THE PERCEPTION OF BENEFITS AND RISKS AS EXTERNAL VARIABLES OF SITUATIONAL TRUST IN AUTONOMOUS VEHICLES

BY

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DISSERTATION

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Abstract

Driving is a widespread quotidian activity that is at the core of human transportation. At the same time, it is the human driver who is the primary cause of most of traffic accidents in the US. The development and implementation of autonomous vehicles (AVs) proposes to dramatically reduce the number of traffic accidents by removing the human from the driving performance. However, the interaction of humans and AVs is currently one of the biggest challenges in AV development. Regarding accidents involving semi AVs from 2014 to 2018, the California Transit Department indicates humans are still the primary cause while only one out of every 38 accidents was due to autonomous system failure. Trust has been identified as one of the main determinants of successful use of different autonomous systems (AS) when calibrated to avoid situations of overtrust, distrust, and mistrust. Trust is a complex process in which individual differences, and external and internal variables have shown to impact the formation and calibration of trust in automation. Drawing from the theoretical model of trust in automation proposed by Hoff and Bashir (2015), in which trust is a dynamic and multidimensional process composed of dispositional, situational, and learned trust, this dissertation aims to empirically examine the situational trust dimension and how external variables—especially the perception of benefits and risks of AVs—are capable of influencing the formation of situational trust in AVs. To achieve these research goals, a survey and interview were conducted which focused on both the perceptions of benefits and risks of AVs as well as the perceptions of an AV's analogous system. This study found that the perception of benefits is more in relation to attributes of AVs for society (accessibility) or in relation to the purpose of the system, while the perception of risks is more in relation to the individual level and performance of the system. This shows that participants perceive risks of AVs according to those attributes responsible for the formation of reliance on the system: purpose, performance and process. These attributes form the foundation for the development of trust in automation. This study also makes contributions on how to investigate the variables that influence situational trust in AVs and finds especially external ones are related and they have the capacity to influence another. Finally, the participants' level of trust in AVs related to the adoption of an analogous system (cruise control). While further investigation is needed, this relationship can facilitate the understanding of situational trust in AVs, bringing contextual data from real life events, to complement the current investigation with prototypes and simulations.

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In loving memory of Junior

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Chapter 1. Introduction

Autonomous Systems (AS) are ubiquitous in modern society, having grown in prevalence and reliance in recent years. People encounter them many times throughout the day in such common actions as setting a coffee maker or using a virtual assistant. The rapid development of computing technologies has resulted in human–AS interactions becoming more intricate, independent, and even human-like (Hoff and Bashir, 2015). These changing technologies are rapidly evolving certain human tasks towards minimal or no human intervention, or even sharing the responsibility of task development with humans.

Representing a technological leap forward that promises to reshape the public's view of mobility (Howard and Dai, 2014), automated vehicle systems (e.g., pilot assist and cruise control) are increasingly part of everyday life. These types of AS are typically applied in relatively simple contexts and structured environments where trustworthiness can be straightforwardly assessed and assured (Moorman, Deshpande, and Zaltman, 1993). However, fully autonomous vehicles (AVs), represent the prospect that future technologies will attempt to cope with complex and uncertain problems once reserved almost exclusively for human judgment.

AVs are often discussed in the sense of a complex and safety-critical system that involves prediction and decision-making under uncertainties and has great potential for improving the safety and efficiency of transportation. With minimized human intervention and optimized traffic control systems, AVs can lead to a new transportation environment with less traffic and safer driving, as part of efforts towards a more sustainable industry.

However, the assertion that AVs will significantly reduce the levels of car accidents caused by human error can be countered by a recent report by the California Department of Motor Vehicles. This is one of the most compelling and recent data sets, providing information about AV accidents in California from 2014 to 2018 (California Transit Department, 2018). It presents one alarming finding related to the disparity between accidents caused by humans (when driving in autonomous mode, semi-autonomously, or with the support of automated vehicle systems) and those caused by the automated system itself. Of the 38 accidents reported while semi-autonomous vehicles were traveling in fully autonomous mode, only one accident occurred as a consequence of AS failure. While the development of AV technology may enhance safety and reduce car accidents, what is not completely understood is why accidents occur with AVs when human is the "backup system" monitoring the system function, and how technology can bridge this gap.

The transfer of control – from human to machine and from machine to human – happens in many AS applications, not only AVs, including safety-critical environments like medicine, air traffic control, and mission control for space shuttle and space station operations. However, predictions that AVs would soon be commercialized have changed, after a self-driving car being tested by Uber hit and killed a woman riding a bicycle across a street in Tempe, Arizona in 2018. According to the Tempe Police Department, a safety driver was at the wheel of the vehicle during the tests, but she was watching a video on her smartphone before the crash and did not brake the car when the system failed to recognize the cyclist. Moreover, three Tesla drivers have died in crashes that occurred when they failed to detect and react to hazards while driving in autonomous mode (Plungis, 2020).

These events and research findings underline that humans' interactions with AVs are from perfect and the transfer of control is far from seamless. As critical uncertainties remain unsettled, new theories and methods to assess and assure trustworthiness have become imperative. Therefore, more exploratory research is needed to ensure that the operators (drivers) of AVs are able to comprehend the capabilities and limitations of the systems in place for AVs, in order to best calibrate their trust in the given system.

The calibration of human trust in AVs is capable of preventing situations of overtrust, in which a driver thinks that the system is perfect and overlooks its performance, or mistrust and distrust, in which the lack of trust prevents the driver from fully adopting the system's capabilities. Calibration of human trust is thus one of the biggest challenges to overcome for AVs to be successfully deployed and adopted by society. Moreover, the successful development of AVs will rely not only on developing optimal AS from a technical perspective, but also on considering human–machine interaction factors that can influence emergent phenomena in the coupled system.

Previous research on human–AV interactions has suggested that people's initial trust in AVs will depend on their experiences with analogous systems, most likely their experiences both with computers and as drivers interacting with increasingly sophisticated automotive technology (Lee and Kolodge, 2020). Furthermore, people attribute statements like "computers make mistakes" and ideas like "technology improvement" to benefits and risks related to AVs. This shows that their trust in AVs is grounded in their experience with other computers and systems; hence, people's initial response to AVs will depend on experience accumulated through interactions with other technology (Rousseau et al, 1998). The use of previous knowledge and system expertise relates to learned trust (Hoff and Bashir, 2015). Knowledge and expertise are context-based attributes that facilitate the process of trust through familiarity, supporting humans in framing unknown situations prior to their interaction with the AS.

Yet the formation of trust in AVs does not only rely on previous knowledge. How trust is formed and the elements that influence its formation is a topic that has been discussed increasingly in the last decade and it is deep-rooted in the studies of human and automation interaction. Numerous researchers, from psychologists to engineers, have developed models to better comprehend and calibrate trust in automation. The model proposed by Hoff and Bashir (2015) is considered one of the most comprehensive theoretical models to integrate empirical evidence of factors that influence trust in AS. Their model encompasses three broad sources of variability in human–automation trust: the human operator, the environment, and the AS itself. These variables respectively reflect the three different layers of trust, previously identified by Marsh and Dibben (2003): dispositional trust, situational trust, and learned trust. While dispositional trust relates to intrinsic aspects of the operator (e.g., age, gender, personality) and cannot be changed during the interaction with the given system, the situational trust dimension relates to variables that might change during a given interaction. Both variables are context dependent: to the operator state (e.g., level of stress or tiredness) or to the environment (e.g., the complexity of the task). Finally, the third layer is learned trust, which can be initial learned trust, based on previous knowledge with analogous systems, or dynamic learned trust, which relates to what is learned about the system itself throughout the interaction.

While numerous works have focused on identifying the factors that influence the formation of trust in automation at the dispositional level (Hancock et al., 2011; Hoff and Bashir, 2014; Lewandowsky, Mundy, and Tan, 2000; Moorman et al., 1993; Schaefer et al., 2014), less is known about how situational trust is formed and calibrated regarding internal and external variables. These situational variable factors are important not only because they directly affect trust, but also because they determine the degree of influence that trust has on behavior towards automation (Hoff and Bashir, 2015). Understanding situational trust can bring about insights on how to help people continuously maintain an appropriate level of reliance on technology, considering the reliability of the capabilities of the system as it functions at a given time and in a given situation context (Hoffman et al., 2013; Lee and See, 2004), thus preventing situations of mistrust, distrust, and overtrust.

A topic widely investigated in academia and industry is how the perception of benefits and risks influences human behaviors. The perception of risks, for example, is essential for the understanding of trust, since risk is defined as the degree of uncertainty associated with a given outcome (Robert et al., 2009). Risk is an important factor because it determines whether trust translates into actual trusting behaviors (Hung et al., 2004; Mayer et al., 1995).

One approach is to investigate how perception of risks and benefits is related to dispositional variables, like gender and age, to predict how people will perceive AVs (Kyriakidis et al., 2015; Siegrist, and Cvetkovich, 2000). Another is to investigate how the perception of risks relates to acceptance and use of AVs (Ward et al., 2017; Zang et al., 2019). Regarding situational trust, in which risks and benefits are considered external variables (Hoff and Bashir, 2015), it is known that safety concerns, for example, have a negative effect on AV acceptance through trust (Liu et al, 2019). However, while more studies are being developed, there is still a lack of knowledge about how the perception of risks and benefits, as external variables, influences situational trust in AVs.

Empirical studies suggest that situational trust in automation is context dependent where users are interacting with the system. However, AVs are still not fully developed, and they are limited in terms of accessibility. Therefore, numerous researchers have adopted different types of simulation, including virtual reality, prototypes, Wizard of Oz methodology, and future scenarios analyses, to investigate the human–system interaction and how trust is created and calibrated. However, the investigation of current behavior, attitudes, and feelings towards the use of similar types of systems might provide more realistic and contextualized insights, since, as previously mentioned, people tend to ground their behavior and perception of AVs on current technologies. For these reasons, this dissertation also adopted an analogous system to investigate situational trust.

This research aimed to answer the main research question **(MRQ):** "How does the perception of benefits and risks of AVs influence the formation of situational trust in AVs?"

Three subordinate research questions were created to support and better answer the main research question, relating specifically to AVs and to AVs' analogous systems:

> **(RQ1)** How does the perception of benefits and risks, as external variables, affect situational trust in AVs?
>
> **(RQ2)** How does the perception of benefits and risks of an AV's analogous system affect situational trust?
>
> **(RQ3)** What are the perceptions of benefits and risks of the AV's analogous systems that influence situational trust in AVs?

To answer these questions, a mixed method approach was adopted. The dissertation is organized into six main chapters. Following this introductory chapter, Chapter Two outlines the research background and foundational knowledge by reviewing the literature on the theoretical model of trust in automation developed by Hoff and Bashir (2015), as well as later studies that have applied and investigated situational trust in AVs. Chapter Three presents the research strategy, detailing the mixed method approach employed to answer the research questions. Chapter Four addresses the first research question, while Chapter Five answers the second. Chapter Six presents the data triangulation from both studies, answering the third research question. Chapter Seven presents the conclusion of this dissertation, limitations and next steps.

Chapter 2. Theoretical Background

In this chapter, I briefly studied the definition of trust from a psychological point of view. Drawing on the theoretical model from Hoff and Bashir (2015), the concept of automation and trust in AS and previous findings are explored. This section lays the foundation of the dissertation and how trust in AV was investigated. Finally, recent studies that investigated the role of internal and external variables on the formation and calibration of situational trust in AS are revisited, focusing on studies about the perception of benefits and risks, bringing theoretical foundation for the development and support of research questions.

2.1 Trust

Trust has been studied in a variety of disciplines, from philosophy, psychology, and sociology to engineering and robotics. These varying contexts have led to multiple definitions and theories of trust. This section presents an overview of the literature on the conceptualization of trust from a psychological perspective.

2.1.1 The Psychological Perspective of Trust

Regardless of its definitions, the primary understanding of trust is the examination of human-human relationships; where trust is being associated with the expectancy that another person, or an institution, will act in a certain manner (Rotter, 1967). Psychologists conceptualize trust as a psychological event within the individual rather than as an inter-subjective or systemic social reality as in sociology (Lewis and Weigert, 1985). In order for trust to be a necessary component of an interaction, two conditions are important: 1) one of the participants in the interaction needs to be cognizant of the risk involved in the situation, and 2) there needs to be an incentive associated with involving oneself in the situation (Mayer, Davis, and Schoorman, 1995).

Due to trust volatility it is essential to understand it within specific contexts. In interpersonal trust literature, trust has been shown to improve the effectiveness of communication (Rasmussen, 1990). In the human-robot context, trust is likely to impact usage similarly to the human-automation context. So, if an operator trusts a system, they will use it and if they do not trust it, they will not use it (Lee and See, 2004). Therefore, trust is a key aspect for successful interpersonal relationships and technology adoption. In the following sections, I present two of the most compelling theories of trust that influenced later studies of trust in AS.

Rempel, Holmes, and Zanna, 1985

Trust has been characterized variously as a belief, attitude, or behavior. Fishbein and Ajzen (2011) propose that behaviors result from intentions which, in turn, are the functions of attitudes that are based on beliefs. Rempel, Holmes and Zanna (1985) suggested a way of categorizing the beliefs that motivate trust, proposing that it can be divided into three dimensions: predictability, dependability, and faith.

Predictability is influenced by the consistency of behavior and generally focuses on performance stability over time. This forms the initial basis of trust (Rempel, Holmes, and Zanna, 1985). When relating this dimension to trust in AS, it similarly relates to the transparency of the AS, meaning how easily observed and understood the system is (Suchman, 1987). This sequence produces a positive assessment of predictability by the operator, thus leading to initial trust (Muir, 1994).

Dependability involves dispositional characteristics of a person and refers to the reliability of the person, in other words the probability that someone, a product, system, or service will develop its intended behavior adequately for a specified period of time. Dependability forms the basis of trust after a period of time and experience, as attention refocuses from assessment of specific behaviors to an assessment of dispositional characteristics of the trustee, most particularly on their dependability, or the degree to which they can be relied upon (Rempel et al., 1985). This can also be understood as the stage when the operator tends to trust the AS if the processes are comprehensible and appear able to achieve the users' goals (Dzindolet et al, 2003).

Faith refers to the beliefs about the future behavior of the trustee and it is the final stage in this model of trust formation. Past predictability and dependability are used as a basis for belief that the trustee will behave in the future as they have in the past, with additional consideration given to the trustee's perceived motives (Mayer et al, 1995). When interacting with AS, many automated processes are too complex for the user to have a complete understanding of them, and will potentially require unanticipated interaction (Muir, 1994); therefore, the operator needs to understands the designer's intent for the purpose and behavior of the given AS (Dzindolet et al, 2003).

Mayer, Davis, and Schrooman, 1995

Mayer, Davis, and Schoorman (1995) authored one of the most influential review papers on trust to date by thoroughly examining literature on the antecedents and outcomes of organizational trust. They developed one of the most employed definitions of trust, which is "the willingness to be vulnerable to the actions of another party based on the expectations that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" (pg. 712).

