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Investigating the effects of open versus closed systems on trust in autonomous vehicles

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By

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The goal of this study is to determine if trust in autonomous vehicles is affected by whether the vehicle is being operated in a closed or open system. A PRQF survey method was used to complete this study. The survey contained items to assess pedestrian behavior, personal innovativeness, and receptivity to autonomous vehicles. Scenario questions were also utilized to determine differences in the trust of automated vehicles in open and closed settings. The results from this study indicated increased pedestrian receptivity scores for the closed system (M=14.11, SD=3.78), compared to the open system (M=13.70, SD=3.90). Average trust scores were also increased for the closed system (M=4.68, SD=1.82) compared to the open system (M=4.56, SD=1.85). These results were used to conclude that trust and receptivity of autonomous vehicles were increased for closed systems.

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CHAPTER I

INTRODUCTION

An autonomous vehicle can be defined as a technology-driven vehicle that operates independently by software and hardware instead of a human driver (Deb, Garrison, Rahman, & Strawderman, 2018). According to the NHTSA, driverless vehicles have been referred to as one of the key disruptors in the next technology revolution (Kaur & Rampersad, 2018). The NHTSA and Insurance Institute for Highway Safety made an agreement with 20 automobile manufacturers in 2016 to include automatic emergency braking, a level of automation, as a standard feature in all vehicles by 2022 (Rahman et al., 2018). Additionally, car manufacturers have set a goal to release the fully automated vehicle by 2025 (Nordhoff, de Winter, Kyriakidis, van Arem, & Happee, 2018; De Boeck & Van Meldert, 2016).

Research has proven that there is a significant need for autonomous vehicles. According to Singh (2015), The National Motor Vehicle Crash Causation Survey that was conducted from 2005 to 2007 concluded that 94% of automobile accidents are, on some level, a result of human error. Kyriakidis, Happee, & de Winter (2015) found that current trends indicate that road traffic injuries will become the fifth leading cause of death by 2030 in low and middle-income countries. Automated vehicles remove the human component of driving and therefore remove human error, drastically improving the safety of roadways across the world (United States Department of Transportation National Highway Traffic Safety Administration, n.d.). According to the NHSTA, “when you consider more than 35,092 people died in motor vehicle-related crashes in the U.S. in 2015, you begin to grasp the lifesaving benefits of driver assistance technologies," (United States Department of Transportation National Highway Traffic Safety Administration, n.d., para 5).

Human safety is an important advantage of autonomous vehicles, but there are also other benefits to be derived from this technology. Automated vehicles can reduce physical and mental stress for drivers by taking the responsibility of the driving task away (Deb et al., 2018). They can also reduce fuel consumption through optimized driving functions (Keen, 2013). Additionally, there are economic and societal benefits to driverless vehicles. According to the NHTSA, motor vehicle crashes in 2010 cost $242 billion. If automated vehicles decrease the majority of traffic accidents, they will also virtually eliminate these costs (NHTSA, n.d.). The same article states, "Americans spent an estimated 6.9 billion hours in traffic delays in 2014." With the use of automated vehicles, the time spent commuting could be put to a different use, as the driving task no longer requires the full attention of the vehicle's occupant. This could free up as much as 50 minutes a day for drivers (NHTSA, n.d.).

Drivers are not the only road users who can benefit from autonomous vehicle technologies. According to Karsch, Hedlund, Tison, and Leaf (2012), around 60% of pedestrians do not trust that drivers of vehicles will respond appropriately towards them. Deb et al. (2017) state that pedestrians face great danger on roads and are one of the most vulnerable groups of road users. Automated vehicles can potentially increase safety for pedestrians because of their ability to sense the external environment and make judgements about the most appropriate action for the vehicle to take (Deb et al., 2017). This could be a safer option for drivers who are distracted and do not see pedestrians or for situations in which the driver does not have appropriate time to respond to a pedestrian in the road.

Although automated vehicles can improve safety, benefit the environment, and save money and time, this is only possible if drivers recognize the worth of these vehicles and integrate them into their lives (Rahman, Lesch, Horrey, & Strawderman, 2017). Therefore, driver acceptance is necessary for successful implementation of these technologies (Rahman et al., 2017). Trust in the technology is critical to elicit driver acceptance (Hutson, 2017; Kaur & Rampersad, 2018; Deb et al., 2018; Choi & Ji, 2015). According to "A Matter of Trust," distrust of the technology could be one of the biggest barriers to the adoption of autonomous vehicles (Hutson, 2017). Jack Weast, the chief systems architect of Intel's autonomous driving group in Phoenix, said "we could have the safest car in the world, but if consumers don't want to put their kids into it, then there's no market," (Hutson, 2017, p. 1375). Furthermore, in a survey by AAA, 78% of respondents stated they were afraid to ride in an autonomous vehicle (Hutson, 2017).

To successfully implement autonomous vehicles, researchers must understand the factors necessary to cultivate trust in these technologies. Kaur & Rampersad (2018) use a definition that describes trust as "one's willingness to place himself/herself in a vulnerable position, with respect to a technology, with a positive expectation of an outcome or a positive nature of future behavior," (p. 90). Choi and Ji (2015) believe that trust mediates the relationship between humans and automation, making it a major determinant of reliance and acceptance of automation along with personal beliefs and intentions to use the technology. According to "Investigating the importance of trust on adopting autonomous vehicles," researchers believe that trust has three dimensions: the belief that the system is predictable and understandable, that the system performs tasks accurately, and that the system provides adequate assistance (Choi & Ji, 2015). For users to achieve these levels of trust, they must have adequate knowledge of the system's functions, benefits, and limitations. Educating the public about the benefits and capabilities of driverless vehicles can allow users to attain a better understanding of autonomous vehicles (Hutson, 2017). Drivers and pedestrians alike must understand and trust that the vehicle can perform as expected, but they must not overestimate the vehicle's abilities, as this can result in dangerous conditions for the users. Overestimation is an issue in perceptions of autonomous vehicles. Walker, Boelhouwer, Alkim, Verwey, & Martens (2018) performed a study on trust in autonomous vehicles and found that most of the participants' initial trust scores indicated an overestimation of the vehicle's abilities. To combat this, Hutson uses the term calibrated trust which is described as trusting the vehicles with respect to the things it is good at but not trusting it with things it is not good at (2017). Not only must users trust these vehicles, but more specifically they must demonstrate calibrated trust before automated vehicles can be safely incorporated into society. Users must also understand the functions of the automated vehicle. According to Bertram Malle, a psychologist at Brown University, "understanding why the vehicle is doing what it is doing will be a critical factor in trust and acceptance," (Hutson, 2017, p. 1376). Designers of the technologies must carefully consider autonomous vehicle limitations to ensure the safety of its users and, therefore, increase trust (Deb et al., 2018).

One trust-building technology that is being implemented into automated vehicles is the anthropomorphism of its features (Dimitrakopoulos & Panagiotopoulos, 2018). Researchers have stated that human-like appearances of the vehicle can enhance trust (Lee, Kim, Lee, & Shin, 2015; Ruijten, Terken, & Chandramouli, 2018). Google utilized this feature by designing the front of the google car to resemble a human face (Ruijten et al., 2018). Other autonomous vehicles are being equipped with a voice, enabling them to audibly communicate with passengers (Hutson, 2017). In 2017, Intel completed a study to evaluate the effectiveness of this feature by placing riders in a simulated automated vehicle scenario. One rider said, "when it said 'Hello,' that one thing gave it enough personality for me to trust it," (Hutson, 2017, p. 1376). The same study also concluded that giving riders some control over the car's behavior can elicit trust. This is reiterated in an Accenture survey conducted in 2011 that concluded that giving up control of the vehicle is an apprehension among potential users, and the users were relieved to have the ability to take back control (Dimitrakopoulos & Panagiotopoulos, 2018). Giving control to the drivers and providing human features to the vehicle are some of the factors that can improve trust in automated vehicles. According to Choi & Ji (2015), "although the importance of the concept of trust between humans and machines has been stated in much of the research, it has yet to be systematically studied in autonomous vehicle domain," (p. 692). Therefore, there is a need for more research on the subject of trust in autonomous vehicles to elicit other factors that could potentially improve trust and that need to be considered when manufacturing these vehicles. Kyriakidis et al. (2015) wrote, "in conclusion, there appears to be a market for automated driving technologies, but one has to acknowledge that a part of the population is reluctant against such technology" (p. 138).

CHAPTER II

BACKGROUND

2.1 TAM

One of the tools used to measure trust and acceptance of technologies is the technology acceptance model (TAM). TAM was developed in 1989 and uses the term ‘acceptance’ to refer to the decision to use technology (Kaur & Rampersad, 2018). TAM explores the reasons behind the adoption of technologies by examining behavioral intentions of the users and the attitudes that influence this behavior (Kaur & Rampersad, 2018). In this model, attitude is defined as “the emotional state toward using a technology” (Rahman et al., 2017). According to Choi and Ji (2015), TAM breaks down the concept of attitude towards behavior into two beliefs: perceived ease of use and perceived usefulness. In the technology acceptance model, a positive attitude and high perceived usefulness cultivate a high intention to use technology which likely results in the eventual use of it (Rahman et al., 2017).

