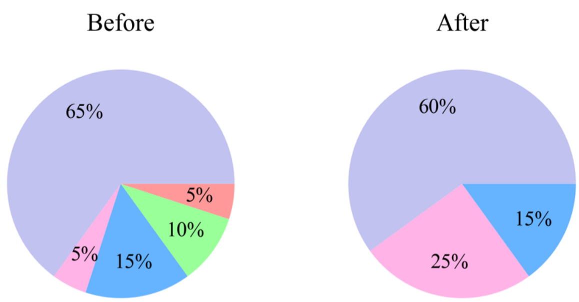
4.2: Comparison of Survey Responses and Game Data

We invited 20 participants to play the final version of our game. Three questions were asked right after their game session ended, aimed to evaluate changes in participants' views on safety, efficiency, and their acceptance of self-driving cars.

Safety Distribution



Efficiency Distribution



Acceptance Distribution

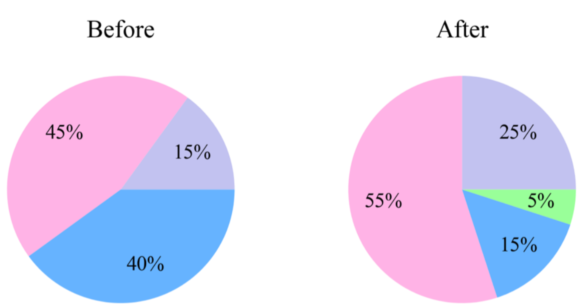


Figure 35: Pie charts representing participants attitudes toward safety, efficiency, and acceptance of autonomous vehicles before and after playing the game simulation

After playing the simulation, all players strongly agreed they cared about the safety aspect of autonomous vehicles. They also valued efficiency as a more important factor compared to their responses in the initial survey. The average acceptance rate seemed to increase generally, so we used the 1 to 5 scales, corresponding with strongly disagree to strongly agree, to calculate the difference.

Among the 503 participants, the mean number was approximately 3.59, lower than the 20 game players whose mean acceptance rate was 3.75. The post-game survey showed that the acceptance rate increased to 4, even though 1 person chose “Disagree”. Thus, players’ acceptance of autonomous vehicles grew after trying our game simulation.

Following the general pattern, we hoped to assess changes of individual opinions. In the below table, SA represents “Strongly Agree”, A represents “Agree”, N represents “Neutral”, D represents “Disagree”, SD represents “Strongly Disagree”.

safety (before)	safety (after)	count
S A	S A	16
A	S A	2
N	S A	1
D	S A	1

efficiency (before)	efficiency (after)	count
S A	S A	11
S A	A	1
S A	N	1
A	N	1
N	A	2
N	N	1
D	A	2
S D	A	1

acceptance (before)	acceptance (after)	count
S A	S A	2
S A	A	1
A	S A	1
A	A	6
A	N	1
A	D	1
N	S A	2
N	A	4
N	N	2

Table 3: Table comparing individual opinions on safety, efficiency, and acceptance of autonomous vehicles

All 16 players who thought the safety aspect of autonomous vehicles is important still insisted on the statement. The rest 4 participants all shifted to strongly agreed, while they didn’t consider safety as the key factor when completing the initial survey. This proved that our safety scenario in the game successfully addressed the advantages of autonomous vehicles in the safety aspect, so more people realized the significance of self-driving cars may reduce the number of accidents.

When evaluating the efficiency of autonomous vehicles, 3 participants rated the factor lower (from strongly agreed to agreed or neutral and from agreed to neutral) after playing the game, while 5 respondents rated the efficiency consideration factor higher (from neutral, disagreed, and strongly disagreed to agreed). The other 13 participants gave consistent answers. Thus, the results indicated our efficiency scenario in the game positively affected those who did not pay much attention to the efficiency aspect of self-driving cars. It might not meet the expectations of those who had high hopes on how driverless cars could improve traffic. We should also consider how to make the efficiency scenario more realistic and practical.

Looking at respondent's acceptance rate of autonomous vehicles, we first noticed who were neutral in the initial survey became more positive toward the technology. The only exception was one participant who shifted from a positive attitude to a negative standpoint. The participant was likely to accept driverless cars in the first place but changed to less likely (disagreed). The respondent suggested that in a complex traffic system, an increase in efficiency might be trivial, as long as autonomous cars could not mitigate the possibility of car crashes (e.g. small car distance), it was likely to cause serious accidents. The respondent also commented on the safety scenario we designed. The person regarded simulation results as insignificant since car crashes were minimized with fewer drunk drivers, so the participant worried that human drivers might rely too heavily on the autonomous driving system and failed to be qualified. Therefore, the participant did not accept driverless cars.