Rather than seeing trust merely as an individual characteristic that remains constant regardless of context, their model defines trust as relational and therefore largely dependent on characteristics of both the trustor (the person who trusts) and the trustee (the person to be trusted) within a specific relationship that varies in depth and strength over time (Mayer, Davis, and Schoorman, 1995). Thus, their model conceptualizes trust as a multidimensional concept that is essentially relational and context-specific in nature.

One factor contributing to the development of trust is the trustor's propensity to trust. Propensity to trust is a stable personality characteristic that captures someone's general ability to trust a party without any prior knowledge of that party; it is "a generalized expectation about the trustworthiness of others" Mayer, Davis, and Schoorman (1995, p. 175). Initial trust levels are influenced by one's propensity to trust prior the interaction, where higher propensity to trust results in greater trust towards the trustee. Moreover, the authors explored three general bases of trust, or the trustworthiness of a trustee: ability, benevolence, and integrity. Ability relates to how capable or skilled a trustee is in implementing an action stated by a trustor. Benevolence is how the goals or intentions of a trustee benefit and align with a trustor. Integrity relates to the similar set of values that a trustor and a trustee share, and how a trustee will act in accordance with these shared beliefs.

In summary, the study of trust in psychology refers to the confidence that a person or group of people has in the reliability of another person or group. Thus, its key factor is intrinsically to another people's predictability. The next section subchapter focuses on trust in automation, the assessment of different theories and models developed to its further understanding.

2.2 Trust in Automation

Increasingly complex AS requires the operator to appropriately calibrate their trust in the automation in order to achieve performance and safety goals. Although humans are capable of making instinctive assessments of the trustworthiness of other people, this ability does not directly translate to technological systems. Thus, in this section I outline the theoretical foundations of trust in AS to better understand the nature of human-automation trust. Second, I review the theoretical model proposed by Hoff and Bashir (2015), which provides a conceptual framework for this dissertation.

2.2.1 Automation

Automation is changing the world rapidly. Rapid advances in automation technologies, including autonomous vehicles, robotics, autonomous web-based systems, user experience frameworks, and decision aids, are dramatically altering activities and impacting upon many areas of daily life, and its primary value is the ability to perform complex, repetitive tasks quickly without error (Hoff and Bashir, 2015). Although, a recent report by McKinsey Global Institute (2017) estimates that by 2030 up to 30% of work activities could be displaced by automation, with up to 14% of the global workforce likely to need to transition to new occupations, previous research has demonstrated that automation does not merely replace human activities but rather alters it in ways which pose different demands upon the human operator (Parasuraman and Riley, 1997). Parasuraman, Sheridan, and Wickens (2000) outlined four classes or types of automation function, derived from models of human information processing, and one AS can involve a combination, or all, of these automation types at different automation levels. They are: (1) information acquisition, (2) information analysis, (3) decision and action selection, and (4) action implementation.

The performance of a human-automation system is a product of the quality of the support provided by the automation and the manner in which that support is used by the human. Optimal system performance depends on the successful collaboration of the human and automation agents. An overarching goal of research investigating human-automation systems is to facilitate human-automation interaction, thus improving overall performance (McBride, Rogers, and Fisk, 2014). Therefore, when attempting to increase the performance of a human-automation system, increasing the reliability of the automation is only half the solution; the other half is ensuring that humans perform their part of the task. Thus, the success of a human-automation system hinges on understanding and being able to predict the behavior of the human in an automated environment.

For instance, when the term autonomy is applied to technology, particularly automation, it is discussed in terms of autonomous function (e.g., performing aspects of a task without human intervention). Although the specific term "autonomy" is not commonly used in the automation literature, some models (Parasuraman, Sheridan, and Wickens, 2000) describe higher levels of automation possessing "increased autonomy of computer over human action" (Parasuraman, Sheridan, and Wickens, 2000, p. 287). In this sense, autonomy represents trading control of authority between the human and automation. Parasuraman and colleagues provided the example of some types of automation exhibiting autonomy over decision making. That is, in this example the task of decision making is allocated to the automated system, giving that system the authority (i.e., autonomy) to perform that aspect of the task without human intervention.

Appropriate Use of Automation, Parasuraman and Riley (1997)

As autonomous systems become more complex, the ability of human operators to effectively interact becomes more challenging. Parasuraman and Riley (1997) claim that the use of automation refers to the human operator's engagement of automation to perform tasks, which could often be performed manually. In addition, they classify the improper use of automation as misuse, disuse and abuse.

Disuse refers to instances in which a human operator fails to utilize automation when it could enhance performance, which can be related to poor performance of the AS. Instead, Misuse refers to over-reliance on automation. Typically misuse arises from a lack of monitoring by the operator, resulting in the neglecting of automation failures or errors, or when human operators use the automation in ways not anticipated by designers (Lee and See, 2004). Abuse of automation refers to instances in which automation is designed and implemented with a technology-centered focus, without regard for its effect on the human operator. Typically, it is when the AS ignores the role that the operator plays in maintaining an effective system and in dealing with unexpected events which automation cannot accommodate (Woods and Dekker, 2000). The appropriate use of automation is essential for the success of human and AS interactions and how trust is formatted and calibrated.

2.2.2 Trust in Autonomous Systems

Trust has become a big concern for the development and integration of complex AS. Just as it does in interpersonal relationships, trust plays a vital role in determining the willingness of humans to rely on AS in situations characterized by uncertainty. As opposed to interpersonal trust, that is conceptualized as an affective process, in trust in AS literature, it has been argued that trust is best conceptualized as a cognitive process, an attitude (Lee and See, 2004). While trust was traditionally viewed as existing between people, the rise of various AS motivated the application of trust to relationships between human and machine. One potential reason for these similarities is that to some degree, people's trust in technological systems represents their trust in the designers of such systems (Parasuraman and Riley, 1997). In this way, human-automation trust, when compared to interpersonal trust, can be characterized by a bigger distance and possible lack of knowledge regarding the trustee.

Similar to situational awareness and mental workload, it is important to stress that trust is a psychological construct. In particular, trust has been described as a cognitive state or attitude, based on factors such as predictability or operator expectations, that usually influences behavior dependence on the automated system (Lee and See, 2004; Parasuraman and Riley, 1997; Parasuraman and Wickens, 2008). Trust is not a performance measure; it is measured subjectively. The automation literature largely supports that the reliability of a system is a predictor of human trust (Lee and See, 2004; Parasuraman and Riley, 1997; Parasuraman, Sheridan, and Wickens, 2008; Sanchez, Fisk and Rogers, 2006). In a multi-task simulation of an automated agricultural vehicle (Sanchez, Fisk and Rogers, 2006), the recency of errors was negatively related to both perceived reliability of and trust in the system. Similarly, participants' trust of a robot has been shown to be negatively impacted after initially experiencing low robot reliability (de Visser et al, 2006) Other factors shown to influence trust in automation included the user's prior knowledge and understanding of system capabilities, the user's age, as well as the user's expectations of system performance (Sanchez, Fisk and Rogers, 2006).

A main issue with human-automation interaction, across a variety of domains, is the paradoxical problem that stems from the presence of automation. That means that while highly reliable automation is desirable in terms of improving overall system performance, it can negatively affect human performance (evident by poor monitoring). As long as the human remains an integral component of the human-automation system, the formula for successful human-automation interaction is the congruency between the human's system representation and the design parameters of the automation (Sanchez, Fisk, and Rogers, 2006).

Facilitating appropriate trust in automation is the key to improving the safety and productivity of human-automation interaction. Therefore, users with appropriate levels of trust in AS can reduce the frequency of misuse, disuse, or abuse of automation (Lee and See, 2004). More importantly, the appropriate use of automation relies on the calibration of trust and the capabilities of automation (Lee and See, 2004). Therefore, facilitating appropriate levels of trust in automation can reduce the frequency of misuse and disuse, and therefore trust is key to improving productivity and safety in human-automation interactions (Hoff and Bashir, 2015).

Numerous accidents can occur when operators misuse automation by over trusting it, or disuse automation as a result of under trusting it (Parasuraman and Riley, 1997). Building from this concept Lee and See (2004) define three states of trust leading to errors: distrust, mistrust, and over trust. Mistrust is lack of trust based on instinct or dispositional factors. Distrust, on the other hand, relates to the lack of trust based on previous experience or during the current interaction with a given AS. Over trust is poorly calibrated trust in which the level of trust overestimates the capabilities of the automation.

With the expansion of research on trust in AS, different definitions of trust with respect to automation have arisen. Muir (1994), for example, defines trust as a generalized expectation related to the occurrence of a future event. While Sheridan (2002) defines trust as a cause and effect that is based on the judged reliability, perceived robustness, and familiarity of automation. In Sheridan's expanded definition, he states that trust affects the interaction with automation and the interaction with automation affects trust. In the following sections explore the most influential theories of trust in automation. These theories are the framework for the theoretical model of trust in AS proposed by Hoff and Bashir (2015) and adopted by dissertation.

Lee and Moray (1992)

Lee and Moray (1992) drew from the model of trust in close relationships from Rempel and colleagues (1992), which defines trust in a human-human context as previously explained. This is the first attempt to model trust in a system dynamically to consider how trust is affected by system faults in addition to performance, however it is limited in the conclusions that can be drawn from it. They extend the concept of predictability, identifying three general dimensions of trust in the context of automation: foundation of trust, performance, process, and purpose, as described below.

- Foundation of trust is a worldview that assumes that there exist certain laws (both natural and man-made) that make trust of any kind possible
- Performance refers to the current and past performance of the automation. Lee and Moray (1992) refer to the stage of 'predictability' defined by Rempel, Homes and Zanna (1985) as a performance and include automation reliability and ability, in addition to predictability, as characteristics influencing this stage of trust development. Performance evaluations are made in relation to the specific goals of the operator, demonstrating the task-dependent nature of trust. Performance concerns whether the automation is completing the goals it was intended to complete. Performance describes what an automation technology is capable of achieving and encompasses both historic and present operational considerations such as reliability.
- Process is a dimension that describes how an automation technology operates and relates to the fundamental principles that regulate a system's actions. Process refers to how the automation operators and whether the thought corresponds to the dimensions of predictability and dependability in the Rempel model, while purpose roughly corresponds to faith.
- Purpose which gives insight into the reason an automation technology exists in the first place. This relates to the stage of 'faith' from Rempel and his colleagues (1985), and considers it to be the extent to which the automation is being used in line with the designer's intent. This stage, then, refers to why the automation was created, and this stage of trust attribution frequently depends on whether the operator understands the designer's intent for the automation.

Lee and See (2004)

The review of trust in automation by Lee and See (2004) greatly influenced subsequent trust in automation research. The model they developed considers the dynamics of trust in automation and its effect on reliance upon automation by proposing a dynamic interaction among the context, the human operator, the automation, and the automation's interface. Moreover, the model details a closed-loop process in which interaction with the automation influences trust, and trust influences interaction with the automation.

The biggest contribution of their model is that subsequently models have followed the format of separating the factors influencing trust in automation into the categories of human operator, automation, and environment/situation/context. However, despite the fact that their definition of trust in AS is one of the most widely used, there is less evidence of this model being used as foundation for empirical and experimental research.

2.2.3 Theoretical Model of Trust in AS

The theoretical model proposed by Hoff and Bashir (2015) is considered one of the most comprehensive models to integrate empirical evidence of factors that influence trust in AS. The model is intended to be applicable to a range of automated systems and situations. They analyzed 127 empirical studies which employed a variety of different AS in diverse experimental paradigms. Their analysis revealed three broad sources of variability in human-automation trust: the human operator, the environment, and the AS itself. These variables respectively reflect the three different layers of trust, previously identified by Marsh and Dibben (2003): dispositional trust, situational trust, and learned trust. Figure 1 details the complete model.

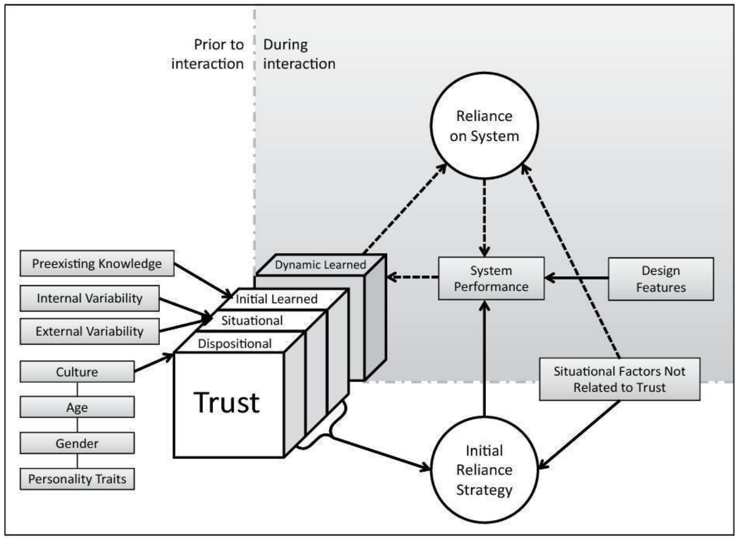

Figure 1: Complete Model of Trust in AS from Hoff and Bashir (2015)

Dispositional trust represents an individual's overall tendency to trust automation, independent of the context or the type of the AS. Moreover, it refers to long-term tendencies arising from both biological and environmental influence, and although these tendencies can change gradually over time (e.g., cultural values, age, and personality traits), it is generally stable within the course of a single interaction, as can be seen in Figure 2. This dimension is related to the human operator and it is highly dependent on tendencies related to individual differences. On the other hand, situational trust depends on the specific context of the human-AS interaction.

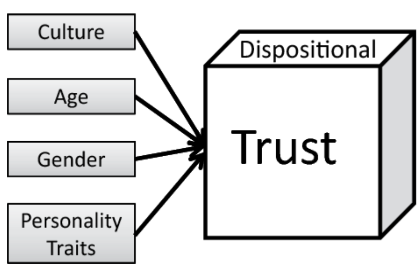

Figure 2: Factors Influencing the Dispositional Trust in AS (Hoff and Bashir, 2015)

The environment exerts a strong influence on situational trust, but context-dependent variations in an operator's mental state can also alter situational trust. The authors suggest two sources of variability in situational trust: the external environment and the internal environment, which are context-dependent characteristics of the operator, as shown on Figure 3. The external variables are perceived by the human operator and influenced by the context.