2.2 PRQF

There are also methods to study pedestrian behavior and receptivity to automated vehicles. Diaz developed a pedestrian behavior questionnaire, or PBQ, that consists of 16 items to assess factors influencing pedestrian behaviors (Deb et al., 2018). However, this method does not apply specifically to behaviors and attitudes about autonomous vehicles (Deb et al., 2018). Because of the lack of an appropriate method to survey pedestrians about autonomous vehicles, Deb et al. (2018) developed the PRQF scale. The PRQF is a questionnaire of pedestrian receptivity towards fully automated vehicles that builds on the PBQ. The PRQF takes into consideration the specific factors that affect pedestrian interactions with autonomous vehicles. According to "Development and validation of a questionnaire to assess pedestrian receptivity toward fully autonomous vehicles," "the PRQF scale includes five items based on attitude, three based on social norm, three for trust, two items related to compatibility, two for system effectiveness, and one shared item between compatibility and system effectiveness," (Deb et al., 2017, p. 182). A higher score on the scale represents higher receptivity towards fully automated vehicles. The PRQF uses the concept that receptivity to autonomous vehicles is displayed by a person's willingness to interact with the technology. This is different from acceptance to autonomous vehicles, as acceptance is displayed by a person's willingness to use the technology (Deb et al., 2017). Receptivity and acceptance to autonomous vehicles also differ from trust. Using Kaur and Rampersad's definition (2018), trust builds on the concepts of receptivity and acceptance, as trust is one's willingness to place himself or herself in a vulnerable position with respect to the technology, having a positive expectation of the outcome. A user must first be receptive to autonomous vehicles, or willing to interact with the technology, in order to trust it. Therefore, the PRQF will be used in this paper to study receptivity to autonomous vehicles as a precursor to trust.

2.3 Factors influencing trust and acceptance of autonomous vehicles

A literature review was completed to determine factors that have been found to influence trust in autonomous vehicles. Some of these factors include anthropomorphic features of the vehicle, personal characteristics of the user, environmental applications, and performance of the autonomous system. These elements are discussed in detail below.

2.3.1 Anthropomorphic design features

As stated earlier, anthropomorphic features such as the human-like face of the google car have been found to establish trust in autonomous vehicles (Haeuslschmid, Buelow, Pfleging, & Butz, 2017; Hutson, 2017). There is also a need to evaluate whether trust is affected by the presence of a passenger in the driver seat versus a completely driverless vehicle. Deb et al. (2018) stated that some pedestrians may want to interact with the passenger instead of the vehicle when crossing the road to determine if it is safe to cross. This is because there is currently a use of informal communication between pedestrians and drivers at crosswalks such as eye contact, facial expressions, and hand gestures (Deb et al., 2018). Some pedestrians may find it difficult to trust and interact with technology without the use of these forms of communication (Deb et al., 2018). Another application of anthropomorphic features is a name, gender, and voice for the vehicle. As stated earlier, Ruijten et al. (2018) also found that people liked and trusted the autonomous vehicle more with these features.

2.3.2 Personal characteristics of the user

In reference to the experience of the interaction itself, personal factors of the user as well as environmental factors can influence trust (Dimitrakopoulos & Panagiotopoulos, 2018). Studies have been conducted that concluded that men are more likely to accept autonomous vehicles than women (Kyriakidis et al., 2015). However, age of the user can also be evaluated to determine if it has an impact on trust. Another important factor is the knowledge of the system and previous experience with autonomous vehicles. According to Khastgir, Birrell, Dhadyalla, & Jennings (2018), it was concluded that "with the introduction of knowledge about the true capabilities and limitations of the automated system, trust in the automated system increased as compared to when no knowledge was provided about the system," (p. 290). The idea that experience with autonomous vehicles has a significant impact on trust is an issue, considering most drivers have not yet experienced automated vehicles (Haeuslschmid et al., 2017). Choi and Ji (2015) also concluded that locus of control influences the driver of an autonomous vehicle. Locus of control can be referred to as a personality trait that defines the extent to which a person believes to be in control of external events (Choi & Ji, 2015). According to Choi and Ji (2015), "someone with an internal locus of control believes he or she can control events, whereas those who do not believe so have an external locus of control," (p. 694). The authors go on to say, "people with an external locus of control tend to believe that humans will always cause accidents and hence that an automated driving system would be far better than human drivers," (Choi and Ji, 2015, p. 694). This factor can be used to study trust in an autonomous vehicle. If the user believes humans cause accidents, then they are more likely to trust an autonomous vehicle over a human driver.

2.3.3 Environmental factors

Environmental factors can also affect trust in autonomous vehicles. One application of this is urban versus rural areas. A study by Nordhoff et al. (2018) indicated that living in a city and frequent use of public transportation have a positive correlation with autonomous vehicle acceptance. This poses the idea that residents of urban cities will have higher acceptance and trust rates for this technology. However, De Boeck and Van Meldert (2016) state that autonomous vehicle technology will most likely be implemented on highways before city streets, because the highway environment is considered to be more predictable and less complex than city environments. There is a need to increase trust and acceptance for drivers in these highway settings. Another environmental factor is sociodemographic status. Nordhoff et al. (2018) concluded that low-income countries suffer from more transport-related problems than higher income countries, indicating the possibility of higher acceptance rates in these countries. However, they also stated, "sociodemographic characteristics are less influential than domain-specific attitudes (e.g., performance expectancy) in predicting self-reported acceptance of driverless vehicles," (Nordhoff et al., 2018, p. 19).

Another application of environmental factors is closed versus open systems. According to Kaur and Rampersad (2018), driverless vehicles will not be mainstream on the majority of roads in the immediate future, rather, their adoption settings will first be in closed environments like university campuses, golf courses, airports, and holiday parks. This identifies the need to determine if users will be more or less trusting of autonomous vehicles in these settings. According to Kaur and Rampersad (2018), there is a gap in research on the specific groups and situations when people will most likely adopt the technology. Specifically, the authors bring up the point that little research has been done on whether people would be willing to use driverless vehicles for public transportation even though this will most likely be the first application of this technology. The same study sought to bridge this gap using a survey distributed to people on a university campus. The study concluded that some situations in which people are more likely to adopt driverless vehicles include closed environments, public transport with a chaperone, and highways where drivers have the option to take full control (Kaur & Rampersad, 2018). This reiterates the belief that people are more trusting of driverless vehicles when they can take control of them, but there is still a need to place more emphasis on the impact of closed versus open systems and public transportation versus passenger driving on the trust of autonomous vehicles.

Another feature of autonomy that has been shown to affect trust is the process the autonomy is being used for, namely controlled logistics environments versus passenger applications. De Boeck and Van Meldert (2016) believe autonomous vehicles may be adopted sooner in logistics settings than in passenger transport. According to the authors, "operating AVs in controlled settings such as warehouses, production plants or harbors, and remote outdoor locations is significantly easier than in the complex setting of urban traffic," (De Boeck & Van Meldert, 2016, p. 8-9). Besides being less complex, logistics settings are subject to fewer laws and regulations, which enables easier adoption (De Boeck & Van Meldert, 2016). Another reason these settings may be preferred is because the liability issue that is present with autonomous vehicles would potentially be less severe since goods are being transported instead of people (De Boeck & Van Meldert, 2016). Because it is seemingly easier to implement autonomous vehicles in logistics settings, current technological advancements are aimed at bringing autonomous vehicles out of these controlled settings and into everyday traffic environments. The reason for bringing this automation into everyday traffic is because the same advantages apply as in the indoor settings. Autonomous vehicles can eliminate human error, improve reliability and accuracy of the driving task, and reduce fuel consumption and costs (De Boeck & Van Meldert, 2016). Because autonomy is more widely adopted in logistics settings, it remains to be studied if the level of trust changes when this technology is brought outside of this environment.

2.3.4 System Performance

System performance is also a key indicator of trust. According to Deb et al. (2018), trust varies as a function of the effectiveness of technology. Deb et al. state, "there is a decline in trust when there is a defect in the automation," (2018, p. 284). The same study also concluded that a negative experience with defective technology results in negative expectations of the technology. A study by Continental AG indicated that 54% of respondents stated that they do not believe autonomous vehicles will function reliably (Kyriakidis et al., 2015). Deb et al. (2018) refer to the process of introducing a new technology, specifically autonomous vehicles, into the market, "the main obstacles in achieving a place in the market include not only technology issues, but also the lack of potential customer trust in them," (p. 280). This indicates the importance of system effectiveness in the study of automation trust. The autonomous vehicle must work as it is designed and be compatible in the applied environment for users to be trusting of it (Deb et al., 2018).

2.4 Conclusion

Autonomous features are on the way to becoming a standard for vehicles in the U.S. (Rahman et al., 2017). Autonomous vehicles are favored by automobile manufacturers for their promise of safety and efficiency, but this must be understood and accepted by the potential users of the technology for successful implementation. There are currently many drivers who do not trust this technology, and there are even some who fear it (Kyriakidis et al., 2015). No matter how safe these vehicles are, if people are afraid to use them, the benefits of this innovative technology may not be fully realized by society. Therefore, there is a need for further research examining trust in autonomous vehicles and uncovering factors that may improve trust for consumers. These factors can then be considered in autonomous vehicle manufacturing and assimilation into applicable environments to ease the transition for users. According to Kaur and Rampersad (2018), “there are certain situations in which users may be more willing to adopt driverless cars, compared to others. Further research in understanding the scenarios when users are most willing to adopt driverless cars will assist in early implementation programs among adopting target groups and settings,” (p. 87-88).