5: Conclusion

This study consists of three stages: a benchmark survey, a game simulation, and a comparison of attitudes. The survey has a total of 23 questions, with 21 multiple choice questions and 2 open-ended questions. 503 participants helped with our survey, a number far more than initially expected. These participants were carefully recruited such that female participants are only 2.2 percent more than male participants. Therefore, the survey result is free of gender bias. The age group ratio of the participants, however, is significantly imbalanced. Out of 504 responses, 50.9 percent are from 21 to 30 years old, with an additional 22.7 percent are from the age of 18 to 20.

Admittedly, the survey has its limitations, but it produces significant results. The questions asking for demographic information have more value than testing if the survey results are biased. These questions are interrelated to the subsequent questions which ask participants about their basic preference on the four key factors of autonomous driving in our study: governmental policy and regulations regarding the adoption of this technology, the safety of autonomous vehicles, the efficiency of autonomous driving systems, and the economic or environmental impacts they may have on the society. We analyzed the data retrieved from such questions and compared the age group and gender distributions from different answers. Although the distributions vary slightly compared to the original distribution collected from demographic questions, people's preference stays constant across genders, age groups, and differences in car ownership.

The result shows that most participants are willing to accept autonomous driving especially when it is under strict surveillance and that participants care the most about the safety of autonomous vehicles but relatively less about the efficiency of the autonomous driving systems. Due to such results, the game simulation focuses more on presenting participants the high efficiency of autonomous driving, anticipating a possible change in preference. As a result, the game simulation has made a positive change to participants' acceptance of autonomous vehicles. Overall, our research shows, when comparing it with results from other literature reviews, that Chinese participants largely accept the newly automated driving technology.

6: Recommendations

6.1 : Recommendations on Autonomous Vehicles Research

We outlined suggestions from the following aspects: potential solutions of ethical decisions, different measures to increase public acceptance rate, and improvements on future research.

To solve the ethical decision in question 14 about prioritizing passengers or pedestrians, one study asked participants about who should determine how the autonomous car responds when it must save either passenger or pedestrian (Moon et al., 2014). 44 percent of participants chose passengers, 33 percent thought lawmakers should decide how the car responds to such scenarios, and manufacturers or designers were supported by only 12 percent of the respondents. 55 percent of the participants who selected passengers shared the idea that passengers should have the freedom to make life-death decisions. In other words, a majority of participants believed passengers should be able to customize their own autonomous vehicles when encountering such moral dilemmas.

The best solution might be avoiding the above scenarios to guarantee everyone's safety. Eliminating potential car crashes ensures that we do not have to choose between passengers or pedestrians. From the IIHS study we mentioned under Figure 27, even though self-driving cars were expected to prevent one-third of possible car crashes, to avoid the other two-thirds, autonomous cars would need to be specifically programmed to prioritize safety over speed and convenience (Baldwin, 2020).

In the next few years, if car companies keep improving their products and persuade the general public that autonomous vehicles are safer than traditional automobiles with more published data and test trials, we believe more people will likely trust the new technology and adopt it. Besides using games to educate people about autonomous vehicles, "Direct experience with AVs along with education and communication would be helpful to change people's attitudes towards AVs in a positive way"(Golbabaei et al., 2020). Robotaxi, or driverless taxi services, are becoming prevalent in both the United States and China. At the time of this research on autonomous vehicles during the summer of 2021, news reported "Beijing and Changsha both offer autonomous taxi services in restricted locations", but most of the people are less likely to notice there are autonomous cars services provided in their cities. Therefore, it's necessary to draw people's awareness about opportunities of direct experience with autonomous vehicles.

The first step would be letting people know about the available services of autonomous cars, but we still expect fewer people are willing to volunteer to take the Robotaxi. Thus, we need more research to understand people’s preferences and the reasons behind them.

A study done by Golbabaei et al. in 2020 summarized about 30 aspects that appeared in the past literature to analyze public acceptance and adoption intention of autonomous vehicles. We suggested that future studies should include the following factors in their research: education level, employment status, household income, household structure, residential condition, technology savviness (awareness of autonomous vehicles), social norms, peer pressure, hedonic motivation (people who enjoy driving), in-vehicle time, commute mode, driving frequency, and mobility impairments (people with disability). These factors could help to achieve a more holistic review of individual decisions.