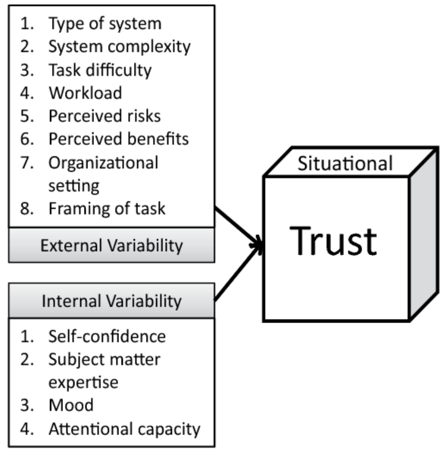

Figure 3: Influential Factors of Situational Trust in AS Proposed by Hoff and Bashir (2015)

Learned trust is closely related to situational trust since both are guided by past experience and the system performance. Moreover, the authors emphasize the difference between subject matter expertise (related to situational trust) and past experience with automation (related to initial learned trust). Therefore, for better understanding of the factors that operate in this dimension, the authors categorize it as initial learned trust and dynamic learned trust. Figure 4 illustrates the factors that influence learned trust, and the dotted arrows represent factors that can change within the course of a single interaction.

Initial learned trust represents the operator's evaluations of automation drawn from past experience, which means pre-existing knowledge prior to the interaction with the system. Initial learned trust can be guided by the system's reputation and previous experience with the given AS or a similar technology. Regarding the system's reputation, previous studies found that people display a tendency to trust automation more when it is portrayed as a reputable or 'expert' system, since it increases their expectations (de Vries and Midden, 2008).

Dynamic learned trust is the trust that evolves during the interaction. Design features of automation, like aesthetics, anthropomorphism, the ease of use of the AS, transparency of information, feedback loops, among others, influence the dynamic learned trust, but they do so indirectly, by altering perceptions of system performance. Thus, once an operator begins interacting with a system, its performance can impact dynamic learned trust, which can change drastically over the course of the interaction. Based on that, substantial research has shown that human operators adjust their trust in automation to reflect its real-time performance (Lee and See

2004). Within the context of a single interaction, most of those variables are stable, whereas performance is not. Thus, the authors complete their theoretical model explaining the influence of AS' performance and how operators adjust their trust in automation to correspond to its ongoing performance, which is affected by the reliability, validity, predictability, dependability, system failure, and usefulness of the system.

Reliability and validity are important antecedents of trust. Reliability refers to the consistency of an automated system's functions, and validity refers to the degree to which an automated system performs the intended task. Predictability refers to the extent to which automation performs in a manner consistent with the operator's expectations, and dependability refers to the frequency of automation breakdowns or error messages (Merritt and Ilgen, 2008). Trust in automation is always relative to a task requirement. If an operator realizes that using automation to perform a task actually makes the task more arduous, he or she will likely see no need to use and therefore trust automation. Thus, automation must first prove itself useful to operators in order for trust to be at stake.

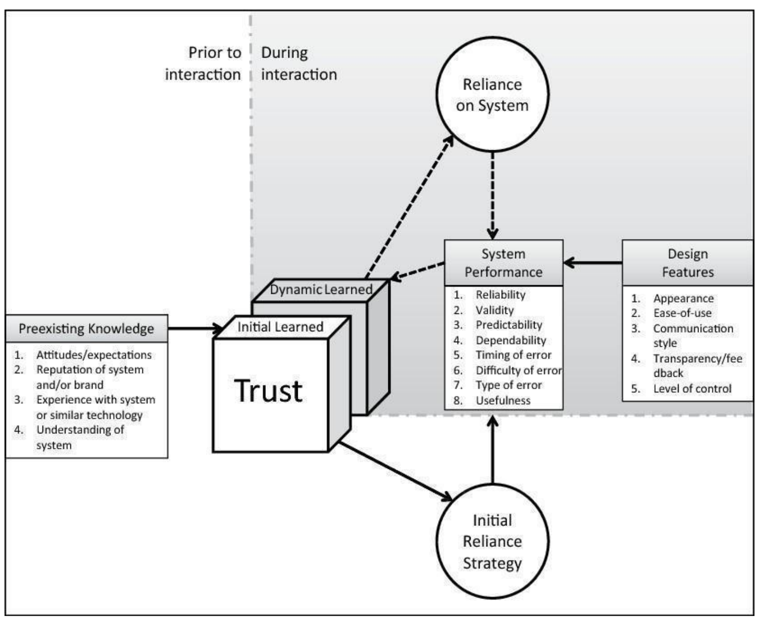

Figure 4: Categories of Learned Trust and Their Influential Factors

2.3 Situational Trust

As previously stated, the development of trust varies depending on the situation. Thus, the situational trust dimension has two broad sources of variability: the external environment and the internal, context-dependent characteristics of the operator. These variable factors are important not only because they directly influence trust, but also because they determine the degree of influence that trust has on behavior towards automation (Hoff and Bashir, 2015). This study focuses on the perception of benefits and risks of automation, as external variables, and their role in the formation of trust.

Each type of automation has certain benefits and risks associated with it. However, the benefits and risks are not equally dispersed across the types of automation, and they vary in how they influence users' situational trust. For example, when driving on cruise control mode, the driver might be issued a ticket for speeding if the cruise control is not working accurately. In contrast, if a person is undergoing open heart surgery with a robotic arm being used for additional assistance, then the risk to the individual would be higher and a person's trust may be affected. Thus, the cruise control, even if not working perfectly, presents a smaller risk compared to the failures related to the medical robotic arm. These are situational factors, and as previously mentioned situational trust is influenced by the external environment and context-specific characteristics of the operator. These factors may include the system's complexity, workload, and most importantly, the perceived risks and benefits of trusting the system (Hoff and Bashir, 2015).

Therefore, to research the internal and external variables of situational trust in AS, it is necessary to consider each type of automation separately, and this study has autonomous vehicles (AV) as its focus. While the development of AV technology may enhance safety and reduce car accidents, what is not completely understood is why accidents occur with AV when humans are the 'backup systems' monitoring the system function, and how technology can fix that. This is one of the biggest challenges to overcome in order for AV to be successful.

Government data identifies driver behavioral error as a factor in 94 percent of crashes (Lynberg, 2020). Higher levels of vehicular autonomy have the potential to reduce risky and dangerous driving behaviors. The greatest promise may be in reducing the devastation caused by impaired driving, driving under the influence of drugs or alcohol, unbelted vehicle occupants, speeding and distraction (Welch and Behrman, 2018), as well as mobile phone use while driving. As an example, in a controlled experiment, researchers found that when drivers were talking on either a handheld or hands-free cell phone, their braking reactions were delayed and they were involved in more traffic accidents than when they were not conversing on a cell phone.

Moreover, the study found that the impairments associated with using a cell phone while driving can be as profound as those associated with driving while drunk, in terms of causing people to drive more aggressively (Strayer, Drews, and Crouch, 2006).

On the other hand, predictions that AV would be commercialized soon have changed after a self-driving car being tested by Uber hit and killed a woman walking a bicycle across a street in Tempe, Arizona in 2018. According to the Tempe Police Department, a safety driver was at the wheel of the vehicle, but was watching videos on the phone before the crash. Three Tesla drivers have died in crashes that occurred when they failed to detect and react to hazards while driving in autonomous mode (Plungis, 2020). Furthermore, a research investigating the use of semi-automated vehicles (i.e. Tesla Model S), found a reduction in driver physiological activation and slower response times in participants when driving in the semi-automated mode compared to manual mode. The researchers concluded that semi-automated driving might not mitigate the safety consequences of human error. Instead, they suggested that it might reduce the level of driver monitoring, possibly followed by a spike in automation-generated distraction (Biondi et al, 2018). The transfer of control from human to machine and from machine to human happens in many AS applications, including safety-critical environments like medicine, air traffic control, and mission control for space shuttle and space station operations.

Previous research on unmanned aerial vehicles have presented similar concerns, and numerous studies have been developed as a result on how to better develop human-machine interfaces. Parke and colleagues claim that inadequate human system integration not only has costs in terms of safety and mission effectiveness, but that it also increases the overall complexity of the system, increases the time needed to perform tasks, complicates training and maintenance, and decreases the capabilities of the system (Parke et al, 2010).

2.4 Autonomous Vehicles

Although fully self-driving vehicles, that is, vehicles capable of driving people from point A to point B without any human-driver intervention, are not yet implemented, driver assistance technologies are already helping to save lives and prevent injuries. Other partial AS systems have been implemented and are on the road. For example, several of today's new vehicles have technology that helps drivers avoid drifting into adjacent lanes or making unsafe lane changes, or that warns drivers of other vehicles behind them when they are backing up, or that brakes automatically if a vehicle ahead of them stops or slows suddenly. These and other safety technologies use a combination of hardware (sensors, cameras, and radar) and software to help vehicles identify certain safety risks so they can warn the driver to act to avoid a crash. However, these systems still require that the user be in control (Flemisch et al., 2013).

According to the National Highway Traffic Safety Administration (NHTSA), the classification of driving automation systems is a way of establishing a universal language in order to understand the basis of these systems. The different levels range from no automation, designated level zero, to fully automated and self-driving systems, designated level four (Marinik, et al., 2014). The description of the different levels of driving automation are presented in Table 1.

Table 1: Levels of Vehicle Automation Description Defined by The National Traffic Safety Administration (Lynberg, 2020)

Level of Automation	**Description**
0	The human driver does all the driving
1	An advanced driver assistance system (ADS) on the vehicle can sometimes assist the human driver with either steering or braking/accelerating, but not both simultaneously.
2	An ADAS on the vehicle can itself actually control both steering and braking/accelerating simultaneously under some circumstances. The human driver must continue to pay full attention ("monitor the driving environment") at all times and perform the rest of the driving task.
3	An ADS on the vehicle can itself perform all aspects of the driving task under some circumstances. In those circumstances, the human driver must be ready to take back control at any time when the ADS requests the human driver to do so. In all other circumstances, the human driver performs the driving task.
4	An ADS on the vehicle can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances. Humans need not pay attention in those circumstances.
5	An ADS on the vehicle can do all the driving in all circumstances. The human occupants are just passengers and need never be involved in driving.

As automation capability advances from Level 2 to Level 3 and above, human drivers become increasingly out of the control loop in the dynamic driving task. With Level 2 automation, the driver is ultimately responsible for the driving task and has to actively monitor the road conditions. With Level 3 automation, by contrast, the autonomous vehicle is able to monitor the environment in some conditions, which allows the driver to engage in other non-driving-related tasks. If the autonomous vehicle reaches its system limit (e.g. due to automation failure, adverse weather, lane marks disappearance), however, the driver will be requested to resume control of the vehicle within a limited amount of time.

According to Bainbridge (1983), takeover transition consists of two primary tasks: monitoring and taking over control. This involves the human driver receiving information, processing the information, and taking the control of the vehicle backs when necessary. For some drivers this is perceived as a benefit, since they are then capable of paying attention to other things while driving, and the safety of the car is enhanced. On the other hand, other drivers perceive certain risks to these technologies, like the probability of technological failures, and their lack of control of the vehicle. Previous research found a positive correlation between perception of risks and benefits and situational trust, as follows.

2.4.1 Perception of Risks

According to the framework provided by Hoff and Bashir (2015), perceived risk is an important situational trust factor because an environment always involves some degree of uncertainty. Some authors even suggest that without some element of risk, trust can be considered irrelevant (Wicks, Berman, and Jones, 1999). Several studies have demonstrated the impact of risk on whether or not humans are willing to rely on AV.

For instance, Perkins and colleagues (2010) found that participants trusted a vehicle's navigation system less in a riskier situation (in this case, the presence of more dangerous road hazards). Conversely, Lyons and Stokes (2012) found that participants relied on an automated aid more than a human aid in a high-risk condition. However, examining risk in the laboratory presents a unique challenge because it is difficult to ensure that participants have something at stake (Satterfield et. al, 2017). Satterfield and colleagues investigated the effect of differing levels of risk on trust in AS, and in accordance with previous findings, they predicted that trust would be lower in a scenario characterized by high risk. Their results suggest that even though participants in a high-risk situation intervened more, they did not score significantly higher on trust than participants in the low risk. This pattern of results demonstrates that in a high-risk situation, operators may under-rely on automation, leading to its misuse, and probably unnecessarily increasing their own workload (Satterfield et al, 2017).

2.4.1.1 Types of Risks

Previous research found differences on the perception of risk with regards to the type of AV. For instance, the scenario of a human operating a driverless car on public roads was not perceived by the driver as risky when compared to the scenario of operating an autonomous motorcycle and autonomous bicycles, the latter of which were subjectively rated on average in the "high" end of the risk scale. Moreover, autonomous cars were rated as equivalent to human-operated cars. However, when given a scenario of traveling in AV, driverless cars were considered significantly riskier than traveling in existing autonomous trains (Thomopoulos and Givoni, 2015).

A study conducted by Hulse, Xie and Galea (2018) found that AV were perceived as a "somewhat low risk" form of transport, and while concerns existed, there was little opposition to the prospect of their use on public roads. However, as opposed to human-operated cars, AV were perceived differently depending on the road user's perspective: riskier when a passenger yet less risky when a pedestrian. These results suggest that perceptions of risk might have been shaped significantly by issues concerning road interactions, thus highlighting the need to consider the public not as a single entity but as various road users. Moreover, people are capable of having multiple different points of view depending on the nature of their potential role in the interactions with AVs (Kyryakidis et al, 2019). This is an important finding specially for the user experience and development of personalization. The context of use, even for the same user, exerts an important role and changes the formation of trust. Moreover, it is important to investigate the user not only based on their individualities, but also on the differences related to which role they played.

Research has shown that an increase in internal risk both reduces trust and makes trust more important, and that with longer periods of time exposed to risk, the perceived risk level decreases even though the objective risk level remains high (Titchener, White, and Kaye, 2009). Additionally, external risk is likely to increase trust and reliance on automated driving systems (ADS), as a sense of vulnerability can prompt trust and trusting behaviors of trustors towards trustees (Pertersen et al, 2018a). For example, we might expect drivers to rely more on ADS in the presence of road sign distractions, fog, etc., with trust in ADS increasing as well (Pertersen et al, 2018a). Research also indicates that driver-perceived uncertainty and risk is dependent on trust in ADS, as subjective risk can be reduced by increasing trustworthiness (Petersen et al, 2018b).

According to Petersen and colleagues (2018b), internal risk and external risk have different effects on trust. The results imply that internal risk, in other words the reliability of the investigated system, has a negative influence on trust in the driving automation: when the warning system is unreliable, the drivers tend to trust less in the vehicle's autonomy. Additionally, the impact of external risk, like the environment, is minor compared to that of internal risk.

2.4.2 Perception of Benefits

Previous research found that with higher and more positive expectations, people would be more likely to accept and adopt AVs (Penmetsa, 2019; Gkartzonik and Gkritza, 2019). Expectations also have an indirect impact on the adoption of AVs: positive expectations influence the generation of positive attitudes, which are correlated with reliance and trust in AV. Although previous studies have already identified this correlation, less is known about how benefits, like the environmental sustainability and accessibility, among other positive expectations relate to higher trust in AV. Perceptions of technology's usefulness may also be tied to perceived benefit. Previous research has noted that how older adults perceived the benefits of technology was more predictive of the technology's acceptance than the technology's perceived expense (Mitzner et al., 2010). Such research indicates the strong role that perceptions play in terms of accepting and ultimately adopting technology. No previous findings have investigated how the perception of specific benefits relates to the level of trust in AV.