CHAPTER III

RESEARCH QUESTION

The goal of this study was to investigate factors that influence trust in autonomous vehicles. Though all of the factors mentioned above could be studied in reference to their effects on autonomous vehicle perceptions, this study focused on one factor in order to have a well-defined scope. The environmental factor of open versus closed systems was evaluated because it poses a significant contribution to current research. For the purpose of this study, a system was defined in terms of its accessibility. An open system is easily accessible to a broad group of people. In contrast, a closed system is only accessible to certain groups of people and vehicles. A closed system eliminates many variables that are present in an open system, one of those being training or experience level. There is a level of training that is assumed to be involved with a closed system as opposed to a broad, open one. Examples of closed systems where autonomous vehicles could be incorporated include university settings, golf courses, airports, or company warehouses. Open systems can refer to highways or roadways. Specifically, the research question for this study was to determine if trust in autonomous vehicles is affected by whether the vehicle is being operated in a closed or open system. The goal was to evaluate trust specifically from a pedestrian perspective as opposed to a general audience.

CHAPTER IV

METHOD

4.1 Experimental Design

The independent variable for this study was system type (general, open, or closed). The dependent variable was trust. Trust was measured in three ways: scenario question one, scenario question two, and the pedestrian receptivity questionnaire. Scenario question two was the most important trust measure, because it explicitly asked participants to rate their level of trust in the vehicle. However, this question alone was not adequate to measure trust because some participants may not know how to report their feelings of trust using a single rating. Therefore, another scenario question was asked to determine how a participant would respond to the vehicle. As trust elicits certain behaviors, we would expect varying trust levels to become apparent in varying reported responses. The behavior question (scenario question one) was used to provide an indirect measurement of trust. Lastly, the receptivity questionnaire measures receptivity to autonomous vehicles. It was an important addition to this study because receptivity indicates a participant's willingness to interact with the technology. A participant must be willing to interact with autonomous vehicles before they can develop trust in them. Therefore, receptivity was a pertinent factor that was used to examine trust in this study.

4.2 Survey

A survey (see Appendix A) was administered to participants via Amazon Mechanical Turk. Participants indicated their consent to participate in the survey after reading a description of its purpose and choosing to participate. The survey began with seven demographics questions to determine gender, age, education, race, and other applicable background questions. The PRQF survey was adapted from a study by Deb et al. (2017) and used to elicit information about participants' beliefs about autonomous vehicles. The first section consisted of a 20-item pedestrian behavior questionnaire. The next section contained 16 items to assess pedestrian receptivity to fully autonomous vehicles and four items to assess personal innovativeness. These questions were followed by a scenario that allowed users to envision themselves in an environment with the autonomous vehicle. There were two questions following the scenario. The first question assessed the participant's response to the autonomous vehicle. The second assessed their level of trust in the vehicle. The first scenario described an autonomous vehicle in a general setting. It is not specified to be an open or closed environment. This scenario was included to compare results to that of the open and closed environments to determine if there are changes in participants' responses from general to open or closed. The first scenario included the following description, "You are taking a walk. On your way, you need to cross multiple crosswalks, both signalized and unsignalized. As you prepare to cross at an un-signalized crosswalk, you find that a driverless vehicle is approaching the crosswalk (with no one sitting in the driver seat). Based on the scenario, please select the choice that best reflects your behavior for each question." The first question asked about behavior in response to the autonomous vehicle in the scenario, "What will your response at the crosswalk be, with the FAV approaching?" The second question asked participants to rate their trust in the vehicle described in the scenario, "Please rate your level of agreement with the following statement: I will trust the vehicle in the scenario."

After completing the first scenario, the participants completed the second scenario. The second scenario consisted of an introduction to autonomous vehicles in the applied setting (either open or closed) followed by a pedestrian receptivity questionnaire. Then, participants read either an open or closed scenario description, followed by the same questions that were asked of the general scenario (one for response to the vehicle and one for trust in the vehicle). The open setting included the following introduction "Consider a fully autonomous vehicle operating in an open system. Examples of open systems could be a downtown city street or the streets of your hometown. The environment is open to all vehicles and pedestrians. The driverless vehicle is interacting with other drivers, pedestrians, bicycles, and is operating under existing traffic laws. Answer the following questions based on this type of environment." After completing the pedestrian receptivity questionnaire, participants read the open scenario, "You are walking downtown. On your way, you need to cross multiple crosswalks, both signalized and unsignalized. As you prepare to cross at an un-signalized crosswalk, you find that a driverless vehicle is approaching the crosswalk (with no one sitting in the driver seat). Based on the scenario, please select the choice that best reflects your behavior for each question." Participants then answered the scenario questions.

The closed system began with the following introduction, "Consider a driverless vehicle operating in a closed system. A closed system is an environment with limited access. An example of a closed system could be a company campus where only certain people can access roads and vehicles must have permission to drive on them. Answer the following questions based on this type of environment." Participants then took the pedestrian receptivity questionnaire for the closed scenario. After this, participants read the following description for the closed scenario, "You are walking across your company campus. On your way, you need to cross multiple crosswalks, both signalized and unsignalized. As you prepare to cross at an un-signalized crosswalk, you find that a driverless vehicle is approaching the crosswalk (with no one sitting in the driver seat). Based on the scenario, please select the choice that best reflects your behavior for each question."

Each participant only answered questions for one of the scenarios: either open or closed. The chosen scenario was randomized for the participants, ensuring that approximately half of the participants completed the open scenario and the other half completed the closed scenario. After completing the survey, participants were given an Amazon Mechanical Turk code to use for compensation for their participation in the survey. The flow of the survey is described Figure 4.1. The entire survey is attached in appendices A and B of this report.

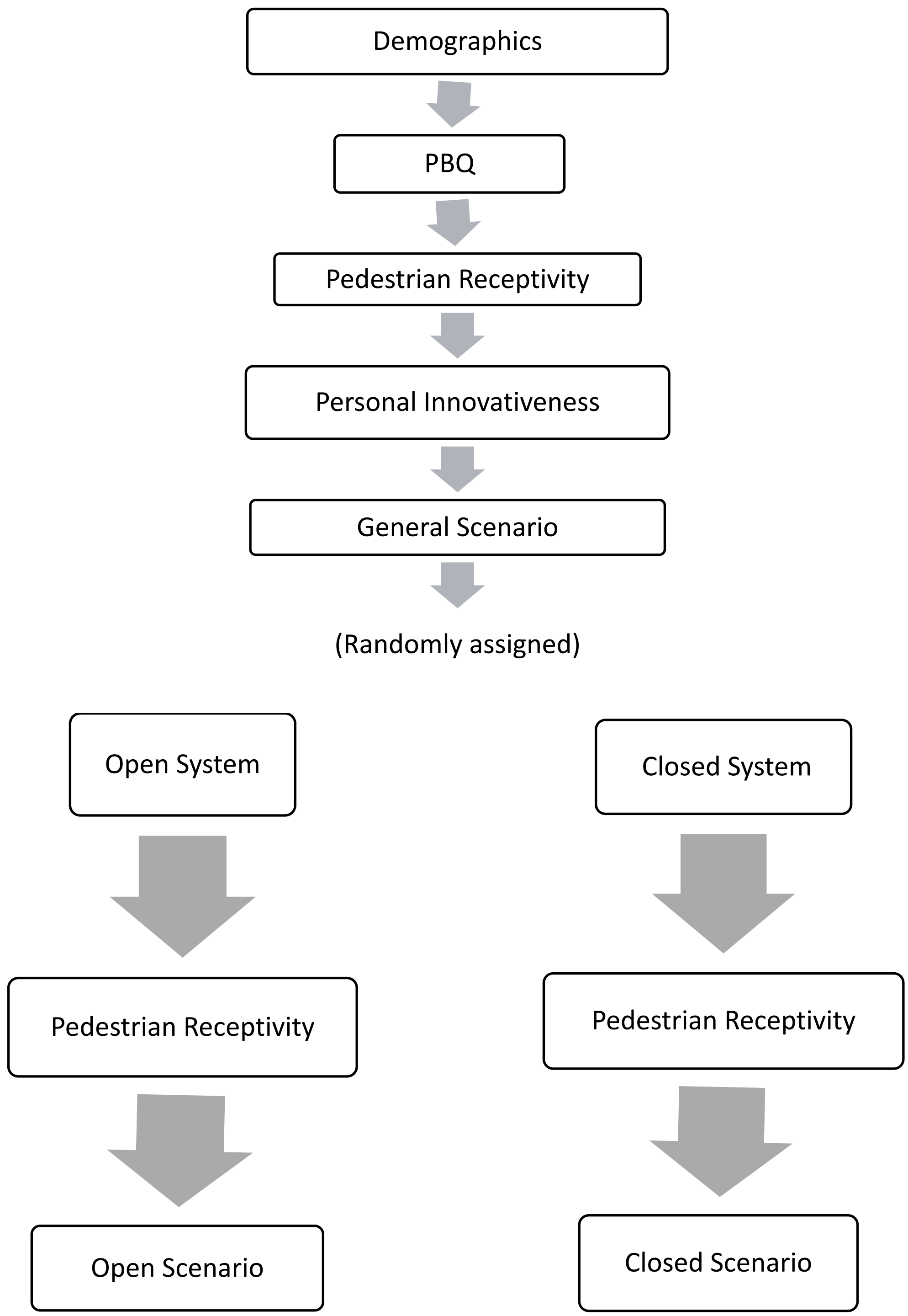

Figure 4.1 Survey Flow

4.3 Hypotheses

Hypothesis 1. Trust will be higher for closed systems. Supported by research from Kaur and Rampersad (2018), it is expected that participants will be more trusting of an autonomous vehicle if it is being operated in a controlled environment as opposed to a noncontrolled environment. Furthermore, a closed system will elicit higher trust scores because it contains fewer variables than an open system, and more training is required to access the system.