6.2 : Recommendations on Autonomous Vehicles Game Design

In this section, we will discuss unfinished, scheduled, and initialized designs in our development cycle. We hope to give insights to future researchers who would like to use games as a research medium.

In our research, we have noticed the potential of using games as a medium of data collection or information conveyance. Participants expressed willingly that the simple simulation gave them more unexpected knowledge about autonomous vehicles. Thus, we can then conclude that using games as tools in social studies is feasible.

However, we did not complete all planned tasks as we would prefer r. Seven weeks is not enough time to develop a complex and dedicated game.

In terms of the game design, we have many versions of plans. Initially, we tried to design a game around the initial benchmark survey (gamified survey) by giving it more fun. The process would be simple: we would start from the survey and gradually add interactive components to it. We have planned the addition of fun outcomes (participants would get a descriptive message about what type of “autonomous vehicle human” they are, like “obedient excellent traffic dominator”). Those outcomes will be generated from the survey. Each question in the initial benchmark survey will have certain hidden points, and the final result will be computed with those points. Also, we have planned to add digital avatars and an "autonomous digital community" along with it as the later step. However, those are too ambitious and could not be done in seven weeks. So, we abandoned this path in the end.

Then, we chose to go with immersive simulations, which will give unexpected knowledge to participants. In the early designs, we tried to design selectable roles to represent different perspectives in the autonomous vehicle community. There were four designed roles before it was abandoned: Law Enforcer, Citizen, Autonomous Vehicle Manufacturer, and Traditional Vehicle Manufacturer. Overall, as Law Enforcers, participants need to consider more from regulations level (like speed limit, maximum acceleration speed, etc.) to reduce the accident rate in the city. Playing as citizens, participants could experience how autonomous taxis are from the view of a passenger, or they can experience the city from a pedestrian view. Roles of manufacturers sound similar while they are not. Autonomous Vehicle Manufacturer would need to consider from the perspective of a machine and develop algorithms to make their vehicles safer, while Traditional Vehicle Manufacturer would need to focus on vehicle performance designs to increase their safety level, speed, etc. The citizen and law enforcer views were under development yet not finished in our project.

We believe that different perspectives will lead to different thinking in the same scenario, and by engaging in different perspectives, participants will be able to stand from a more neutral ground when evaluating their opinions on autonomous vehicles. Also, we have planned logging and auto-saved in the game to save playing data for analysis. However, due to the limited time, we were not able to complete those under development components.

Regarding the efficiency and safety scene, we also have some unfinished designs. In the efficiency scene, we planned to add algorithms to show that autonomous vehicles can solve the main cause of traffic jams, the "stop and go" problem, by keeping a reasonable distance between the car in front and the car on the back. Also, in the safety scene, we were working on a more complex city with dedicated entrances and exits to make it more realistic. Types of vehicles are also scheduled, yet only bus, truck, and taxi were under development. We assigned them different tasks to make them seem more real. For example, buses need to trip around bus stops in a fixed route, and taxis will stop at random task points to load or unload passengers.

We have also planned to add a traffic-economy-related system to indicate the overall efficiency of the city. Successful tasks will guarantee increases in the economy while accidents will make it lower. Environment system is another scheduled design. Part of the human-operated vehicles will discharge carbons and we would add carbon emission monitors inside the game to see the environmental benefits of autonomous vehicles. More than that, since autonomous vehicles do not need drivers, they can be parked in a central space or constantly running on the road. This will save space for the city, and we planned to indicate this by showing that human-operated vehicles need more parking spaces.

There are many tasks we have planned yet not finished owing to the time limit. However, we do not regret those processes. We did learn a lot from those big dreams and deduce the simple things we can do in our simple simulation to make it more appealing. This is a design school called “speculative design”, and we would encourage future researchers to investigate it if interested.

6.3: Recommendations to IMGD Department

Based on our experience of using games as a research medium in our IQP, we would also want to share this possibility of utilizing games formally in social studies in IQP with the IMGD (Interactive Media and Game Development) Department at WPI. Both in other research and our own IQP project, we found that gamified mediums are powerful for information conveyance and are effective on data collections.