Chapter 3. Method Overview

This chapter presents an overview of the methods employed in this dissertation, which is exploratory and designed to use mixed methods – quantitative (survey) and qualitative (interviews). While the survey and the interview had different purposes and outcomes, both contributed to answering the main research question: "How does the perception of benefits and risks of AVs affect the formation of situational trust in AVs?". Moreover, the planning and completion of the interview played a role in building upon the survey results. The Institutional Review Board at the University of Illinois at Urbana-Champaign approved all procedures from data collection to study measures through the IRB 20182 (documents presented in Appendix A). All participants provided electronic informed consent before data collection.

The survey aimed to answer the supportive research question **(RQ1)** "How does the perception of benefits and risks, as external variables, affect situational trust in AVs?" The survey was developed based on the theoretical trust model in automation from Hoff and Bashir (2015), and 226 responses were adopted for the analysis. The quantitative analysis process included descriptive statistics and word frequency of open-ended questions using the software SPSS. After identifying the most frequent words, the open-ended questions were qualitatively analyzed using thematic analysis. Further details are described in Chapter 4.

Responses from the survey might not represent what users do or will do when interacting with an automated automobile system in real-life events. The results show what participants think they would do. Therefore, it is difficult to understand the role of internal and external variables and how they affect situational trust by purely analyzing data from the survey. In terms of research methods, the solution would be to conduct observations and task exercises. It would then be possible to observe and capture the role of the situational trust variables while users interact with AVs. However, due to the lack of fully AVs available to be tested on campus, neither a working high-fidelity prototype, the challenge was to understand how to investigate trust in AV in real-life events. The most feasible solution was to adopt analogy research, or Design-by-Analogy (DbA). Analogy refers to associating a situation from one domain (source) that is usually poorly understood to another domain (target) that is well-understood. The association is possible due to relations or representations (Gentner and Markman, 1997; Kurtz, Miao, and Gentner, 2001). Design-by-Analogy (DbA) is a design methodology wherein new solutions are generated in a target domain based on inspiration drawn from a source domain through cross-domain analogical reasoning (Goel, 1997; Christensen and Schunn, 2007). Studies have shown that DbA can help designers mitigate design fixation (Linsey et al., 2010) and improve design ideation outcomes (Fu et al., 2013).

The qualitative part of the research conducted a semi-structured interview to answer the supportive research question: **(RQ2)** "How does the perception of benefits and risks of an AV's analogous system affect situational trust?" The chosen analogous system was a cruise control. Although the analogous experience is different in nature, in both cases (while using cruise control or riding an AV) users do not have complete control of the vehicle and they interact with an autonomous system. Due to the COVID 19 pandemic, the initial plan to conduct in-person observations was canceled, and the employed method was remote and semi-structured interviews. Seventeen participants were interviewed, and their responses were analyzed using content analysis. The detailed process is described in Chapter 5.

Finally, Chapter 6, as an exploratory reflection, aims to answer: **(RQ3) "**What are the perceptions of benefits and risks of the AV's analogous systems that influence situational trust in AVs?" Here, the responses from both studies are triangulated, and the benefits and risks from both experiences are discussed regarding the evidence of their connection.

Chapter 4. Survey

This chapter details the procedures, sample size, and analysis process of the survey, which includes descriptive statistics and thematic analysis of open-ended questions. The results identified internal and external variables that might influence situational trust in AVs.

4.1 Survey Structure

I conducted a survey to identify the internal and external situational variables that might influence trust in AV. This survey consisted of 21 questions in total that included one self-report questionnaire, three open-ended questions, and 16 multiple- and single-choice questions. As presented in Table 2, these questions aimed to collect information about the participants' perception of AV trustworthiness, automation preferences, transportation habits, automation knowledge, and interaction scenarios involving AVs, as well as their perceptions of the risks and benefits of AVs.

Additionally, I used three questions as an attention check to assess the respondents' levels of attention, which is common in Mechanical Turk surveys. For example, an attention check might read, "Please select the option 'strongly agree'." Of the three attention check questions, the participants needed to answer at least two correctly; otherwise, their results were omitted from the analysis. In total, 226 answers were accepted. The complete survey can be found in Appendix B.

Table 2: Survey Organization

Main Topic	**Topics investigated**	**Number of Questions**
Demographics	Age, gender, ethnicity, location, and income	6 single-choice
Transportation habits	Vehicle ownership, reasons for buying the vehicle, hours in traffic or driving, and use of public transportation	4 single-choice
Trust	Perception of trustworthiness, benefits and concerns about AV adoption, and interaction scenarios that involve AV	4 multiple-choice, 5 single-choice, and 2 open-ended
Validation	The participants' attention levels during the survey	3 single-choice

4.1.1 Measures

Perception of AVs' Trustworthiness

I used the scale developed by Jessup, Schneider, Alarcon, Ryan, and Capiola (2019) to measure the participants' perceptions of AVs' trustworthiness. In comparison to research that involves interpersonal trust, research that investigates the propensity to trust automation is sparse. As such, there are few scales with which to measure this construct. Several researchers have used the Complacency-Potential Rating Scale (CPRS), and it has an empirical basis, but the items it uses are broad and reference different types of automation (e.g., ATMs, cruise control, and automated devices that are involved in aviation). Jessup et al. (2019) developed a scale based on CPRS to measure the perceived trustworthiness of AVs, which is presented in Table 3. The responses to this scale were scored on a five-point Likert-type scale that ranged from 1 ("strongly disagree") to 5 ("strongly agree"), which means that the higher a participant's score was, the higher their trust in AVs would be.

Table 3: AVs' Trustworthiness Questionnaire (Jessup et. al, 2019)

Perceptions of AV Trustworthiness Likert Scale Items
1. Generally, I will trust autonomous vehicles.
2. Autonomous vehicles will help to solve different types of problems.
3. I think that it will be a good idea to rely on autonomous vehicles for help.
4. I will not trust the decisions made by an autonomous vehicle *[Reversed - Score]*.
5. Autonomous vehicles will be reliable.
6. I will rely on the technology used in autonomous vehicles.

The Main Benefits and Risks Related to AVs

Based on previous academic and non-academic research (Milakis, 2019; Capgemini, 2019; Perkinscoie, 2019; Westenberger, 2018; Adriano et al, 2017; Hohenberger et al., 2016; Howard and Dai, 2014; Begg, 2014; Payre et al., 2014), that explored the risks and benefits of AVss, I selected 20 items more commonly identified as potential benefits of the development and adoption of AV, and 20 items related to risks of AVs. These items relate to social aspects, accessibility, safety, the economy, law, the environment, and infrastructure. In order to understand the main benefits and concerns that the participants perceived, I asked them to choose the eight most considerable benefits and concerns from the list. They were then asked to reduce each set to highlight their three most significant benefits and concerns related to AVs and categorize them as being related to individual or societal benefits or concerns. This set of questions was designed to gather information on how trust in AVs might change when considering benefits and concerns regarding their impact on society (the collective level) or the participant (the individual level).

The Participants' Current Behaviors and Individual Preferences Towards Vehicles and Transportation

The remaining questions in the survey were designed to gather information regarding the participants' current behavior in relation to automation and other transportation habits, as well as their related preferences.

- Preferred levels of automation in AV: describes the five levels of automation and asks the participants to choose their preferred levels.
- AVs interaction scenarios: describes different situations in which the participant chooses their preferred type of interaction with AVs in the given scenario.
- Transportation habits: utilizes different sets of questions to understand the participant's current habits and preferences regarding transportation, such as their weekly time spent in traffic, weekly time spent driving, use of public transportation, and adoption of alternative modes of transportation.
- Previous experiences with driving technologies: utilizes a list of automated automobile technology from established features such as seat belt sensors to more recently developed solutions such as automated breaks.

4.1.2 Analysis Process

I analyzed the data in three phases using descriptive statistics and qualitative thematic analysis. I used the descriptive statistics to identify the participants' scores on trust in AVs, their perceptions of AVs' benefits and risks, their preferred levels of automation, their preferred spare activity time while riding in a vehicle that is operating in autonomous mode, transportation habits (transportation modes and time spent in traffic), current experiences with autonomous automobile technology, and what they would do in four different scenarios that were designed to explore interaction with AVs. I analyzed their answers according to their frequency, mean, standard deviation, and variance in responses using SPSS software.

The second phase of the analysis aimed to understand why the participants chose one item over the others as the biggest risks of AVs. Two open-ended questions ("Please write a few sentences to describe why do you think [the topic chosen as #1 concern] might be the biggest concern regarding autonomous vehicles in society" and "Please write a few sentences to describe how do you think [the topic chosen as #1 concern] might be the greatest concern for an individual") were qualitatively analyzed. First, I created a word cloud to identify the words that appeared most frequently in the responses. Second, I grouped the answers according to the most frequent words. Afterward, I analyzed each group of answers using thematic analysis and organized them into sub-categories of concerns.

4.1.3 The Recruitment Process and the Participants

I recruited the participants on Amazon Mechanical Turk using a non-probability convenience sample. This sample collected responses from 271 participants from 30 states, which covered every region of the continental US. I conducted three batches of data collection to guarantee the distribution of gender. Based on the completion rate and attention check responses, 227 participants were accepted for analysis. The participants (46% male) ranged between 20 and 78 years old (M = 35, SD = 10). The full online experiment was designed to last 10 minutes. The participants in this experiment were paid $1.00.

4.2 Results

4.2.1 The Participants

This section aims to identify the participants' main habits and current behaviors that relate to the use of vehicles. This section also attempts to explain the nature of the participants' current behaviors. This is an important step in the investigation since it is known that previous experience influences trust and can impact an individual's perception of a vehicle's trustworthiness.

The average participant in the survey identified as female (48.58%), was between 23 and 38 years old (54.06%), and had at least a college degree (59.29%). They owned at least one vehicle (86.33%). They reported that they spend 1 to 2 hours per week in traffic (74%) and the main reason is for commuting to work (55%). They had a trust in AV score of 22 points (from a range between 6 to 30).

4.2.1.1 Vehicle Ownership

The majority of the participants (86.33%) owned at least one vehicle, while 8.37% of the participants knew how to drive but did not own a car at the moment; 5.28% did not know how to drive. Among the participants that owned at least one car, the majority owned a passenger car (47.79%) or an SUV (27.71%), as described in Table 4.

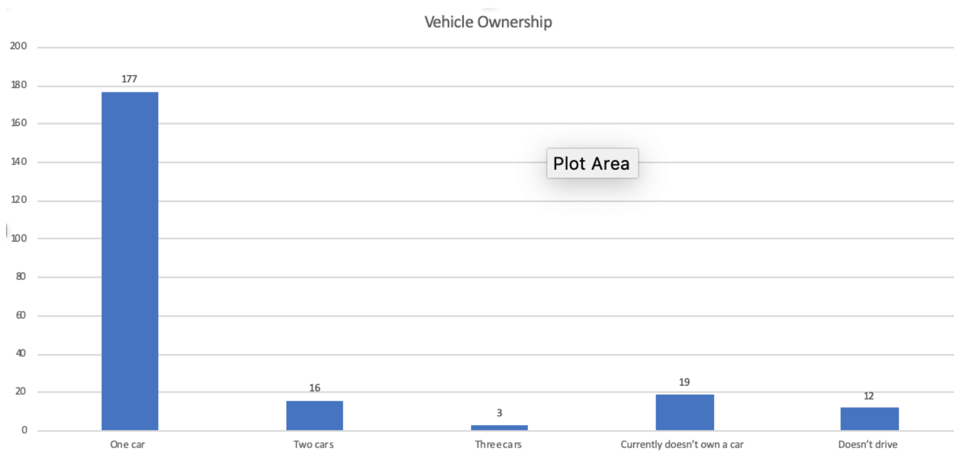

Figure 5: Frequency Spread of Type of Vehicle Ownership

Table 4: Frequency of Type of Vehicle Ownership

Type of owned vehicle	**%**
I do not drive.	4.82%
I had a vehicle in the past, but I don't own one anymore.	3.61%
I know how to drive, but I currently do not have a vehicle.	4.02%
I drive a minivan, van, or MPV (multipurpose vehicle).	3.61%
I drive a motorcycle or scooter.	1.20%
I drive another type of vehicle (please specify what type of vehicle you own).	0.80%
I drive a passenger car (any type or size).	47.79%
I drive a pickup truck.	6.43%
I drive an SUV (sport utility vehicle).	27.71%

The participants who confirmed that they owned a vehicle were asked to answer a follow-up open-ended question to explain their motivations and reasons for having chosen the car that they currently owned. This question was asked as an open-ended question to avoid biasing the participants into choosing between given alternatives that are more socially responsible than others and less individualistic.

I manually analyzed all 196 responses from the participants who owned at least one vehicle using content thematic analysis. First, I read all the answers were read to initially understand the participants' reasons. The categorization process focused on determining why each participant chose to purchase their vehicle. The ten initial categories included the following: the economy, the size of the vehicle, safety, comfort, style, reliability, sustainability technology, acceptance of a gift, and locomotion.

For the second step of the categorization process, I read the participants' responses in each category to verify whether all the responses had the same meaning and were related to the same attributes and/or behaviors. I divided three main categories into subcategories because the responses related to different attributes. For instance, many participants shared the same main reason for purchasing their vehicles: the –economy. However, the participants presented different economical aspects that affected their decisions: for example, some based their decisions on a vehicle's purchase pricing ("The price for this vehicle was very good"), and others based their decisions on fuel economy ("I bought a sedan to minimize fuel consumption"). Table 5 presents all the categories and subcategories.

Table 5: Why Participants Bought Their Current Vehicles

Reasons for buying the car	**Description**	**Subcategory**	**Reference**	**Count**
Financial Economy	The money that can be saved with the vehicle's purchase regarding either the vehicle's value or fuel economy.	Vehicle's purchase price	"I loved the **price when I bought**…"	94
		Fuel economy	"...because of the excellent **gas mileage**…"	77
Size	The size of the vehicle.	Size, regardless of the reason	"**Compact** size…"	27
		Large enough to transport my family	"I have a **large family**, and we needed this vehicle"	32
		Large enough to transport a variety of things	"I brought my sub to be able to **haul bigger things** …"	54
Locomotion	The main reason to use the vehicle for transportation.	The independence to move around	"So that I didn't have to **rely on people** to get me to the places I needed to go to. I like to have the **freedom** of my own car."	12
		Convenience	"It is **convenient,** especially with children and errands to run."	29
		Commute to work	"The vehicle was needed for **commuting to work**."	19
		No other type of transportation was available	"I live in an area where **public transit is limited** because it is a suburb of a city…"	27
Safety			"The **safety** rating of the car reviews…"	24
Comfort	Overall comfort of the vehicle.		"It provides **comfort.**"	13
Style	The vehicle model and style (luxury, sedan, or SUV).		"It was the **style** of the car. It's a **sedan**…"	9

Table 5 (cont.)