Hypothesis 2. Trust will increase as personal innovativeness increases. The more experience a participant has with technology, the more likely they are to accept and trust autonomous vehicle technology. This concept is supported by research from Khastgir et al. (2018) stating that knowledge of the system increases trust in autonomous vehicles. Applied to this study, increased personal innovativeness scores indicate deeper knowledge of technology. This technological knowledge will subsequently transfer to autonomous vehicle technology to result in increased trust scores.

Hypothesis 3. Trust will be higher for participants who have a high general pedestrian receptivity score. Participants who indicate a high receptivity to autonomous vehicles will be more likely to trust the vehicles described in the scenarios in the survey. Receptivity is the willingness to interact with a technology (Deb et al., 2017), while trust is the willingness to place oneself in a vulnerable position with respect to technology with a positive expectation of the outcome (Kaur and Rampersad, 2018). Therefore, receptivity is a necessary precursor to trust. If participants indicate receptivity to autonomous vehicles, they may be more likely to trust the vehicles as well.

4.4 Participants

This study was approved by Mississippi State's Institutional Review Board prior to beginning. The survey was assembled on Qualtrics and posted on Amazon's Mechanical Turk service as a work task. In order to complete the survey, participants were required to be U.S. residents aged 18 and older who are members of Amazon Mechanical Turk. There were no other inclusion or exclusion criteria for survey participation. Participants indicated consent to complete the study after reading a description and choosing to participate in the survey. Participants were compensated for completing the survey. A total of 442 people participated in the survey. A check question was included in the survey to confirm that participants were reading the questions and providing accurate responses. Forty-three of those responses were not included in the analysis because they failed an attention check question. Therefore, 399 responses were used in subsequent analyses. Of the total sample size of 399 participants, 201 responded to the open scenario and 198 responded to the closed scenario.

CHAPTER V

DATA COLLECTION AND RESULTS

5.1 Data Preparation

The responses from the survey were exported to Excel to begin analysis. First, the data was cleaned and coded. The responses that failed a check question were removed. Some of the items were reverse-coded to maintain consistency in the results.

After coding the responses, the scores were calculated for the various questionnaires included in the survey. The methods used to calculate the scores for this survey were drawn from a study performed by Deb et al. (2017). To calculate the PBQ score, the responses were divided into subscales. The subscales are indicated by their headings in the survey, with questions 1-4 indicating violations, questions 5-8 indicating errors, questions 9-12 indicating lapses, questions 13-16 indicating aggressive behavior, and questions 17-20 indicating positive behavior. These subscale scores were calculated by averaging the items in each category to create a score for each subscale. These items were then added together to create the total PBQ score. There were five subscales for the PBQ, so possible scores ranged from 5 to 30. For the pedestrian receptivity questionnaire, there were three subscales: safety, interaction, and compatibility. The safety category included questions 1, 2, 8, and 11. The interaction category included questions 3, 4, 5, 6, 7, 12, 13, 14. The compatibility category included questions 15, 16, 17. These subscales scores were calculated by averaging the items in each category to create a score for each subscale, just like what was done for the PBQ. These items were then added together to create the total PRQ score. Possible scores for the PRQ ranged from 3 to 21. These steps were completed three times to calculate the general PRQ, open PRQ, and closed PRQ scores. In order to calculate the personal innovativeness score, the responses for the four items in the personal innovativeness questionnaire were averaged together to create a total score. The possible scores for the personal innovativeness questionnaire ranged from 1 to 7.

After calculating the scores, the data was reduced to 17 variables. These variables included the demographics questions, total scores for the PBQ, receptivity (PRQ), and innovativeness, as well as the scenario responses. There was missing data for the scenario responses since half of the participants answered each scenario, so these responses were consolidated into a single variable, known as "second." The second item represented the second scenario participants viewed in the survey which was either open or closed. Lastly, a variable was added to distinguish these "second" responses between open and closed. The list of variables is described in detail in Table 5.1.

Table 5.1 List of final variables and descriptions

Variable Name	Description
Participant Number	Participant identification
Age	Participant age
Gender	Participant gender
Education	Participant education level
Walk	Participant walk frequency
Walk Time	Participant walk time
State	Participant state of residence
Urban v Rural	Participant identification of living area
PBQ Total Score	Pedestrian Behavior Questionnaire total score
Innovativeness Total Score	Personal Innovativeness Questionnaire total score
General PRQ Total Score	Pedestrian Receptivity Questionnaire total score
General Behavior	General Scenario question 1, "What will your response at the crosswalk be, with the FAV approaching?"
General Trust	General Scenario question 2, "Please rate your level of agreement with the following statement: I will trust the vehicle in the scenario."
Second Behavior	Second scenario participants viewed (either open or closed) behavior question. Responses from the open and closed scenarios were stacked into one column to create this variable.
Second Trust	Second scenario participants viewed (either open or closed) trust question. Responses from the open and closed scenarios were stacked into one column to create this variable.
Second PRQ Total Score	Second Pedestrian Receptivity Questionnaire total score (either open or closed). Responses were stacked into one column to create this variable.
Open_Closed	Identifies whether participants completed the open or closed scenario (1=open, 2=closed)

5.2 Results

5.2.1 Descriptive summaries

After cleaning and coding the responses and calculating the scores, the data was imported to SPSS to begin analysis. First, a set of descriptive summaries were obtained. In terms of the participants of the study, the mean age was 34 with a standard deviation of 10 years. The majority of participants (67.9%) were male. Most of the participants had an associate's or bachelor's degree (52.6%). Participants were asked how often they walk in a day. The most frequently reported answer (41.6%) was that participants walk often, or two to four times a day. The second most reported answer (34.1%) was that participants walk rarely, or 0-2 times a day. Of this walking frequency, 38.1% of participants stated that they typically walk 15-30 minutes a day. The majority of respondents (78.7%) reported that they live in an urban area, which was defined as a place with an overall population density of at least 500 people per square mile.

In Table 5.2, the means and standard deviations were listed for the PBQ, personal innovativeness questionnaire, and the three PRQ's. As discussed previously, a high PBQ score indicated adverse pedestrian behavior. The average score for the respondents was in the middle of the scale (*M*=11.66, *SD*=5.04), indicating standard pedestrian risk-taking behavior. The personal innovativeness scores were fairly high (*M*=5.08, *SD*=1.17), which shows that the participants were innovative. The results for the general PRQF (*M*=13.69, *SD*=3.74) and the open PRQ (*M*=13.70, *SD*=3.90) were not much different. However, the closed PRQ average score had the highest numerical value, indicating high receptivity to autonomous vehicles (*M*=14.11, *SD*=3.78).

Table 5.2 Descriptive Statistics for Questionnaire Scores (PBQ, PRQF, Innovativeness)

	N	Min	Max	Mean	SD
Pedestrian Behavior Questionnaire (PBQ)	399	5.00	24.00	11.66	5.04
Personal Innovativeness	399	1.00	7.00	5.08	1.17
General Pedestrian Receptivity (PRQ)	399	3.00	21.00	13.69	3.74
Open Scenario PRQ	201	3.00	21.00	13.70	3.90
Closed Scenario PRQ	198	3.75	21.00	14.11	3.78

Table 5.3 describes the frequencies in percentages of the answer choices for the behavior question for all three scenarios. In all three scenarios, when participants were asked about their response at the crosswalk with the FAV approaching, the most reported answer was "I will make sure that the driverless vehicle stops before I start crossing" (General: 43.9%, Open: 33.8%,

Closed: 44.4%). The least reported answer for all three scenarios was “I will stand in front of the vehicle because I know it will not hurt me” (General: 0.8%, Open: 1.0%, Closed: 0.5%). This answer choice was included to test for over-trust in the autonomous vehicle. Most of the participants of this study were not over-trusting of the autonomous vehicle described in the scenario, as they would not stand in front of it. The mean responses were the same for the open and closed scenarios, and they both had slightly higher values than the general scenario. The higher values indicated more trusting behavior around autonomous vehicles. Therefore, these results can be used to conclude that participant behaviors were slightly more trusting for the open and closed scenarios as opposed to the general scenario, possibly due to an order effect or the additional detail included in the second scenario.