During our research, we found that many researchers have classified this category of “studying the functional purpose of games rather than entertainment” as “serious games”. The study of serious games started in the early 2000s and grew rapidly in the last decade. Majorly, researchers are focusing on the educational potentials of serious games. In his research, Loh had tried to use serious games for quantitative data collection, though we could not find other cases (Loh, 2007).

Even though Loh is the only case we can find in which serious games were used for data collection, we could still suggest that students need to learn about serious games to better utilize them in IQPs. Fortunately, we do have IMGD 4600 and IMGD 5500 that focus on serious games. However, students at WPI typically would only reach a few 4000-level courses when they are doing IQPs. Data analysis in games is another crucial skill for research purposes. Luckily, there is another course, IMGD 2905, Data Analysis for Game Development, which talks about quantitative data analysis in games. It correlates to IQPs very well, but as far as we know, only a few IMGD students have taken the course so far.

Therefore, we recommend the department starting an introductory level IMGD course about serious games, like designs and implementations of gamified surveys, which would link between the IMGD department and the IQP projects. Also, we should talk and discuss the possibility of utilizing games in IQPs in our IMGD community more frequently in the future. We should bring these ideas of “games are powerful research tools” and “we could utilize gamified research methods in IQPs” to our community to make more students aware of these possibilities. Our experience showed that it is not an infeasible thing to introduce games to IQPs. With clever designs and time management strategies, we believed that we would go further in our simulation developments. Then we might collect more meaningful data for analysis. If there could be annual dedicated seminars or community-wide discussions on game project timeline and development cycle management, we could certainly save lots of wasted time in wrong directions. Those skills would be crucial for students to complete their course projects in seven-week terms. With efforts to build our community better, we believed we could see the happy faces of IMGD students enjoying their time in collecting and analyzing data from dedicated games in IQP projects in the future.

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Appendices

Appendix A: Interview Questions for Sponsor from TuSimple

1. What is your role in the TuSimple's Beijing office? Would you please tell us a little about your history?
2. What is the role of TuSimple's Beijing office, compared to headquarter at San Diego, CA and office at Shanghai?
3. Do you want us to focus on the technical side or the ethical side of autonomous trucks?

   o If technical side: Is that the major reason you require students with CS backgrounds? What is the specific area you hope us to conduct research on?

   - If traffic management/AI technology/model related
     - Share current knowledge on the topic & ask for specific project direction
   - If not specified, explain the idea of making a simulator/other potential ideas
     - Explain IMGD background

   o If ethical side: Why do you choose students with CS backgrounds? Do you have some specific expectations for us?

4. Why is this project important to you and to the field of autonomous vehicles?
5. Could you elaborate more on the social implications of autonomous vehicles, particularly in China?
6. Since we saw TuSimple tested many trials in the United States, did you experience any issue on implementing autonomous trucks in China? If so, how long has this been an issue?
7. What if some solutions have been proposed in the past? Did anything come out of them?
8. Are you aware of other companies that have tried to address this issue? (e.g. Waymo?)
9. What type of solutions would be considered acceptable?

10. Do you have reports, websites, organizations or other resources to share that would help us? (Briefly summarizing information we already got from some of the 20 references that may relate to the topic)
11. Who should we talk to about the challenges of?
12. What other available resources on this project (money, people, databases, reports)?
13. Is there anybody else you think we should discuss this project with?
14. What are we missing? Anything you would like to add?
15. If necessary, when would you like to meet again?

Appendix B: Informed Consent for Study Participants

Informed Consent Agreement for Participation in a Research Study about the Public Acceptance of Autonomous Vehicles

Investigator: Yongcheng Liu, Zhifei Ma, Zhecheng Song, Jieping Zhao
Contact Information: gr-gr-autonomousvehiclesbeijingiqp@wpi.edu
Title of Research Study: A Study of Change in Public Acceptance of Autonomous Vehicles in China by Designing a Game Simulation to Address Related Ethical Issues
Sponsor: TuSimple

Introduction: You are being asked to participate in a research study about the public acceptance of autonomous vehicles. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: This research study will investigate the public acceptance of autonomous vehicles in China. The project investigators hope to implement a game simulation that helps people to think critically about the technology.There are three main goals: First, to assist and educate the society to be more aware about existing technology related to autonomous vehicles. Then, to investigate, identify, and address potential ethical implications of autonomous vehicles. Finally, to analyze how ethical concerns would influence the public acceptance rate and evaluate people's attitudes toward the technology.