Reliability	The perception of the vehicle's reliability.	Overall reliability		
		Brand reliability	"It's reliable and a good **brand** (Toyota)."	21
Sustainability	The vehicle's low impact on the environment.		"I chose a hybrid car because it saves some gas and it's **more ecological."**	3
Gift	The vehicle was not bought by the participant but was received as a gift. There was not a purchase decision involved.		"My parents **bought it for me** when I was in college"	5
Technology	The vehicle's available technological features.		"...has the **technology package** included, so I have driver assist, lane change assist, brake assist…"	7

The benefit that most frequently impacted the participants' purchasing decisions was the economic attributes, with a total of 164 statements found; the participants' responses related to the amounts of money that they were able to save when buying their vehicles (94) or the money that they saved because of more economical fuel consumption (77). The size of the vehicle was the second most cited benefit. Thirty-two statements related to the fact that a larger vehicle was needed to drive family members, and 54 statements mentioned that bigger size is a need a larger vehicle was needed for caring and transportation. While the majority of the participants preferred larger vehicles, especially SUVs, only three participants out of 195 stated that the small size of their vehicles motivated their purchasing decisions.

In summary, it is possible to say that the participants made their decisions based on attributes that affected them directly instead of the effect that their car might have on society through aspects such as sustainability and security.

4.2.1.2 Time Spent in Traffic Using Public Transportation Versus Driving.

In the next question, participants were asked about the time they spend in traffic such as number of hours, type of transportation used, and reasons for being in the traffic. This information can bring understanding on how current habits might affect trust in AVs.

The majority of the participants spent less than one hour per week in traffic using public transportation (74.34%) or driving (31.28%), as Table 5 demonstrates. However, it is possible to observe from the plot presented in Figure 6 that the participants spent more time in traffic driving than they did using public transportation.

Further investigation should be done to understand if the score of trust in AV can be correlated with the use of public transportation and ride sharing. In both situations, participants are not in control of the driving performance and they usually engage in a spare time activity, which is analogous to the experience of riding an AV. This analysis was not possible to be completed in this study with an acceptable margin of error (5%) and confidence level (95%) because of the lack of responses.

The participants gave several reasons why they encountered traffic related to commuting to work (55.95%) and grocery trips (17.62%). Ten participants cited other activities, including doctor or healthcare appointments (4 out of 10), multiple errands (3 out of 10), and social visits with family and friends (3 out of 10). The complete results are presented in Table 6.

Table 6: Comparison of Weekly Time Spent Using Public Transportation and Driving

Hours per Week	**Public Transport**	**%**	**Driving**	**%**
Less than 1 hour	168	74.34%	71	31.28%
From 1 to 2 hours	23	10.18%	55	24.23%
From 2 to 3 hours	21	9.29%	43	18.94%
From 3 to 4 hours	7	3.10%	24	10.57%
More than 4 hours	7	3.10%	34	14.98%

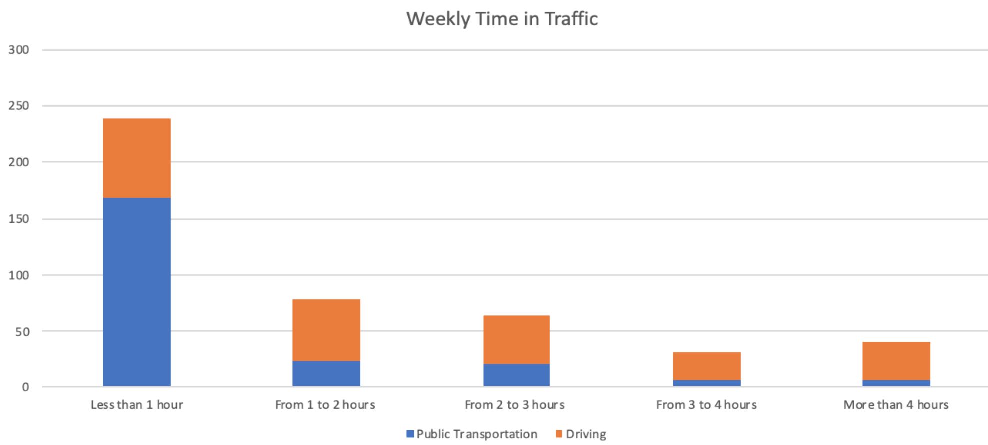

Figure 6: Comparison of Weekly Time Spent Using Public Transportation and Driving

Table 7: Frequency of Reasons for Time Spent in Traffic, Regardless of It Being Spent on Personal or Public Transportation

Reasons for driving	**Count**	**%**
Driving children to school	15	6.61%
Grocery shopping	40	17.62%
Other types of activities	10	4.41%
Personal shopping trips	31	13.66%
School	4	1.76%
Work	127	55.95%

4.2.1.3 Alternative Transportation Modality.

To understand transportation habits besides driving, I asked the participants to reply to the following question: “What are the different modes of transportation that you have used during the past year as an alternative to driving either a car or motorcycle?” They responded using a Likert scale, which allowed me to measure the frequency of use. Their scores ranged from 6 (“every day”) to 1 (“never”). Table 8 presents all the results for each transportation mode. Ridesharing (e.g., Uber or Lyft) was the most frequently cited mode of transportation besides driving, which was followed by public transportation.

Table 8: Transportation Habits Frequency Analysis

Alternative types of transportation	**Never**	**Rarely**	**1X or 2X per month**	**Every week**	**2X per week**	**Every day**
Car sharing (e.g., Zipcar)	78.41%	14.98%	2.64%	2.64%	0.88%	0.44%
Ride sharing (e.g., Uber and Lyft)	31.28%	33.48%	23.35%	6.61%	4.41%	0.88%
Bike sharing	82.82%	10.57%	2.64%	0.88%	2.64%	0.44%
Electric scooter sharing	87.22%	9.25%	0.88%	0%	1.32%	1.32%
Bike from a city rental service	80.62%	14.10%	1.76%	1.32%	1.76%	0.44%
Electric bike from a city rental service	88.55%	6.61%	1.76%	1.32%	1.32%	0.44%
Public bus	42.29%	31.28%	10.13%	9.25%	3.96%	3.08%
Taxi	44.49%	38.77%	9.69%	2.64%	3.08%	1.32%
Subway or train	50.22%	28.19%	6.17%	6.17%	3.96%	5.29%
Carpooling	54.19%	23.35%	12.78%	4.85%	2.20%	2.64%
Private company transportation	77.53%	12.78%	2.64%	3.08%	2.64%	1.32%

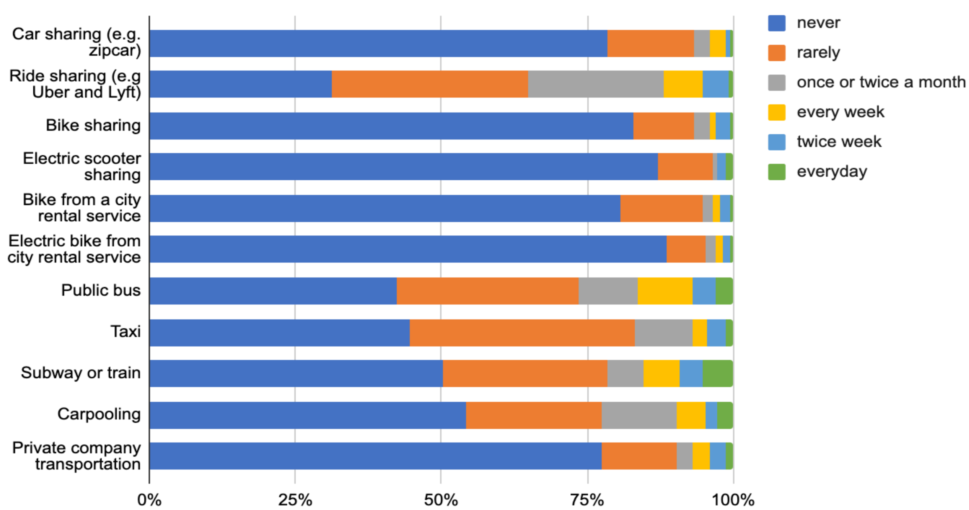

Figure 7: Frequency of Alternative Transportation Modes

4.2.2 The Perception of AVs' Trustworthiness

Each item that was part of this scale was individually analyzed, and the results of the descriptive statistics are presented in Table 9. As described by Jessup et al. (2019), the total score for AV trustworthiness is obtained by averaging the scores for each question. The total score, which is used to measure the participants' trust in AVs, ranged from a minimum score of 6 to a maximum of 27. The responses presented a mean score of 20.12 and a median of 22. Figure 8 plots the spread of the participants' scores; it is possible to observe a right-skewed trend, which means that the majority of the participants perceived AVs as highly trustworthy. The standard deviation was 4.08 with a variance of 16.06. The complete report of the participants' total scores is presented in Table 10.

Table 9: Descriptive Statistics of Perception Regarding AV Trustworthiness

	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**
Mean	3.24	3.87	3.36	2.77	3.47	3.38
Std Error	0.075	0.066	0.077	0.075	0.065	0.075
Median	4	4	4	2.5	4	4
Std Dev	1.12	0.99	1.15	1.12	0.98	1.12
Variance	1.26	0.98	1.32	1.26	0.96	1.26
Kurtosis	-0.93	0.98	-0.65	-0.79	0.006	-0.50
Skewness	-0.35	-1.06	-0.47	0.389	-0.65	-0.63
Conf. Level (95%)	0.147	0.130	0.151	0.148	0.129	0.147

Table 10: Total Score of the Descriptive Statistics Regarding the Perception of AV's Trustworthiness

AVs' Trustworthiness	
Mean	20.12
Std Error	0.27
Median	22
Std Dev	4.08
Variance	16.65
Kurtosis	0.20
Skewness	-0.74
Range	21
Count	226
Conf Level (95%)	0.53

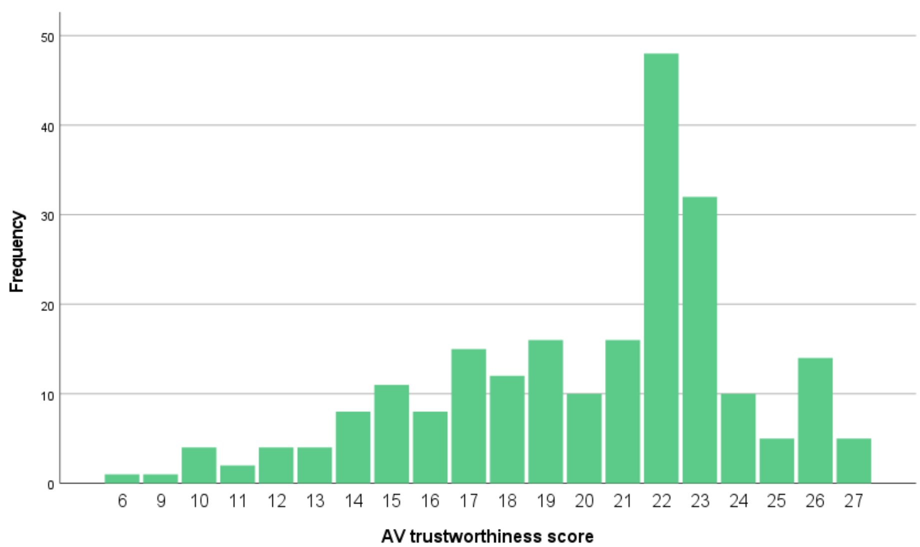

Figure 8: Spread of Perception Regarding AV Trustworthiness Scores

4.2.3. The Main Benefits of AV Adoption

For the next set of questions, I asked the participants to choose their top eight benefits from a list of 20 items, as presented in Table 11. The goal was to understand the relationship between the perception of benefits and concerns regarding AVs and situational trust in AVs. The results demonstrated that "More locomotion independence for disabled and elderly people"

(9.46%) was regarded as the biggest benefit of AV adoption, which was followed by “Fewer traffic accidents” (8.60%) and “Greater access for people living in areas with limited public transportation or in remote areas” (7.50%).

Table 11: Frequency of AV Benefits

#	Answer	%	Freq
1	Increased free time for family, entertainment, and work while traveling or commuting.	6.11%	128
2	More locomotion independence for disabled and elderly people.	9.46%	198
3	Greater access to healthcare with improved patient mobility.	6.11%	128
4	Greater access for people living in areas with limited public transportation or in remote areas.	7.50%	157
5	Improved safety for pedestrians and bikers.	6.88%	144
6	Fewer traffic accidents.	8.60%	180
7	Producer liability preventing technology failures from happening.	2.48%	52
8	Lower insurance premiums because the autonomous vehicle will be insured rather than the driver.	6.69%	140
9	Lower insurance premiums because insurance claims would be made against the autonomous vehicle’s manufacturer and not the driver.	5.11%	107
10	Driver licensing will not be required anymore.	3.58%	75
11	Vehicle registration will be easier and faster.	2.72%	57
12	New laws and legislation regarding autonomous vehicle operation will be led by the U.S. Department of Transportation instead of manufacturers and technology companies.	3.34%	70
13	Even though the vehicle is fully automated, the law requires drivers to be present at the wheel and ready to intervene at the first sign of tech failure.	4.58%	96
14	Decreased expenditure on fuel.	5.06%	106
15	Reduced energy consumption.	6.35%	133
16	Less dependence on foreign oil.	3.39%	71
17	Higher vehicle flow rates on existing roads, which will increase lane capacity.	4.73%	99
18	Fewer cars on the roads.	3.15%	66
19	More parking spaces.	1.91%	40
20	Successful interactions with non-autonomous vehicles.	2.24%	47
	Total	100%	2,094

To respond to the following group of questions, the participants needed to categorize each of the top eight benefits and concerns that they previously chose as if they were related to society or them as individuals. I asked the participants to categorize the items to better understand their mental models when deciding what is a benefit and what is a risk and what type of assessments they were making. For instance, were they thinking more of the impact that AVs might have on their own lives or the overall impact that they might have on society? This set of questions was provided after they had already chosen their top eight benefits and risks (the previous two questions) to reduce any bias that might cause them to choose societal concerns.

Regarding the biggest societal benefits, the participants perceived "More locomotion independence for disabled and elderly people" as the main benefit (14.84%), which was followed by "Fewer traffic accidents" (13.68%) and "Greater access for people living in areas with limited public transportation or in remote areas" (9.68%). The frequency is described in Table 12.

Regarding AV benefits for the individual, "Increased free time for family, entertainment, and work while traveling or commuting" was the greatest benefit (12.65%), which was followed by "Lower insurance premiums because the autonomous vehicle will be insured rather than the driver" (11.234%). "More locomotion independence for disabled and elderly people," which represents the biggest societal benefit, was the third main benefit for individuals (10.19%).