Table 5.4 describes the frequencies in percentages of the answer choices for the trust question for all three scenarios. When participants were asked about their trust in the vehicle described in the scenario, the most reported response for the general scenario was “somewhat agree” (28.1%). However, for the open and closed scenarios, the most reported response was the same for both scenarios, “moderately agree” (Open: 24.9%, Closed: 24.7%). This indicated an increase in trust for the open and closed scenarios as opposed to the general scenario. The least reported response was the same for all three scenarios, “moderately disagree” (General: 8.0%, Open: 5.5%, Closed: 7.6%). For the closed scenario, the least reported response was tied between “moderately disagree” and “somewhat disagree,” with both responses showing a frequency of 7.6%. The mean response for the closed scenario was numerically greater than that of the open and general scenarios. Because a greater mean value indicates more trust, this finding can be used to conclude that participants were generally more trusting of the autonomous vehicle in the closed system.

Table 5.3 Percentages of responses to Scenario Question 1 ("What will your response at the crosswalk be, with the FAV approaching?")

	General Scenario (N=399)	**Open Scenario** (N=201)	**Closed Scenario** (N=198)
1. I will not cross the road at the crosswalk to avoid crossing in front of the FAV.	23.6%	23.9%	21.2%
2. I will run across the road even though the driverless vehicle has stopped for me.	7.3%	7.5%	4.5%
3. I will make sure that the driverless vehicle stops before I start crossing.	43.9%	33.8%	44.4%
4. I will wait to see if the vehicle decelerates before I start crossing.	19.5%	25.9%	23.2%
5. I will cross the road with full confidence that the driverless vehicle will stop for me.	5.0%	8.0%	6.1%
6. I will stand in front of the vehicle because I know it will not hurt me.	0.8%	1.0%	0.5%
Mean (SD)	2.77(1.20)	2.90(1.30)	2.90(1.19)

Table 5.4 Percentages of responses to Scenario Question 2 ("Please rate your level of agreement with the following statement: I will trust the vehicle in the scenario.")

	General Scenario (N=399)	**Open Scenario** (N=201)	**Closed Scenario** (N=198)
1. Strongly disagree	8.5%	10.9%	9.1%
2. Moderately disagree	8.0%	5.5%	7.6%
3. Somewhat disagree	10.0%	11.4%	7.6%
4. Neutral (neither disagree or agree)	10.8%	11.4%	12.1%
5. Somewhat agree	28.1%	22.9%	24.2%
6. Moderately agree	22.8%	24.9%	24.7%
7. Strongly Agree	11.8%	12.9%	14.6%
Mean(SD)	4.57(1.77)	4.56(1.85)	4.68(1.82)

5.2.2 Inferential analysis results

Repeated measures ANOVA was used to compare the results for the general scenario to that of the open and closed scenarios. Scenario type was set as the within subjects variable (general scenario or second scenario) and system type was set as the between subjects variable (open or closed). Repeated measures ANOVA was used to evaluate differences in responses to behavior, trust, and PRQ scores.

For behavior, there was a significant difference between the general scenario (*M*=2.77, *SD*=1.20) and the second scenario participants viewed (*M*=2.90, *SD*=1.25), indicating a significant main effect ($F(1, 1)=6.85$, $p=0.009$) with participants rating question 1 higher on the second scenario. A higher rating for the behavior question indicated more trusting behavior, as the responses increased numerically from the least trusting behavior, 1: "I will not cross the road at the crosswalk to avoid crossing in front of the FAV," to the most trusting behavior, 6: "I will stand in front of the vehicle because I know it will not hurt me." However, there was not a significant difference between the general scenario and the open/closed scenario ($F(1,1)=0.01$, $p=0.942$). Therefore, there was a difference between the general scenario and the non-general scenario, but that difference was not affected by the open/closed factor.

For trust, there was not a significant main effect difference between the general scenario and the second scenario ($F(1,1)=1.21$, $p=0.272$). However, there was a significant interaction effect between the general scenario and the open/closed scenario ($F(1,1)=2.88$, $p=0.090$), with the change in closed scenario scores being greater than the change in open scenario scores (Closed $\Delta\overline{x}= 0.12$, Open $\Delta\overline{x}=-0.03$). This indicated a significant change in how participants responded based on whether they viewed the open or closed scenario. Similarly to behavior, a higher response for trust also indicated more trusting behavior, as the responses increased numerically from the least trusting response, 1: "moderately disagree," to the most trusting response, 7: "strongly agree."

There was a significant difference between the general receptivity score (*M*=13.69, *SD*=3.74) and the second receptivity score (*M*=13.90, *SD*=3.84), indicating a significant main effect ($F(1,1)=7.95$, $p=0.005$), with second receptivity scores being higher than general receptivity scores. Higher receptivity scores indicated that participants were more willing to interact with the autonomous vehicles. There was also a significant interaction difference between the general receptivity score and whether the participants took the open or closed receptivity questionnaire ($F(1,1)=3.56$, $p=0.060$), with the change in closed receptivity scores being greater than change in open receptivity scores (Closed $\Delta\overline{x}=0.36$, Open $\Delta\overline{x}=0.07$). This means the open or closed scenario had an effect on the receptivity responses.

To determine whether participant's stated behavior was different based on if they viewed open or closed scenarios, a Chi-Square test was completed on the behavior question. According to this analysis, there was not a significant difference between participants' behavior based on whether the scenario was open or closed ($\chi^2(6, N=399)=5.71$, $p=0.335$).

A Chi-Square test was also completed to determine whether participants' trust changed based on the open and closed scenarios, using the responses for the trust question. According to this analysis, there was not a significant difference between participant's trust scores based on whether the scenario was open or closed ($\chi^2(5, N=399)=2.92$, $p=0.819$).

A bivariate Spearman correlation with a two-tailed significance level was completed on a number of variables. The first compared the personal innovativeness total score to the general trust question. This was done to test the hypothesis that trust would increase as personal innovativeness increased. The results from this analysis showed that the two variables had a weak positive correlation ($r_s(397)=0.282$, $p<0.01$), with higher personal innovativeness scores relating to higher trust scores. A scatter plot comparing the two variables was included in Figure 5.1.

A high pedestrian receptivity score corresponded to an increased willingness to interact with autonomous vehicles, whereas a low pedestrian receptivity score indicated a decreased willingness to interact with autonomous vehicles. A bivariate Spearman correlation was completed to compare the general pedestrian receptivity total score to the general trust score. The results indicated that the two variables had a strong positive correlation ($r_s(397)=0.772$, $p<0.01$), with higher PRQ scores relating to higher trust scores. The relationship between the two variables was represented in the scatter plot in Figure 5.2.

The PBQ total score and the general trust question had a weak positive correlation ($r_s(397)=0.197$, $p<0.01$), with higher PBQ scores relating to higher trust scores. A high PBQ score represented adverse pedestrian behavior. Therefore, adverse pedestrian behavior corresponded to an increased level of trust in autonomous vehicles. The relationship between the two variables was represented in Figure 5.3.

The only demographic variable that showed a significant correlation to trust was participant age. Age and general trust had a weak negative correlation ($r_s(397)= -0.178$, $p<0.01$), with higher aged participants showing a lower level of trust. The relationship between age and trust was represented in Figure 5.4.

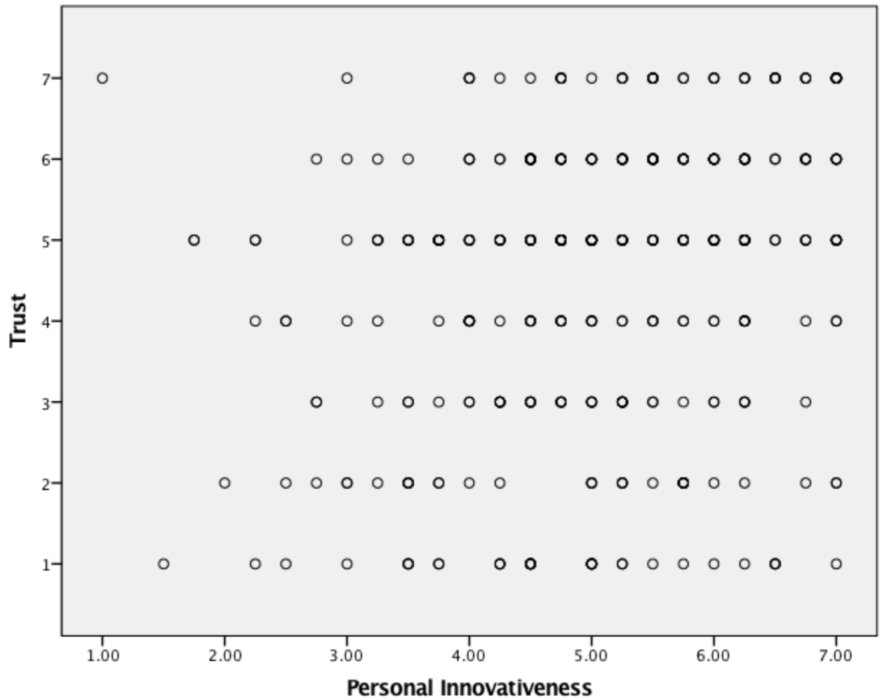

Figure 5.1 Scatter Plot comparing Personal Innovativeness Total Scores Trust (General Scenario Question 2) ($r_s(397)=0.282$, $p<0.01$)