Procedures to be followed: You are being asked to fill out a Google survey in English (accessible here: https://forms.gle/d6JhYPRCjVKgHKmk6) (or a Tencent survey in Chinese, accessible here: https://wj.qq.com/s2/8518268/0bd0/). The survey contains questions regarding your attitudes toward automated driving technology. It contains 21 multiple choice questions with 1 open-ended question. Multiple choice questions will ask about your perception on the regulation, safety, efficiency, and environmental/economic impact of autonomous vehicles. The last open-ended question asks you to nominate other concerns you have about autonomous vehicles. It will take 3 mins to fill out. If you are willing to participate in a game simulation of autonomous vehicles in the future, please write down the last 4 digits of your phone number, it will be your username in the game. Your participation in our research is voluntary. You can contact us with questions at gr-gr-autonomousvehiclesbeijingiqp@wpi.edu.

Risks to study participants: This study is of minimal risk. Please fill out as many questions as possible, but if you are unable to complete any of these questions, you may stop at any time. Your refusal to continue participating in this study will not result in any penalty.

Benefits to research participants and others: The research participants will gain more knowledge about autonomous vehicles. Evaluation of the public acceptance rate will help the research sponsor to understand the concerns and needs of its customers to improve corresponding services, for instance, if safety is the most significant concern among all other factors, then the sponsor should enhance the safety procedure of shipping products with autonomous trucks and take multiple safety measures in the future.

Record keeping and confidentiality: Answers to the survey will be stored on WPI One Drive. Participants will be kept anonymous and each will be identified by last 4 digits of their phone numbers, so that project investigators can match their initial responses with their decisions in the later game simulation. Only the aggregated data, including public acceptance rate and changes in individual opinions will be reported anonymously in the IQP report. Initial data will be accessible only to researchers on this project. Records of your participation in this study will be held confidential so far as permitted by law. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of injury: Since the study is of minimal risk, the project researchers expect there are no injuries to the participants, so there is no compensation in the event of injury. You do not give up any of your legal rights by signing this statement.
For more information about this research or about the rights of research participants, or in case of research-related injury, contact: all the group members at gr-gr-autonomousvehiclesbeijingiqp@wpi.edu.. You can also contact the IRB Manager (Ruth

McKeogh, Tel. 508 831- 6699, Email: irb@wpi.edu) and the Human Protection Administrator (Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu).

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

Study Participant Signature:__________________ Date:

Study Participant Name (Please print):__________________

Signature of Person who explained this study: __________________ Date:

Appendix C: Initial Survey Questions for Study Participants

1. What is your gender?
2. What is your age group?
   [18-20, 21-30, 31-40, 41-50, 51-above]
3. Do you have a driver license?
4. Do you own a car?
5. Have you ever been in a car accident?
6. The government policy and regulation of autonomous vehicles will influence your acceptance of autonomous vehicles [strongly disagree, disagree, neutral, agree, strongly agree]
7. The safety aspect of autonomous vehicles will influence your acceptance of autonomous vehicles [strongly disagree, disagree, neutral, agree, strongly agree]
8. The efficiency aspect of autonomous vehicles will influence your acceptance of autonomous vehicles [strongly disagree, disagree, neutral, agree, strongly agree]
9. The economical/environmental aspect of autonomous vehicles will influence your acceptance of autonomous vehicles [strongly disagree, disagree, neutral, agree, strongly agree]
10. There should be specific traffic laws just for autonomous vehicles [strongly disagree, disagree, neutral, agree, strongly agree]
11. Using completely autonomous vehicles should require a driver's license [strongly disagree, disagree, neutral, agree, strongly agree]
12. If an autonomous vehicle violates traffic rules while it is driving completely autonomous, who should be responsible? [Driver, CarCompany, ProgramEngineers, AI]
13. If an autonomous vehicle causes a car accident while it is driving completely autonomously, who should be responsible for the loss and who should be penalized? [Driver, CarCompany, ProgramEngineers, AI]
14. While driving autonomously, should the vehicle prioritize the safety of its passengers, or should it prioritize pedestrians around it?
15. How likely would you accept automated driving technology?
16. Are you willing to travel by autonomous car? (as passenger)

17. Will you buy and drive an autonomous car?
18. Do you accept the following vehicles to be autonomous? (check all that apply) [Taxi, Ambulance, Fire engine, Police car, Bus, School bus, Trucks(shipping), Construction trucks, None of above]
19. Would you accept an autonomous vehicle if it's monitored by a driver?
20. What is the most important factor that will change your mind on deciding to switch to autonomous vehicles? [Regulation, Safety, Efficiency, Economic&Environmental，Cost]
21. What number of portions do you think is an appropriate amount for autonomous cars in a city if they are available? [Under 5%, 5% - 20%, 20% - 50%, 50% - 75%, 75% - 90%, 90%-100%]
22. (Optional) Do you have any other concerns about automated driving technology?
23. IMPORTANT. Please leave the last 4 digits of your phone number to be your username (e.g.2320) for future game playing!!!