Based on the initial ranking of the overall benefits of AVs, it is possible to observe that the three main benefits ("More locomotion independence for disabled and elderly people," "Fewer traffic accidents," and "Greater access for people living in areas with limited public transportation or in remote areas") are all the same as the main benefits for the society. That means that the overall perception of benefits of AVs is considered more beneficial on the societal level than the individual level. The current analysis of the benefits of AVs is especially helpful to understand the participants' mental model towards AVs. Here, they showed to favor a more societal vision when thinking about the benefits of AV adoption.

Table 12: Perception of AVs' Benefits for Society and Individuals

#	I believe these are the TOP 3 benefits for society...	Society %	Society Count	Individual %	Individual Count
1	Increased free time for family, entertainment, and work while traveling or commuting.	2.97%	23	12.65%	98
2	More locomotion independence for disabled and elderly people.	14.84%	115	10.19%	79
3	Greater access to healthcare with improved patient mobility.	7.61%	59	5.94%	46
4	Greater access for people living in areas with limited public transportation or in remote areas.	9.68%	75	6.45%	50
5	Improved safety for pedestrians and bikers.	9.29%	72	5.94%	46
6	Fewer traffic accidents.	13.68%	106	9.55%	74
7	Producer liability preventing technology failures from happening.	1.55%	12	1.81%	14
8	Lower insurance premiums because the autonomous vehicle will be insured rather than the driver.	2.84%	22	11.23%	87
9	Lower insurance premiums because insurance claims would be made against the autonomous vehicle's manufacturer and not the driver.	2.32%	18	6.84%	53
10	Driver licensing will not be required anymore.	1.42%	11	3.61%	28
11	Vehicle registration will be easier and faster.	1.42%	11	2.45%	19
12	New laws and legislation regarding autonomous vehicles operation will be led by the U.S. Department of Transportation instead of manufacturers and technology companies.	2.45%	19	1.03%	8
13	Even though the vehicle is fully automated, the law requires drivers to be present at the wheel and ready to intervene at the first sign of tech failure.	1.68%	13	2.32%	18
14	Decreased expenditure on fuel.	3.61%	28	6.19%	48
15	Reduced energy consumption.	8.90%	69	4.65%	36
16	Less dependence on foreign oil.	5.16%	40	1.55%	12
17	Higher vehicle flow rates on existing roads, which will increase lane capacity.	4.26%	33	3.48%	27
18	Fewer cars on the roads.	3.35%	26	1.55%	12
19	More parking spaces.	1.68%	13	1.94%	15
20	Successful AV interactions with non-autonomous vehicles.	1.29%	10	0.65%	5
	Total	100%	775	100%	775

4.2.4 The Main Risks Regarding AV Adoption

The analysis of the participants' concerns related to AVs followed the same process as the analysis of their perception of the benefits. I began this process with the identification of the main eight risks from a list of 20 items. Afterward, I asked the participants to identify those eight risks as either societal or individual.

From the list of 20 possible risks related to the adoption of AVs, the participants chose "Performance failure" as the biggest overall concern (10.22%), which was followed by "Pricing" (8.16%) and "Cybersecurity and privacy issues regarding data sharing with car and technology companies" (7.49%), as presented in Table 13.

Regarding the organization of the items as societal or individual risks, "Performance failure" was categorized in both levels. It represented 11.55% of the concerns at the societal level and 18.73% of the individual concerns. "Cybersecurity and privacy issues" was also a significant risk on both levels. "Pricing," the third greatest concern, was considered an individual risk rather than a societal one. Table 14 presents the frequency of the societal and individual concerns.

When comparing the results for the categorization of the benefits and risks, I found that the performance of AVs accounted for more than 80% of the respondents' risks, while they considered safety as one of the top benefits of AV. These results reveal that the participants acknowledged the benefits of technology (safety) but that they were simultaneously worried about its performance. While performance and safety are intrinsically related, the safety of an AV relies on its performance, and performance concerns could be related to the uncertainties of these systems. This issue must be further investigated to understand whether it also impacts the participants' levels of trust.

Table 13: Frequency of the risks of AVs

#	Answer	%	Count
1	More dependence on technology.	6.19%	129
2	Performance failures.	10.22%	213
3	The technology used in autonomous vehicles is unreliable.	6.24%	130
4	The companies in charge of manufacturing autonomous vehicles are not liable.	3.89%	81
5	Cybersecurity and privacy issues regarding data sharing with other vehicles.	6.96%	145
6	Cybersecurity and privacy issues regarding data sharing with car and technology companies.	7.49%	156
7	Cybersecurity and privacy issues regarding data sharing with government and traffic control.	6.86%	143
8	Too expensive.	8.16%	170
9	Fully autonomous vehicles may not exhibit statistically significant safety benefits as a percentage of people are using them.	3.26%	68
10	Autonomous vehicles may not have the capacity to interact with non-autonomous vehicles, animals, pedestrians, or other hazards on the road.	6.81%	142
11	Users will have less control and freedom.	4.75%	99
12	Issues related to car ownership.	2.35%	49
13	Even though the vehicle is fully automated, the law requires drivers to be present at the wheel and ready to intervene at the first sign of tech failure.	2.78%	58
14	Driver licenses will not be required anymore.	1.73%	36
15	The lack of a regulatory framework.	4.08%	85
16	There will be issues regarding the reconciliation of federal and state regulatory jurisdiction.	2.64%	55
17	Road conditions will not be good enough for autonomous vehicles to drive safely.	4.70%	98
18	It will be necessary to invest in smart technology for road signs, traffic lights, and merge lanes.	3.79%	79
19	The loss of jobs.	5.04%	105
20	More cars on the road.	2.06%	43
	Total	100%	2084

Table 14: Frequency of Main Risks of AV at the Societal and Individual Levels

#	I believe these are the TOP 3 concerns	Society %	Society Count	Individual %	Individual Count
1	More dependence on technology.	6.37%	48	6.07%	46
2	Performance failures.	11.55%	87	18.73%	142
3	The technology used in autonomous vehicles is unreliable.	5.18%	39	7.52%	57
4	The companies in charge of manufacturing autonomous vehicles are not liable.	5.58%	42	2.11%	16
5	Cybersecurity and privacy issues regarding data sharing with other vehicles.	6.64%	50	6.33%	48
6	Cybersecurity and privacy issues regarding data sharing with car and technology companies.	7.04%	53	7.52%	57
7	Cybersecurity and privacy issues regarding data sharing with government and traffic control.	7.97%	60	6.99%	53
8	Too expensive.	4.65%	35	16.09%	122
9	Fully autonomous vehicles may not exhibit statistically significant safety benefits as a percentage of people are using them.	3.05%	23	1.45%	11
10	Autonomous vehicles may not have the capacity to interact with non-autonomous vehicles, animals, pedestrians, or other hazards on the road.	7.97%	60	7.26%	55
11	Users will have less control and freedom.	1.99%	15	6.20%	47
12	Issues related to car ownership.	1.99%	15	1.58%	12
13	Even though the vehicle is fully automated, the law requires drivers to be present at the wheel and ready to intervene at the first sign of tech failure.	1.20%	9	2.77%	21
14	Driver licenses will not be required anymore.	1.73%	13	0.79%	6
15	The lack of a regulatory framework.	4.25%	32	0.92%	7
16	There will be issues for the reconciliation of federal and state regulatory jurisdiction.	1.86%	14	0.53%	4
17	Road conditions will not be good enough for autonomous vehicles to drive safely.	4.38%	33	3.56%	27
18	It will be necessary to invest in smart technology for road signs, traffic lights, and merge lanes.	5.84%	44	0.40%	3
19	A loss of jobs.	8.63%	65	2.24%	17
Table 14 (cont.)					
20	More cars on the road.	2.12%	16	0.92%	7
	Total	100%	753	100%	758

4.2.5 The Number One Individual Risk About AV Adoption: The Open-Ended Question Results

For the next step in the survey, I asked the participants to choose only one issue as the biggest individual risk and explain why this is so concerning using an open-ended question; I did this to gain a better understanding of the participants' AV adoption concerns. I began the analysis process by identifying the words that the participants used most frequently to identify their main concerns and used SPSS to create a word cloud that featured the 40 most frequently used words. As expected, during the text analysis processes, I found that the most frequently used words were used for grammatical purposes; they did not change the meaning of the text and did not add information about the topic. I cleaned the data by removing the following stop words, which were presented in the first word cloud: "again," "autonomous," "big," "biggest," "can't," "car," "concern," "driving," "drive," "don't," "good," "happen," "I'm," "issue," "large," "make," "problem," "people," and "worry". Figure 9 illustrates the top 40 words.

Figure 9: Top 40 Words Related to Individual Concerns About AV Adoption (Version 1)

The first version of the word cloud demonstrates that "technology" was the most recurrent word. To make sure that the use of this word was related to a specific concern, I filtered all the responses with the word technology and read them. I noticed that "technology" was not related to one concern but was used as a complement and contextualization. Therefore, I developed a new word cloud by adding the words "technology," "driver," "person," and "road" to the stop word list since they did not inform a reason and were used to explain the problem. The new word cloud, Version 2, presented more compelling information about individual concerns, as presented in Figure 10.

Figure 10: Top 40 Words Related to Individual Risks About AV Adoption (Version 2)

The second version of the word cloud demonstrates that “failure” (85 times) and “performance” (76) were cited as the most significant risks. When I referred to the previous results of the multiple-choice questions which asked the participants to choose their top three individual concerns, I found that “performance failure” (18.73%) and “too expensive” (16.09%) were the greatest concerns.

Although “expensive” (32) and “afford” (30) are represented in the word cloud, they do not appear as frequently as “control” (46) and “data” (42). This led to a review of the previous question to verify what the other items that were chosen as the biggest risk were and which ones had the words “control” and “data” associated with them. I found that the items “Cybersecurity and privacy issues regarding data sharing with other vehicles” (6.33%), “Cybersecurity and privacy issues regarding data sharing with car and technology companies” (7.52%), “Cybersecurity and privacy issues regarding data sharing with government and traffic control” (6.99%), and “Users will have less control and freedom” (6.20%) all included the words “data” and “control.”

While using the word cloud provided a beneficial overview of the most frequently used words, it did not provide a clear understanding of why these words represented a concern for the participants. Since the words “perform” and “failure” were used in the same item, I wanted to validate whether "failure" was attributed to AV's performance. Therefore, I read all the responses that included the word "failure" and individually categorized them using the thematic analysis approach.

4.2.5.1 "Failure" as an Individual Risk

After reading all the responses, I observed that all the responses related to the "failed performance of the system" leading to the occurrence of traffic accidents. This categorization allowed me to organize the responses according to why a system failure can cause an accident and the consequences of system failure accidents. For each of these categories, I identified subcategories to better explain each type of risk, as presented in Table 15.

Table 15: Categorization of the Word "Failure" as an Individual Risk

Category	Subcategory	Statements	Count
Failure cause What is responsible for making the AV performance fail	Technology always fails	"... piece of technology that does not have a flaw or two..."	10
	The system is hacked	"... other people may hack the system, which can cause mayhem..."	6
Accidents The characteristics of accidents caused by performance failure	Accidents with fatalities	"... results in an accident that leads to serious injury or death…"	21
	Accidents will involve more victims	"... everyone in the immediate area is affected."	13
	Future decrease of accidents	"... even though, when working perfectly, it can decrease accidents."	4
Lack of human control The different human reactions to system failure based on control	Accidents could be prevented if humans intervene with the system when it fails	"... you're trapped in a runaway car with no way to regain control."	15
	Drivers do not control the system in case of failure to prevent accidents because of a lack of attention	"... relying on these cars more and… won't pay attention to the road since the car is doing all the work."	7
System control How the system will make decisions in case of failure	N/A	"How would it make the appropriate decision?"	4

Table 15 (cont.)

Technology reliability The need for proof of system reliability through research and tests	N/A	"... want to see more evidence of the technology being reliable for what it's currently designed..."	10

By analyzing all the occurrences of the word "failures," I found it possible to associate it with "performance." Through the initial categorization, I organized the responses into five categories: what causes the system failure (16), accidents caused by the performance failure (38), the lack of human control when the system fails (22), vehicle control when the system fails (4), and the proof of technological reliability (10). The next step in the analysis process was to delve into all the categories by re-reading and identifying commonalities and differences. The subcategories provided a better understanding of what the participants thought about system failure and why this was an individual risk for them.

What Causes the System to Fail?

Although only 16 statements indicated why the participants thought that the system would fail, this is important information to consider, especially to understand whether there is an association with trust in AVs. Ten out of 16 statements mentioned that AV performance would fail because technology fails. In other words, some of the participants believed that technology fails regardless of the type of system or situation. Thus, they expected that this would be no different with AV technology. For instance, one participant stated, *"The biggest concern would be performance failures because not every technology is perfect. Every technology has some flaws, and autonomous vehicles are no exception. An auto vehicle might accidentally hit a pedestrian, and it would be a disaster."*

This finding demonstrates that, as mentioned by Hoff and Bashir (2015), previous experiences influence trust in AV. Here, more research is necessary to understand whether this relates to specific situations in which the participants interacted with technology and its failure (distrust) or whether this relates to a suspicion that was not necessarily based on a previous situation that was experienced by the participant. Moreover, if participants are using technology, in general, more research should be conducted on what type of analogous technology people related to AVs as a predictor of AV performance.

Six out of 16 participants stated that AVs will fail as a consequence of hacking and cyber-attacks. In this situation, someone else or another system would take control of the vehicle, which would possibly cause accidents. For instance, *"... be cyber hacking, which could make it possible for someone else to control your AV."*

Accidents Caused by the System Failure

This was the greatest category since the majority of the responses connected system failures with accidents. I identified three subcategories that explained that the participants thought that the system failure of AVs would lead to fatal accidents (21 out of 38) and that those accidents would involve more victims (13 out of 38).

However, only four participants mentioned that although their main concern was the system failure, they were aware that, in the long run, AV can prevent and reduce accidents. For example, one participant said, *"I know accidents happen every day that could be prevented by AV. However, I'm also concerned about what kind of accidents will be caused by AV."*

This category reveals that regardless of whether the participants were aware of the future benefits of AVs, they considered those accidents to be more *"serious"* than accidents in which the driver is in control.

The Lack of Human Control

The second most frequently made statement concerned the lack of human control, which was used to create two subcategories. Several participants stated that they thought human control would prevent accidents from happening if an AV's system failed (15 out of 22). Most of the participants related these situations to themselves and how they would prefer to have control: *"If an accident occurred that resulted in the injury or death of someone, I would always feel like maybe it wouldn't have happened if I was in control of the driving."*

The second subcategory—the drivers' lack of attention preventing them from controlling the car—describes a monitoring dilemma. When riding in AVs, drivers would engage in other activities that would reduce their attention regarding the system's performance or cause them to over-trust the system. This would consequently reduce the chances of the driver taking control if a failure were to happen. For instance, *"Performance failures are my biggest concern because I feel like users will get complacent and be slow to act during a performance failure."*

Individuals would start relying on their cars more and won't pay attention to the road since their car is doing all the work. And perhaps, [if] the car [malfunctions] in the process of driving, they wouldn't be quick enough to stop an accident from occurring.