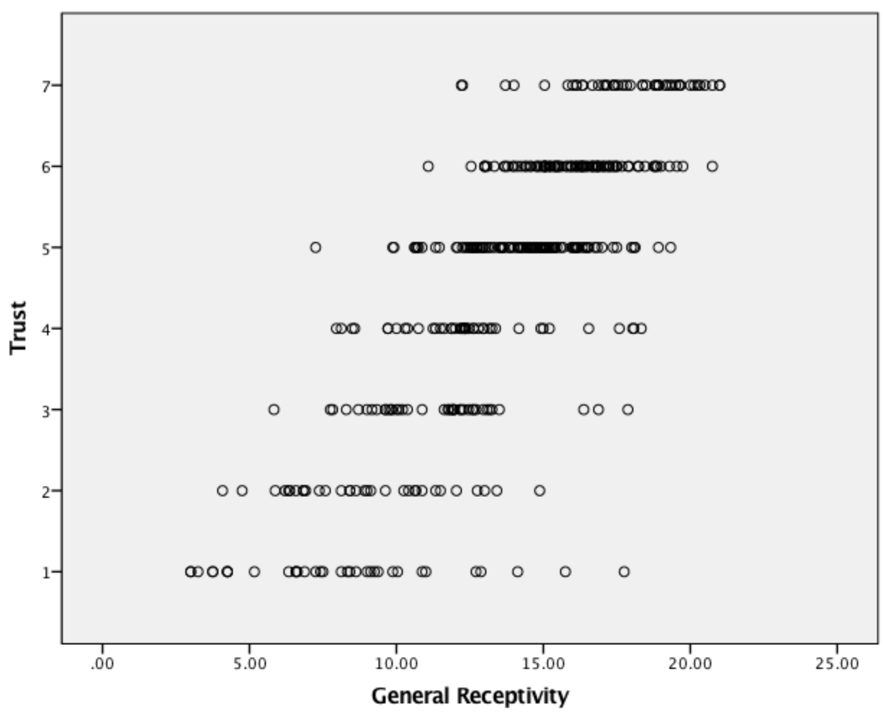

Figure 5.2 Scatter Plot comparing General Receptivity Total Scores Trust (General Scenario Question 2) ($r_s(397)=0.772$, $p<0.01$)

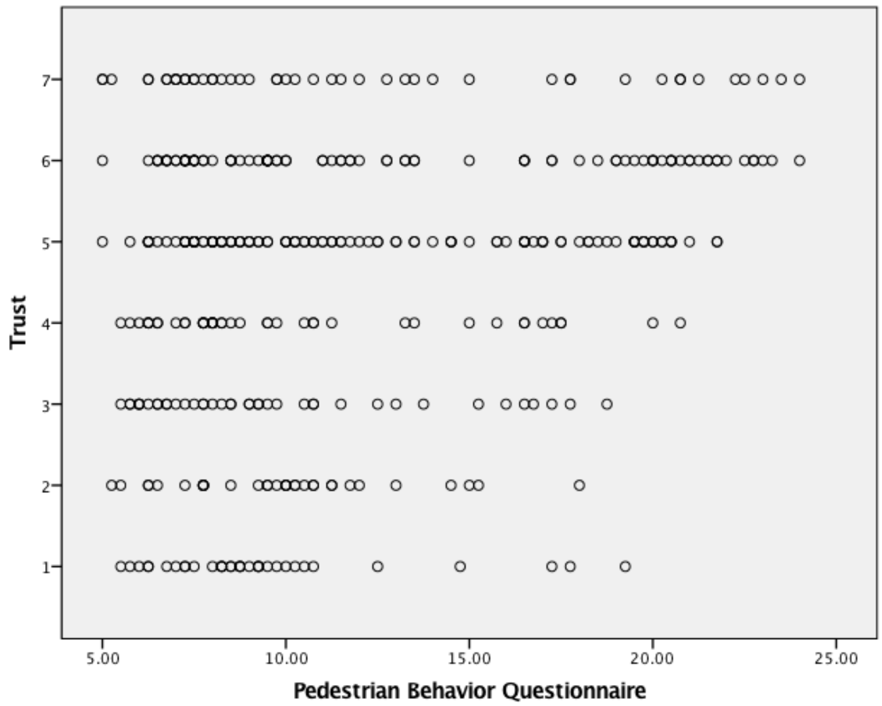

Figure 5.3 Scatter Plot comparing PBQ Total Scores to Trust (General Scenario Question 2) (($r_s(397) = 0.197$, $p<0.01$))

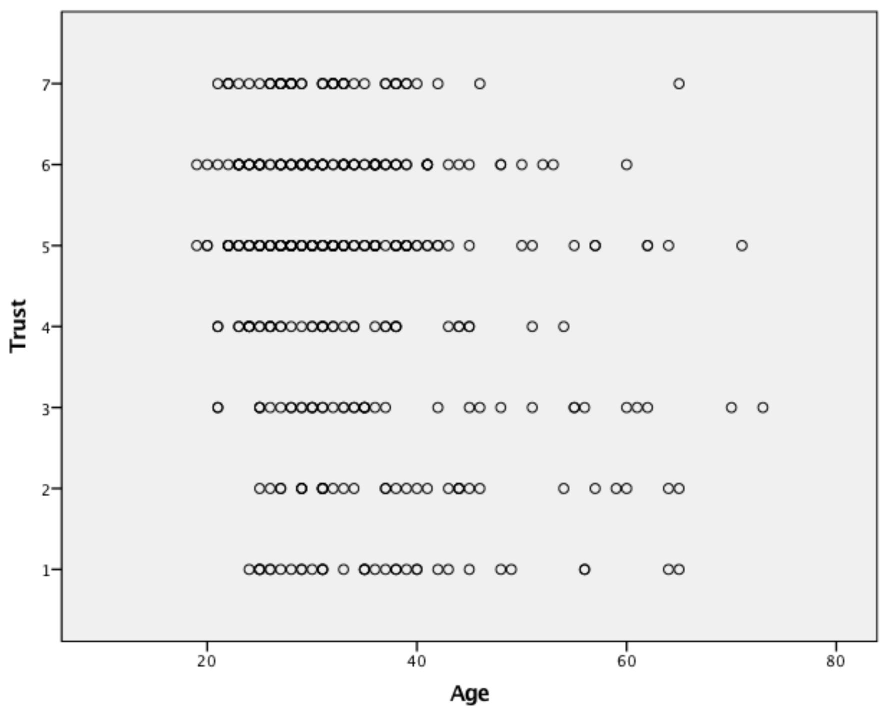

Figure 5.4 Scatter Plot comparing Participant Age to Trust (General Scenario Question 2) (($r_s(397) = -0.178$, $p<0.01$))

CHAPTER VI

DISCUSSION

The purpose of this study was to investigate the effects of open and closed systems on trust in autonomous vehicles. The first hypothesis was that participants would be more trusting of the autonomous vehicle in the closed system. Although the results from the repeated measures ANOVA did not indicate a significant difference in the responses to the trust question for the general scenario and the second scenario participants viewed, there was a significant change in scores based on the open/closed variable. Specifically, there was a positive change for the closed scenario, representing an increase in trust for that scenario. The mean response for trust was also higher for the closed scenario compared to the open scenario. The other two trust variables for this study were the behavior question and the PRQ. For behavior, the second scenario had higher scores than the general scenario, representing an increase in trusting behavior for the second scenario. However, there was not a difference between the open and closed scenarios. For receptivity, there was a significant difference in responses to the general receptivity questionnaire and the second receptivity questionnaire, and a significant change in scores based on the open/closed variable. Specifically, there was a positive change for closed receptivity, indicating increased receptivity to the autonomous vehicle in the closed system. Additionally, when looking at the average scores across the scenarios from Figure 2, the closed PRQ average score was the highest. As discussed previously, the PRQ is a measure of receptivity to autonomous vehicles, with a high PRQ indicating increased receptivity to autonomous vehicles.

Receptivity is a necessary predecessor for trust, so this result can be used to conclude that receptivity and trust were higher for the closed scenario.

The second hypothesis was that trust would increase as personal innovativeness increased. This was tested using a correlation between the personal innovativeness total score and the results from the general trust question. The general scenario was used because it was completed by all of the participants. The results from this analysis showed that the two variables were positively correlated, meaning that a higher personal innovativeness score was associated with higher trust scores. A high personal innovativeness score represented an increase in innovativeness. This proves the hypothesis that the more technologically innovative a person was, the more likely they were to trust the technological innovation of autonomous vehicles. This finding is supported by research stating that trust in autonomous vehicles is increased for those that have more knowledge about the system's abilities and limitations (Khastgir et al., 2018; Hutson, 2017). It can be deduced that participants who were more technologically innovative also had more knowledge about autonomous vehicle technology than those that did not frequently use new technologies.

The third hypothesis was that trust would be increased for participants who had a high general pedestrian receptivity score. This hypothesis was also tested for the general scenario. There was a positive correlation between the two variables in this scenario. This indicated that a higher general receptivity score was associated with higher trust scores. This proved the hypothesis that people who indicated a high receptivity to autonomous vehicles were more likely to trust the autonomous vehicle described in the survey.