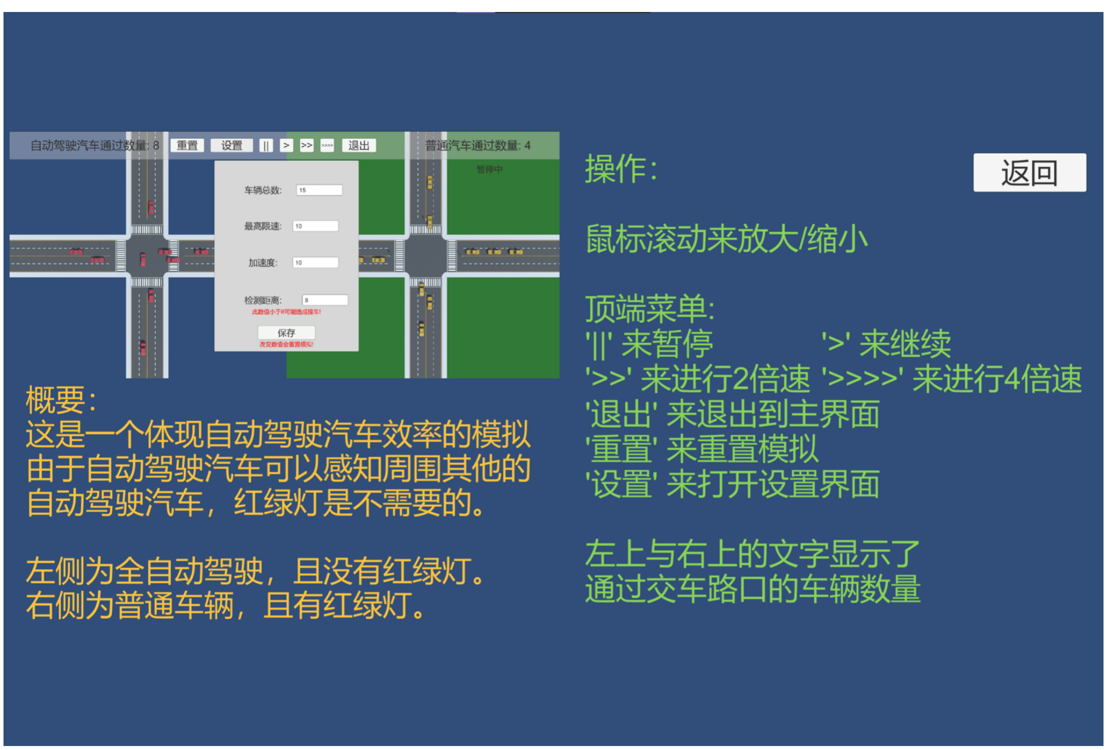
Appendix D: Project Timetable

Stage & Tasks	Week						
	May/June		July				
	0	1	2	3	4	5	6
Stage 1: Benchmark research for general background on public opinion. **Objective 1**: Evaluate current public acceptance rate and general attitudes towards Autonomous Vehicle technologies	Develop, revise, and release the initial survey						
		Analyze current acceptance rate and general attitudes					
Stage 2: Game simulation for knowledge informing and further data collection. **Objective 2**: Design game simulation to inform Autonomous Vehicle related knowledge using engaging scenarios and bring potential attitude changes	Design initial game scenarios						
		Add interactive components					
			Add more information, knowledge, and roles				
				Construct a game world			
Stage 3: Summary for data collected of key stakeholders. **Objective 3**: Summarize data collected to assess general acceptance rate and individual opinions of key stakeholders	Gather initial data						
			Host game trials				
						Compare and summarize data	
IQP Report			Start writing				
				Keep track of progress			
						Finalize	

Appendix E: Game Interface and Instructions

Game Interface

Efficiency Scenario Instructions (in Chinese)



Safety Scenario Instructions (in Chinese)