The control category demonstrates that the majority of participants wanted to be able to take control of the vehicle to avoid accidents in case of a system failure. They also stated that if the driver were able to take control back, then they might be able to avoid accidents. However, only a few participants acknowledged the fact that drivers can over-rely on the system, which would reduce their attention regarding the system's performance. Based on current data regarding accidents involving semi-autonomous vehicles that occur in the state of California, as mentioned in Chapter 2, the majority of these accidents were a consequence of the lack of monitoring. In those situations, the drivers were supposed to be in control of the vehicle, but instead, they were engaging in other activities (e.g., watching movies or sleeping).

4.2.5.2 "Control" as an Individual Concern

As discussed in the previous analysis, the word "failure" is used in responses related to the performance failure of AVs. I analyzed the third most-frequent word, "control," using the same thematic analysis conducted to analyze the occurrences of the word "failure." During the initial categorization I found four well-structured themes capable of explaining how and why participants perceived "control" as a risk when driving AVs, as presented in Table 16.

As shown, control and failure are closely related. When considering system failure, control is related to both why an accident might happen (users cannot take control when it is necessary because they were not paying attention) or how to avoid accidents (users can avoid more serious types of accidents by controlling the AV).

Table 16: Categorization of Individual Risks Related to "Control" of AVs

Theme	Category	Statements	Count
Governmental control Tracking and monitoring people's actions and data	N/A	"[...] biggest advantage for the government and that is why they want everyone in these cars. Everyone will be tracked in these cars. That data WILL be saved."	9
Human control The lack of driver control in the AV	The preference towards having control of the vehicle for safety	"[...] I would feel unsafe at first because I would have the need to control the car."	11

Table 16 (cont.)

	The preference towards having control of the vehicle for personal "pleasure"	"[...] Taking a road trip or exploring the rural back roads. I feel like autonomous vehicles will make the decisions for me. I want to be able to control my car and how I go to the places I want to go."	2
Loss of freedom AV control is part of a bigger trend of loss of freedom in people's lives	N/A	"[...] Once we start to give away our control it will not be good. This would just be the beginning to give up our freedom."	6
Cyber-attacks Someone can hack the AV and control it	N/A	"The idea of being hacked by another car and potentially controlled is terrifying."	3

The highest occurrence of the word "control" was when participants explained why they were concerned about the lack of human input. Participants stated that they would prefer to stay in control of the vehicle for safety or pleasure reasons. Furthermore, 11 of 13 statements related to the participants' preference to remain in control of the AV because it is safer to do so, which corroborates previous findings. For instance,

> *[...] If an accident occurred that resulted in the injury or death of someone, I would always feel like maybe it wouldn't have happened if I was in control of the driving. I definitely won't let my car be 100% in control.*

Two individuals mentioned that they would like to retain control of the vehicle because of pleasure. These participants think that driving is a pleasurable activity, and the development and adoption of AVs would prevent them from this: *"It would be the first one - more dependence on technology. I love driving so I would miss the feeling of driving if the technology takes control."*

The concern with control is not only related to the individual lack of control when using an AV but also to the issue of outside sources taking control of the AVs. Participants stated that cyber-attacks and hacking could control an AV's system. For instance, *"I worry about the cyber threat of losing control of the technology to a bad actor leading to accidents. Cyber security threats are as present as ever."*

"Control" was also used to explain two types of risks that are not related to control of the vehicle. One of the biggest concerns relates to the control that governments, traffic agencies, and industry can have when using drivers' and passengers' data. Respondents assume that the government can use personal information collected by AVs to monitor and control people.

> *[...] There will be laws passed saying the police and government NEED the tracking information so they can keep the roads safe, but that will be a ruse, and the data will be used to monitor us more than keep the roads safe. This will be another way to keep tabs on everyone.*

In summary, results show that “control” is most prominently related to the participants’ desire to be in control of the vehicle for either safety or pleasure reasons. Furthermore, individuals are concerned about cybersecurity and how individuals and agencies might hack an AV’s system and take control of it. Finally, related to privacy and cybersecurity, there is concern surrounding the lack of control over personal data shared by the AV to traffic controllers, manufacturers, and possibly governments that can use this information to control and monitor the drivers.

4.2.6 The Number One Societal Risk About AV Adoption: The Open-Ended Question Results

To a analyze the societal risks of AVs, I adopted the same analysis process used to analyze open-ended questions about the perception of individual risks of AVs adoption. The initial stop word list included the following words: “again,” “autonomous,” “big,” “biggest,” “can’t,” “car,” “concern,” “don’t,” “driving,” “drive,” “good,” “happen,” “I’m,” “issue,” “road,” and “vehicle.” Of the 40 most-frequent words shown in the word cloud in Figure 11, “people,” “road,” and “technology” are the most frequent ones. Answers containing these words were filtered, and like in the previous analysis words, I found that these words were used for context and explanation as they did not support the identification of the main risk of AVs In a trial and error process, I added those three words to the word stop list, and a new word cloud was created, illustrated in Figure 12.

Figure 11: Top 40 Words Related to Societal Risks of AV Adoption (Version 1)

The resultant word cloud (Version 2) shows "job" (37 counts), "loss" (31), "failure" (29), and "control" (28) as the most mentioned words. This result corroborates with the top three main risks identified in the analysis of previous research question (RQ1) (see chapter 4.2.4.), in which "performance failure" (11.5%) and "loss of jobs" (8.63%) were perceived as the biggest societal risks of AVs adoption.

Figure 12: Top 40 Words Related to Societal Risks of AV Adoption (Version 2)

The responses were then filtered and organized into two main categories: one with responses containing the word "job" and another with responses containing the word "failure." I individually analyzed each of these categories using thematic analysis to understand why "job" and "failure" are the biggest societal risks regarding the adoption of AVs. Tables 17 and 18 show the categorization of the responses.

4.2.6.1 “Job” as a Societal Risk

After reading all responses, I observed that risks labeled as “loss of jobs” is, mostly, associated with the replacement of drivers by automation. Most statements, 27 out of 33, mentioned that the types of drivers that will lose their job because of the adoption of AVs are those working with particular passengers, such as taxi drivers or drivers for ridesharing apps. On the other hand, a smaller portion, 5 out of 33 responses, mentioned other types of drivers, including those in the transportation industry, such as truckers, delivery drivers, and movers. This result shows that participants are associating the risks of AVs with what they are currently experiencing in their lives since taxis and ridesharing apps are the most used alternative mode of transportation besides cars, as mentioned by one participant.

> *If this becomes very successful, they won't need Uber and Lyft anymore. Many people will be replaced and have to look for jobs elsewhere. Or they will be forced to have to compete against other applicants when applying for a job that still employs humans.*

Table 17: Categorization of the Word “Job” as a Societal Risk

Theme	Category	Statements	Count
Loss of jobs	Drivers in the transportation industry will be replaced by AVs	“Fewer people would need personal drivers, and I could see taxi services employing automated cars over actual humans.”	33
	Unqualified workforce that will not be able to work with technology	“[...] may leave out the older employer and those that can't learn technology.”	3
Unemployment will impact the economy	N/A	“Our economy cannot take any more loss of jobs.”	9

Three statements mentioned that people would not only lose jobs because drivers would be replaced by automation. They argued that numerous people would not be able to work in environments where they would need to use or interact with technology. They claimed that this is a specialized skill, and some people would not be able to learn it and would be unqualified for the jobs. For instance, *“[...] this will happen regardless because of technological advances, but some people just do not have the mental ability to do higher-level skilled jobs, which is all that will be left.”*

Only nine statements demonstrate that the main concern with the loss of jobs is the economic impact that this will have on society. Although people argue this will be a consequence of AVs, they do not elaborate significant on how and why this would occur. For instance, one person stated, *"Our economy cannot take any more loss of jobs. It puts a strain on the government as well as society,"* while another said, *"[...] with there being less people employed, it can hurt the economy quite a bit."*

4.2.6.2 "Failure" as a Societal Risk

Following the same analysis process, I categorized all responses containing the word "failure," as detailed in Table 18.

Table 18: Categorization of Word "Failure" as Societal Risk

Theme	Categories	Statements	Count
Reasons an accident happens after system failure	No human control to intervene when the system fails	"[...] the driver may not be able to intervene properly [...]"	7
	The failure in recognizing pedestrians, obstacles, animals, and other vehicles on the road	"[...] do not recognize obstacles correctly."	3
Consequences of accident caused by system failure	Fatal accidents	"[...] cause accidents and even injuries or death while on the road."	15
	Increased number of accidents	"[..] lead to an increase of accidents."	4
	Liability and legislation	"[...] it needs to be more regulated."	3
Reasons for a system to fail	Technology always fails	"Performance failures happen all the time with technology [...]"	4
	System failure due to cyber-attacks	"[...] failures leading to accidents as a result of cyber incidents."	1

Most of the occurrences mentioned the consequences of an accident caused by system failure instead of the reasons for the accident. Less than half of the statements, 15 out of 37, refer to a concern regarding fatal accidents if the system fails. Four responses posit that the number of traffic accidents would increase with the adoption of AVs. As mentioned by two participant*s*

“Performance failures can possibly cause accidents and even injuries or death while on the road. This can be scary. You can never be too safe.” and *“As with my concern, performance failure is the top concern here. This would lead to an increase in accidents and injuries.”*

Three responses mentioned that the biggest concern related to accidents caused by system failure is the lack of legislation, including companies’ liability. This concern aligns with a vast number of studies and publications, both in academia and the media, that explore who will be in charge in the case of an accident involving AVs.

> *The manufacturers should be liable for performance failures or unreliable tech. If the passenger has to be alert to taking over in an emergency, then they can't sit there and work during their commute or play with their kids. You can't have it both ways.*

Discussing why a system failure can cause an accident, most participants expressed that it happens because of a lack of human control. This lack of control can occur because humans do not know how to control the system, because the system does not permit human intervention, or because humans will not be attentive enough to supervise the system and will not control it if necessary.

> *I worry about performance failures, especially in populations that cannot take control of the vehicle or take steps to prevent / fix the situation (such as the elderly). When the technology is new, there will be performance failures, and these may occur at the hands of individuals ill-equipped to handle the situation.*
>
> *The biggest societal concern that I have is the failures that may result in the death of the drivers or others as if the software fails, the driver may not be able to intervene properly or the car may kill them without a chance for them to correct it.*

In contrast, 4 out of 37 sentences mentioned that the cause of accidents is that technology fails. Thus, there is a lack of trust in technology, leading to the belief that technology will fail regardless of the type of system or situation.

> *[The] biggest societal concern is performance failures. Not everything is perfect. We will have to go through trial and error to find out what could possibly go wrong and people's lives may be at stake. I would worry about performance failures that could cause accidents.*

Although most respondents implicitly believe that the system will not work properly due to a technological failure, one response discussed system failure resulting from cyber-attacks. For instance, *"Performance failures leading to accidents as a result of cyber incidents."*

Failure appeared as a top word in both individual and societal risks of AVs. The content analysis was essential to understand what are the nuances and differences in each of these levels. In both levels, the increase of accidents and fatalities is the main risk associated with "failure". However, regarding the relation between lack of human control and system failure, there is an overall increase of 10% in number of responses in the individual level (28.94% of total failure categories) when compared to the societal level (18%). In both, societal and individual levels, control is perceived as a prevention mechanism, in which the human control intervene with the system when it fails. In the individual level, some participants have the opposite perception, and the lack of control is the cause of accident, and not the system failure.

Another difference between the individual and societal risks related to the failure of AVs is that only the societal level, the failure of the system also relates to concerns about legislation and liability. For instance, who will be responsible if the AVs fail.

In summary, the responses show that the most significant societal risks of AVs adoption are related to the economy and security. Economic concerns highlight the impacts of job losses, especially the impact on unemployment levels, which is directly related to the economy. Security concerns related to system failures, which can increase the number of accidents involving not only drivers but also pedestrians.

4.2.7 Scenarios

In the last set of questions in the survey, I asked participants to imagine that they were walking home from shopping. On their way, they would need to cross multiple crosswalks, both with and without signals. As they prepared to cross an unsigned crosswalk, they would find that a driverless vehicle was approaching the crosswalk. In the first scenario, in which participants were told to imagine themselves alone, a majority of respondents said that they would make sure that the driverless vehicle stopped before they started crossing (47.58%) or would not cross the road to avoid the driverless car (37.00%).

Table 19: Frequency of Scenario 1

Scenario 1: Crossing the street alone	Count	%
I would make sure that the driverless vehicle stops before I start crossing.	108	47.58%
I would not cross the road at the crosswalk to avoid crossing in front of the driverless vehicle.	84	37.00%
I would run across the road even though the driverless vehicle has stopped for me.	9	3.96%
I would wait to see if the vehicle decelerates before I start crossing.	26	11.45%

In scenario two, participants would be walking with their 5-year-old child by their side and their two-month-old baby in a stroller. The majority of participants (52.42%) stated they would not cross the road, as described in Table 20. Thus, having kids with them increased the perception of risk in the situation when compared with the first scenarios, where they would be alone.

Table 20: Frequency of responses of Scenario 2

Scenario 2: Crossing street with children	Count	%
I would make sure that the driverless vehicle stops before I start crossing.	93	40.97%
I would not cross the road at the crosswalk to avoid crossing in front of the driverless vehicle.	119	52.42%
I would run across the road even though the driverless vehicle has stopped for me.	3	1.32%
I would wait to see if the vehicle decelerates before I start crossing.	12	5.29%

The third scenario, shown in Table 21, asked participants to imagine they were walking with a pet. The responses are very similar to the first scenario as the majority of participants (47.14%) stated they would make sure that the vehicle stopped before starting to cross. Comparing the three scenarios, as shown in Figure 13, shows that respondents are most likely to cross the street in the first scenario, in which they are alone. Instead, they are least likely to cross the street in the second scenario, in which they are crossing with kids.