The results from this study agreed with the expected findings. There was a significant positive change in PRQ scores for the closed system. Average scores for the trust question were also increased for the closed system. This indicated increased trust and receptivity to autonomous vehicles in closed systems. This was an interesting finding that can be applied to autonomous vehicles in these settings.

Another noteworthy finding was the response to the behavior question. Although there was a significant change in responses from the general scenario to the second scenario, there was not a difference between the open and closed scenarios. Additionally, in Table 3, the frequencies for the responses to this question were listed. It was interesting to note that few participants chose the answer choice that stated, "I will cross the road with full confidence that the driverless vehicle will stop for me," (General: 5%, Open: 8%, Closed: 6.1%). One of the possible explanations for this could be based on the findings from Deb et al. (2018) that indicated that the lack of ability to interact with autonomous vehicles through informal communication methods like eye contact and hand gestures could make it difficult for pedestrians to trust these vehicles.

Furthermore, it was discovered that the participants' ages and responses to the trust question were negatively correlated. This means that older participants indicated less trust of the vehicles described in the scenarios, while younger participants tended to be more trusting of these vehicles. This finding was not surprising, as younger generations typically have more experience with technology and can, therefore, be more trusting of it. There were no other demographic variables that were found to have a significant impact on trust. Although there has been research stating that city residents are more likely to accept autonomous vehicles (Nordhoff et al., 2018), this finding was not supported by this study, as trust was not significantly affected by whether the participants lived in an urban or rural area ($\chi^2(6, N=399)=5.30, p=0.506$).

There was also a significant correlation between PBQ scores and trust, with the two variables being positively correlated. This was an interesting finding because high PBQ scores represented adverse pedestrian behavior. Therefore, participants who exhibited adverse pedestrian behavior were more trusting of the autonomous vehicle in this study. This could indicate over-trust in autonomous vehicles, as some of the questions from the PBQ were items like, "I cross even if vehicles are coming because I think they will stop for me," and "I forget to look before crossing because I am thinking about something else." It can be concluded that the participants who had higher PBQ scores and higher trust scores were already trusting of vehicles and were therefore more trusting of autonomous vehicles than those that indicated being more cautious around vehicles in general.

In conclusion, there was a difference in participants' identifications of trust based on autonomous vehicle settings. Participants of this study indicated higher trust and receptivity to autonomous vehicles in closed settings, as indicated from the increase in receptivity scores for the closed setting and the higher mean for responses to the trust question. This finding can be used to further research the topic of trust in autonomous vehicles and to develop scenarios for autonomous vehicle use that will elicit maximum trust from drivers and pedestrians. Autonomous vehicles are currently on their way to being introduced in the general market, but there is still a need to improve user perceptions and trust of these vehicles before this technology can truly be successful.

Although there were interesting findings from this study, there were also some limitations. It would have been helpful to include a question in the demographics section about how much exposure the participant had to autonomous vehicles prior to completing the study. This could have been useful to determine if previous knowledge and exposure impacted trust in autonomous vehicles. It also might have been beneficial to include more detail in the open and closed scenarios in order to gain a better understanding of participants' feelings towards the vehicles in these settings. For instance, the scenario description could have been more detailed so participants could have a deeper understanding of the differences between an open and closed setting. There also could have been multiple scenarios for each setting. These additions would have created a more thorough evaluation of the differences in participants' responses to autonomous vehicles in open and closed settings.

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APPENDIX A

SURVEY

PRQF Questionnaire (Deb et al., 2017)

Demographic questionnaire

1. What is your age?
2. What is your gender?
[ ] Male [ ] Female
3. What is your level of education?
[ ] Some high school
[ ] High school graduate
[ ] Some college
[ ] Associates/Bachelor's Degree
[ ] Graduate Degree
[ ] Other:
4. How often do you walk in a day?
[ ] Never [ ] Rarely (0–2 times a day)
[ ] Often (2–4 times a day) [ ] Frequently (4+ times a day)
5. What range best describes your daily walking time?
[ ] 0–15 min
[ ] 15–30 min
[ ] 30–45 min
[ ] 45–60 min
[ ] 60 min and above
6. In which US state do you live?
7. How would you describe the area where you live?
[ ] Urban: Places with an overall population density of at least 500 people per square mile
[ ] Rural: Places with less than 500 people per square mile

Pedestrian behavior questionnaire (short version)

''As a pedestrian, how often do you have the following behaviors?" Answers should be given on a 6-point scale:
1=very infrequently or never,
2=infrequently,
3=quite infrequently,
4=quite frequently,
5=frequently,
6=very often or always.

Violations
V1 I cross the street even though the pedestrian light is red.
V2 I cross diagonally to save time.
V3 I cross outside the pedestrian crossing even if there is one (crosswalk) less than 50 meters away.
V10 I take passageways forbidden to pedestrians to save time.
Errors
E2 I cross between vehicles stopped on the roadway in traffic jams.

E7 I cross even if vehicles are coming because I think they will stop for me.
E8 I walk on cycling paths when I could walk on the sidewalk.
E9 I run across the street without looking because I am in a hurry.

Lapses

L5 I realize that I have crossed several streets and intersections without paying attention to traffic.
L6 I forget to look before crossing because I am thinking about something else.
L7 I cross without looking because I am talking with someone.
L8 I forget to look before crossing because I want to join someone on the sidewalk on the other side.

Aggressive behaviors

A1 I get angry with another road user (pedestrian, driver, cyclist, etc.), and I yell at him.
A3 I cross very slowly to annoy a driver.
A4 I get angry with another road user (pedestrian, driver, cyclist, etc.), and I make a hand gesture.
A6 I have gotten angry with a driver and hit their vehicle.

Positive behaviors [reverse-coded]

P1 I thank a driver who stops to let me cross.
P3 When I am accompanied by other pedestrians, I walk in single file on narrow sidewalks so as not to bother the pedestrians I meet.
P4 I walk on the right-hand side of the sidewalk so as not to bother the pedestrians I meet.
P5 I let a car go by, even if I have the right-of-way, if there is no other vehicle behind it.

Pedestrian receptivity questionnaire

A fully autonomous vehicle (FAV) is driven by technology instead of by a human. A FAV is equipped with radars, cameras, and sensors which can detect the presence, position, and speed of other vehicles or road-users. With this information, the FAV can then respond as needed by stopping, decelerating and/or changing direction. A driverless vehicle has the potential to reduce pedestrian-motor vehicle crashes and to decrease the possibility of severe injuries by controlling the driving task effectively.

You have recently learned that there will be fully autonomous vehicles on the road in your area. As you consider this, how much would you agree or disagree with the following statements. All items will be measured on the following 7-point Likert scale:
1 = strongly disagree
2 = moderately disagree
3 = somewhat disagree
4 = neutral (neither disagree nor agree)
5 = somewhat agree
6 = moderately agree
7 = strongly agree

1. (A) FAVs will enhance the overall transportation system.
2. (A) FAVs will make the roads safer.
3. (A) I would feel safe to cross roads in front of FAVs.

4. (A) It would take less effort from me to observe the surroundings and cross roads if there are FAVs involved.
5. (A) I would find it pleasant to cross the road in front of FAVS.
6. (S) People who influence my behavior would think that I should cross roads in front of FAVs.
7. (S) People who are important to me would not think that I should cross roads in front of FAVs. [reverse-coded]
8. (S) People who are important to me and/or influence my behavior trusts FAVs (or has a positive attitude towards FAVs).
9. I Interacting with the system would not require a lot of mental effort.
10. I FAV can correctly detect pedestrians on streets
11. (T) I would feel comfortable if my child, spouse, parents – or other loved ones – cross roads in the presence of FAVs.
12. (T) I would recommend my family and friends to be comfortable while crossing roads in front of FAVs.
13. (T) I would feel more comfortable doing other things (e.g., checking emails on my smartphone, talking to my companions) while crossing the road in front of FAVs
14. I The traffic infrastructure supports the launch of FAVs.
15. I FAV is compatible with all aspects of the transportation system in my area.
16. (E, C) FAVs will be able to effectively interact with other vehicles and pedestrians.
Note: A-Attitude, S-Social norms, E-Effectiveness, T-Trust, C-Compatibility
Higher scores indicate higher receptivity toward FAVs

Personal Innovativeness – adapted from Agarwal and Prasad (1998) and Chen and Chen (2011)
17. If I heard about a new technology, I would look for ways to experiment with it.
18. Among my peers, I am usually the first to try out new technologies.
19. In general, I am hesitant to try out new technologies. [reverse-coded]
20. I like to experiment with new technologies.
Note: Responses collected on a 7-point Likert scale from strongly disagree to strongly agree.
Higher scores indicate higher innovativeness toward new technologies

General scenario-based questions
You are taking a walk. On your way, you need to cross multiple crosswalks, both signalized and unsignalized. As you prepare to cross at an un-signalized crosswalk, you find that a driverless vehicle is approaching the crosswalk (with no one sitting in the driver seat). Based on the scenario, please select the choice that best reflects your behavior for each question.

A. What will your response at the crosswalk be, with the FAV approaching?
1. I will not cross the road at the crosswalk to avoid crossing in front of the FAV.
2. I will run across the road even though the driverless vehicle has stopped for me.
3. I will make sure that the driverless vehicle stops before I start crossing.
4. I will wait to see if the vehicle decelerates before I start crossing.
5. I will cross the road with full confidence that the driverless vehicle will stop for me.
6. I will stand in front of the vehicle because I know it will not hurt me.

B. Please rate your level of agreement with the following statement: I will trust the vehicle in the scenario.
1 = Strongly disagree

2 = moderately disagree
3 = somewhat disagree
4 = neutral (neither disagree nor agree)
5 = somewhat agree
6 = moderately agree
7 = strongly agree

Open System

Consider a fully autonomous vehicle operating in an open system. Examples of open systems could be a downtown city street or the streets of your hometown. The environment is open to all vehicles and pedestrians. The driverless vehicle is interacting with other drivers, pedestrians, bicycles, and is operating under existing traffic laws. Answer the following questions based on this type of environment.

Pedestrian receptivity questionnaire

How much would you agree or disagree with the following statements. All items will be measured on the following 7-
point Likert scale:
1 = strongly disagree
2 = moderately disagree
3 = somewhat disagree
4 = neutral (neither disagree nor agree)
5 = somewhat agree
6 = moderately agree
7 = strongly agree
1. (A) FAVs will enhance the overall transportation system.
2. (A) FAVs will make the roads safer.
3. (A) I would feel safe to cross roads in front of FAVs.
4. (A) It would take less effort from me to observe the surroundings and cross roads if there are FAVs involved.
5. (A) I would find it pleasant to cross the road in front of FAVS.
6. (S) People who influence my behavior would think that I should cross roads in front of FAVs.
7. (S) People who are important to me would not think that I should cross roads in front of FAVs. [reverse-coded]
8. (S) People who are important to me and/or influence my behavior trusts FAVs (or has a positive attitude towards FAVs).
9. I Interacting with the system would not require a lot of mental effort.
10. I FAV can correctly detect pedestrians on streets
11. (T) I would feel comfortable if my child, spouse, parents – or other loved ones – cross roads in the presence of FAVs.
12. (T) I would recommend my family and friends to be comfortable while crossing roads in front of FAVs.
13. (T) I would feel more comfortable doing other things (e.g., checking emails on my smartphone, talking to my companions) while crossing the road in front of FAVs
14. I The traffic infrastructure supports the launch of FAVs.
15. I FAV is compatible with all aspects of transportation system in my area.

16. (E, C) FAVs will be able to effectively interact with other vehicles and pedestrians.
Note: A-Attitude, S-Social norms, E-Effectiveness, T-Trust, C-Compatibility
Higher scores indicate higher receptivity toward FAVs

Scenario-based questions for Open System
You are walking downtown. On your way, you need to cross multiple crosswalks, both signalized and unsignalized. As you prepare to cross at an un-signalized crosswalk, you find that a driverless vehicle is approaching the crosswalk (with no one sitting in the driver seat). Based on the scenario, please select the choice that best reflects your behavior for each question.

A. What will your response at the crosswalk be, with the FAV approaching?
1. I will not cross the road at the crosswalk to avoid crossing in front of the FAV.
2. I will run across the road even though the driverless vehicle has stopped for me.
3. I will make sure that the driverless vehicle stops before I start crossing.
4. I will wait to see if the vehicle decelerates before I start crossing.
5. I will cross the road with full confidence that the driverless vehicle will stop for me.
6. I will stand in front of the vehicle because I know it will not hurt me.

B. Please rate your level of agreement with the following statement: I will trust the vehicle in the scenario.
1 = Strongly disagree
2 = moderately disagree
3 = somewhat disagree
4 = neutral (neither disagree nor agree)
5 = somewhat agree
6 = moderately agree
7 = strongly agree

Closed System

Consider a driverless vehicle operating in a closed system. A closed system is an environment with limited access. An example of a closed system could be a company campus where only certain people can access roads and vehicles must have permission to drive on them. Answer the following questions based on this type of environment.

Pedestrian receptivity questionnaire

How much would you agree or disagree with the following statements. All items will be measured on the following 7-point Likert scale:
1 = strongly disagree
2 = moderately disagree
3 = somewhat disagree
4 = neutral (neither disagree nor agree)
5 = somewhat agree
6 = moderately agree
7 = strongly agree

1. (A) FAVs will enhance the overall transportation system.
2. (A) FAVs will make the roads safer.
3. (A) I would feel safe to cross roads in front of FAVs.
4. (A) It would take less effort from me to observe the surroundings and cross roads if there are FAVs involved.
5. (A) I would find it pleasant to cross the road in front of FAVS.
6. (S) People who influence my behavior would think that I should cross roads in front of FAVs.
7. (S) People who are important to me would not think that I should cross roads in front of FAVs. [reverse-coded]
8. (S) People who are important to me and/or influence my behavior trusts FAVs (or has a positive attitude towards FAVs).
9. I Interacting with the system would not require a lot of mental effort.
10. I FAV can correctly detect pedestrians on streets
11. (T) I would feel comfortable if my child, spouse, parents – or other loved ones – cross roads in the presence of FAVs.
12. (T) I would recommend my family and friends to be comfortable while crossing roads in front of FAVs.
13. (T) I would feel more comfortable doing other things (e.g., checking emails on my smartphone, talking to my companions) while crossing the road in front of FAVs
14. I The traffic infrastructure supports the launch of FAVs.
15. I FAV is compatible with all aspects of transportation system in my area.
16. (E, C) FAVs will be able to effectively interact with other vehicles and pedestrians.

Note: A-Attitude, S-Social norms, E-Effectiveness, T-Trust, C-Compatibility
Higher scores indicate higher receptivity toward FAVs

Scenario-based questions for Closed System

You are walking across your company campus. On your way, you need to cross multiple crosswalks, both signalized and unsignalized. As you prepare to cross at an un-signalized crosswalk, you find that a driverless vehicle is approaching the crosswalk (with no one sitting in the driver seat). Based on the scenario, please select the choice that best reflects your behavior for each question.

A. What will your response at the crosswalk be, with the FAV approaching?
1. I will not cross the road at the crosswalk to avoid crossing in front of the FAV.
2. I will run across the road even though the driverless vehicle has stopped for me.
3. I will make sure that the driverless vehicle stops before I start crossing.
4. I will wait to see if the vehicle decelerates before I start crossing.
5. I will cross the road with full confidence that the driverless vehicle will stop for me.
6. I will stand in front of the vehicle because I know it will not hurt me.

B. Please rate your level of agreement with the following statement: I will trust the vehicle in the scenario.
1 = Strongly disagree
2 = moderately disagree
3 = somewhat disagree
4 = neutral (neither disagree nor agree)
5 = somewhat agree
6 = moderately agree
7 = strongly agree

APPENDIX B

INFORMED CONSENT AND SURVEY INTRODUCTION

Please read the following informed consent form and if you would like to participate in this survey, indicate your consent by continuing with the survey.

Title of Study:

Investigating the Effects of Open versus Closed Systems on Trust in Autonomous Vehicles

Researchers:

Morgan Nutt, Dr. Lesley Strawderman, Dr. Brian Smith, Dr. Reuben Burch and Shuchisnigdha Deb

Purpose:

The purpose of this study is to investigate factors influencing trust and acceptance of autonomous vehicles.

Procedures:

If you agree to participate, your participation will be for approximately 15 mins. You will be given a survey that will ask questions about your typical pedestrian behaviors, receptivity towards driverless vehicles, and scenario questions to determine your response to driverless vehicles.

Benefits:

There will be no direct educational or health benefits to you for participating in this research.

Risks:

This is a survey study. There is no possibility for risk or harm to participants as a result of participation in the study.

Confidentiality:

Individual identifies will be protected and all participant responses will be kept confidential. The data collection process will be anonymous, and all of the data will be kept in PI's office and locked.

Compensation:

You will receive compensation upon completing this study from Amazon Mechanical Turk. No payment will be made for an incomplete survey .

Questions:

If you have any questions about this research project, please feel free to contact Morgan Nutt at mhs129@msstate.edu

Voluntary Participation:

Please understand that your participation is voluntary. Your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue your participation at any time, however, we will not be able to pay you for an incomplete survey.

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.

By entering the survey area, you indicate that you are at least 18 years old and are giving your informed consent to participate in this study. If you would like to print a copy of this document, please use the "print" function on your internet browser.

Investigating the Effects of Open versus Closed Systems on Trust in Autonomous Vehicles

This study is examining factors affecting pedestrian trust and acceptance of autonomous vehicles. An autonomous vehicle is a technology-driven vehicle that operates independently of a human driver. These vehicles can be referred to as fully autonomous vehicles (FAVs) or driverless vehicles. The study will ask questions about your typical pedestrian behaviors around regular vehicles and your receptivity to autonomous vehicles and other technologies. You will also be given scenarios and asked to answer questions regarding the vehicle described in the scenarios. While you are reading the scenario, try picturing an autonomous vehicle in the described setting. For your reference, a few photos of autonomous vehicles are listed below.

Figure 1: Autonomous Vehicles.

Top Left: https://www.3dnatives.com/en/local-motors-olli-160120184/

Top Right: https://www.theverge.com/2014/5/27/5756436/this-is-googles-own-self-driving-car

Bottom Left: https://www.aspeninstitute.org/blog-posts/autonomous-vehicles-ces/

Bottom Right: http://www.easymile.com/