Table 21: Frequency of Responses of Scenario 3

Scenario 3: Crossing the street with pets	**Count**	**%**
I would make sure that the driverless vehicle stops before I start crossing.	107	47.14%
I would not cross the road at the crosswalk to avoid crossing in front of the driverless vehicle.	97	42.73%
I would run across the road even though the driverless vehicle has stopped for me.	8	3.52%
I would wait to see if the vehicle decelerates before I start crossing.	15	6.61%

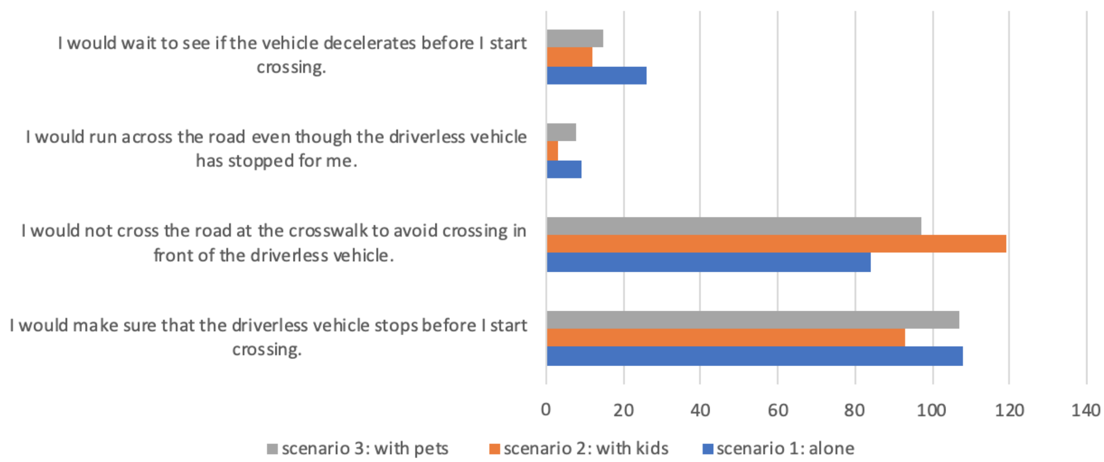

Figure 13: Comparison of responses for each scenario

The fourth, and last, scenario explored how participants would react to the presence of AVs in their neighborhood. Most respondents (36.56%) reported that they would feel anxious since they do not trust them. A smaller portion of participants (23.79%) said that they would be indifferent as it does not matter to them. These two most frequent responses are contrasting and show that most participants have different views regarding AVs: they either do not trust them or are indifferent to them. Therefore, it is not possible to draw a conclusion based on this result.

Table 22: Frequency of Responses of Scenario 4

Scenario 4	Count	%
I would be angry to see driverless vehicles in my area; I think they will cause more problems.	15	6.61%
I would be indifferent to the presence of driverless vehicles in my area; it doesn’t matter to me.	54	23.79%
I would feel anxious about the presence of driverless vehicles in my area; I don’t trust them.	83	36.56%
I would feel excited to see driverless vehicles in my area; I believe they will make my area safer.	30	13.22%
I would have no problem with driverless vehicles in my area; I trust the technology.	45	19.82%

4.3 Discussion

In the following section, I analyze and discus the results of the survey to answer the research question: How does the perception of benefits and risks, as external variables, affect situational trust in AVs?

4.3.1 Process Review

This dissertation uses a survey to investigate the perception of benefits and risks related to AVs, adopting a three-step analysis as shown in Figure 14 below. First, it provided participants a list of 20 possible benefits and 20 possible concerns, based on academia, media, and industry publications, and asked them to rank the main risks and benefits of AVs.

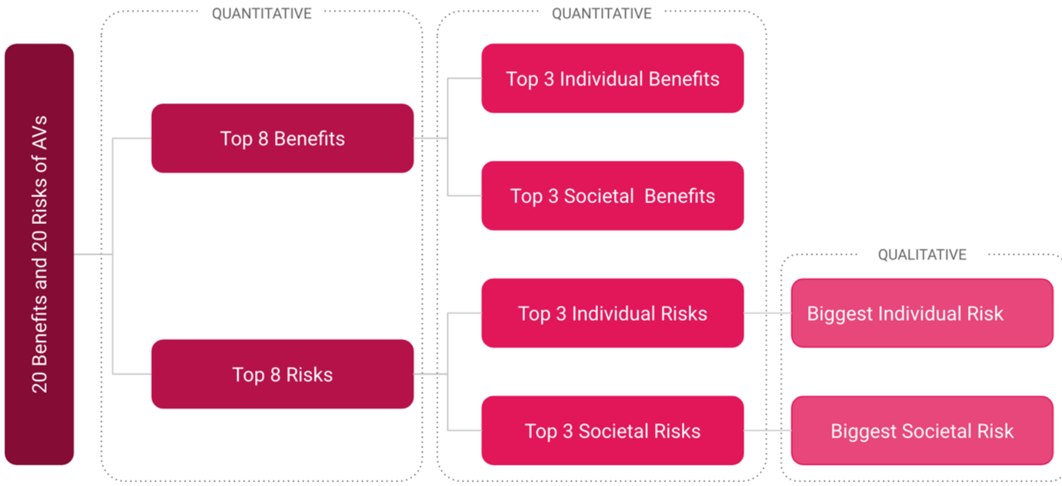

Figure 14: Review of the Survey Data Analysis Focusing on the Outcomes

In the next question, participants were presented with their top 8 benefits and needed to select the top 3 societal and individual benefits from this list. The same process occurred with the concerns, and participants selected the top 3 concerns for society and for them individually. As mentioned, this approach aimed to reduce the bias towards choosing societal benefits and risks over individual ones. Moreover, it also attempted to identify how participants think about the development of AVs and whether understanding their mental models would provide information on their current trust.

In the third step, they were asked to choose their primary concern, both for society and for themselves individually. The open-ended question was not employed to explore the top benefit. This step focused only on the concerns and used thematic analysis to analyze the data. Although trust is inherently related to risk, previous studies are still exploring the relationship between both, and some claim that trust is not proportional to risk (Solhaug, Elgesem, and Stolen, 2007). However, specifically regarding AS, Hoff and Bashir (2015) claim that the perception of risk is an external variable of situational trust, and Ferronato and Bashir (2020) find that the propensity to take risks is part of dispositional trust in AS. Corroborating this, when investigating a model of AV acceptance based on perceived risks, Zhang and colleagues claim that the perception of risk does not directly determine users' attitudes towards AVs. Instead, it indirectly affects their attitudes by influencing their level of trust towards AVs (Zhang et al., 2019).

I organized the discussion of the results into three parts to better respond to the research question, “How does the perception of benefits and risks, as external variables, affect situational trust in AVs?” The first part identifies what are the benefits and risks of AVs perceived by the participants. Second, it explores the relation between the benefits and risks of AVs with situational trust. Finally, the third step discuss the relation between the perception of risks and benefits of AVs with the participants experience with their own vehicles.

4.3.2 What are the benefits and risks associated with AVs?

Figure 15 summarize the benefits and risks identified in this research and how participants’ perception changed when asked to choose between the individual and societal levels.

Figure 15: Risks and Benefits Associated with AVs in Each Step of Data Analysis

Overall benefits of AVs are focused on the societal level, while overall risks of AVs are focused on the individual level

Figure 16 shows that, when comparing the overall benefits of AVs with the benefits at the societal and individual levels, there are no differences between the overall benefits and the benefits at the societal level. This means that the overall perception of the benefits of AVs has a societal nature.

- "More locomotion independence for people with disabilities and elderly people" (from 9.46% to 13.68%).
- "Fewer traffic accidents" (from 8.60% to 13.68%).
- "Greater access for people living in areas with limited public transportation or remote areas" (from 7.50% to 9.68%).

Instead, participants did not change their perceptions regarding the concerns with AVs when asked to evaluate their individual and societal concerns. This indicates that the perception of concerns tended to be more individual in nature.

- Performance failures (from 10.22% to 18.73%).
- Too expensive (from 8.16% to 16.09%).
- Cybersecurity and privacy issues regarding data sharing with car and technology companies (from 7.49% to 7.52%).

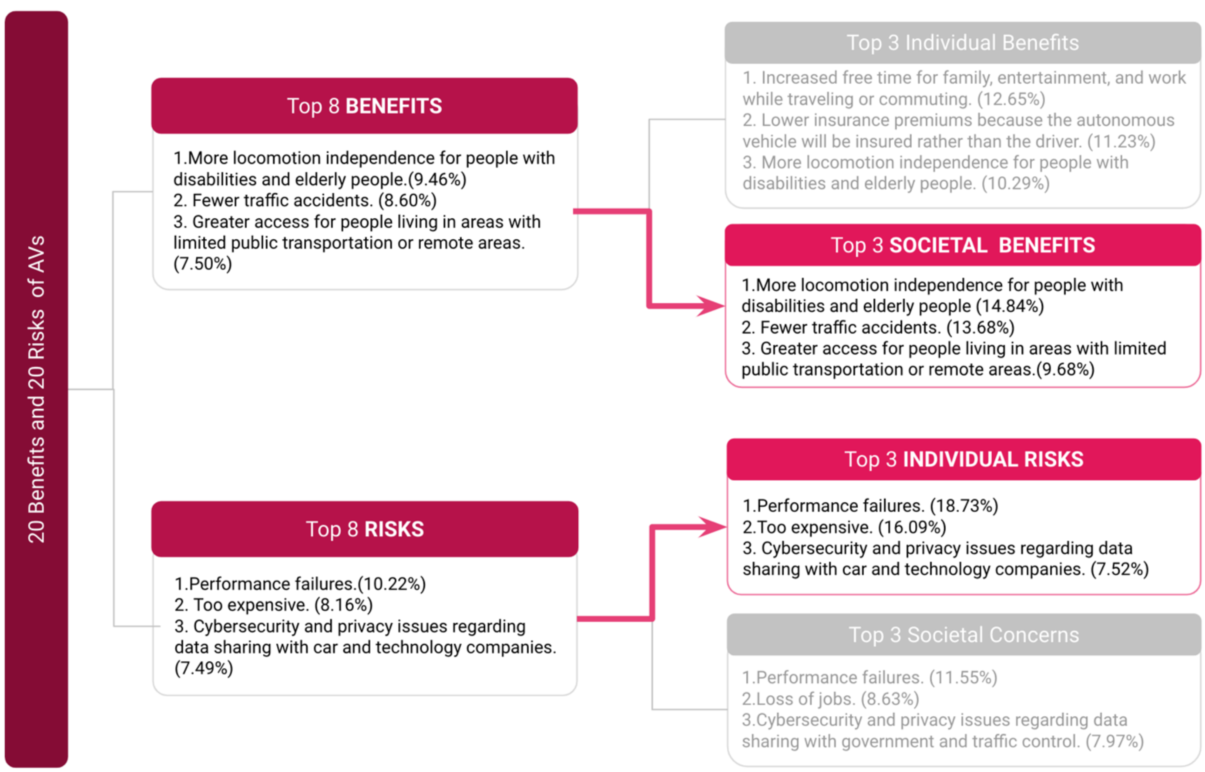

Figure 16: Relationship of Main Risks and Benefits with Societal and Individual Levels

When using a societal lens, participants focused on the performance attributes of the AVs. When focusing on the individual level, participants tended to focus on the financial attributes of AVs

Figure 17 shows that the common consideration at the societal level for the concerns and benefits is performance ("fewer traffic accidents" and "performance failure"). On the individual level, the common consideration for the concerns and benefits is the financial repercussions ("lower insurance premiums" and "too expensive").

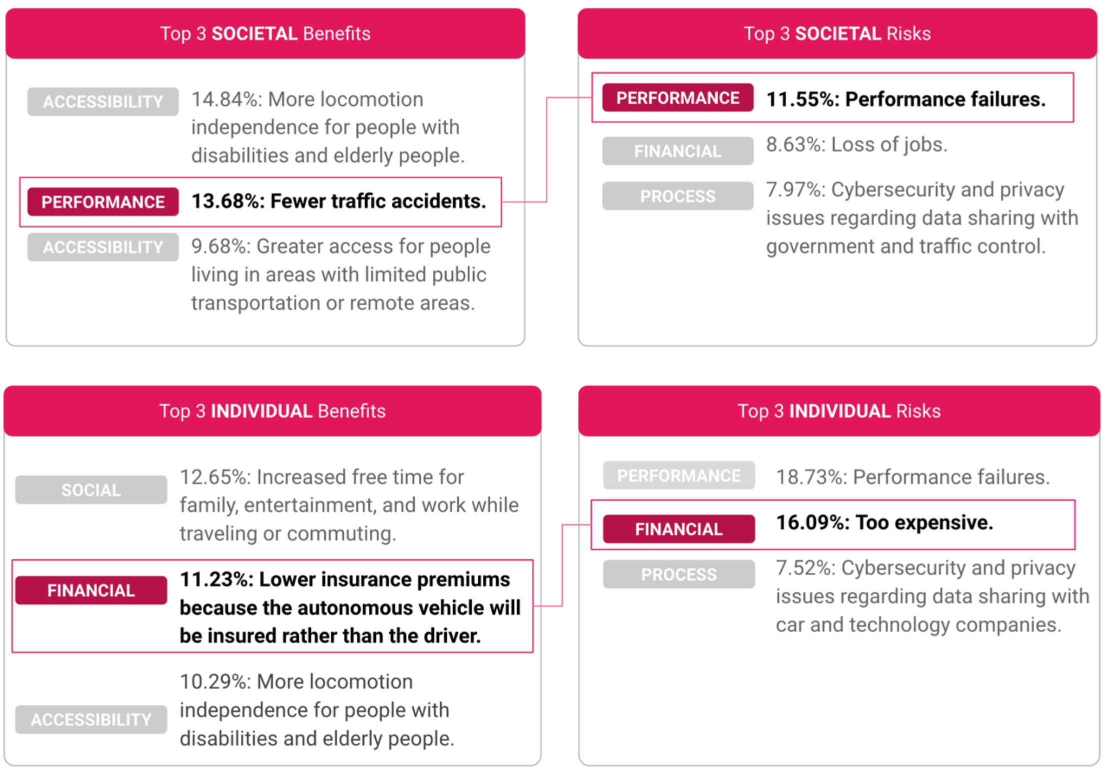

Figure 17: Attributes of individual and societal levels

The differences between individual and societal perceptions proved to be an effective way of understanding how participants perceive the benefits and concerns associated with AVs. Therefore, it is essential to further understand the differences between those levels and their impact on perception formation and participants' behavior. Further research focusing on the user experience should investigate if trust in AVs can be calibrated by using a societal focus to increase the perception of benefits and an individual focus to mitigate concerns.

The main benefits and concerns perceived by the participants are related to the foundational elements that form reliance on AS: performance, process, and purpose

Research has shown that the perception of benefits and concerns is an external variable capable of influencing trust in automation (Hoff and Bashir, 2015). In this dissertation study, I added an extra level of complexity to understand the nature of benefits and concerns by considering societal and individual levels. Besides these two levels, the main categories of benefits and concerns relate to accessibility, system failure, and data sharing and privacy. As presented in Figure 18, I found that these external variables influence situational trust in ways related to Lee and See's (2004) description of the process of trust in AS formation and Hoff and Bashir's (2015) elements of the reliance on the system strategy.

As discussed, regardless of the individual or societal level focus, participants perceive improving accessibility as the main benefit of AVs. This benefit can be considered one of the purposes of AVs or even the reason the system exists. The benefit of the system relates to Rempel and his colleagues' (1985) description of the stage of "faith," defined as the extent to which the automation is being used in line with the designer's intent. The successful perception of the system's purpose depends on whether the operator understands the designer's intent for the automation.

The main concern that participants had regardless of the societal or individual focus is performance failure, which is related to system performance. Lee and Moray (1992) refer to system performance as the stage of "predictability" in the formation of trust, where the user predicts what the experience will be like and how the system will perform. This stage also includes automation reliability and ability in addition to predictability.

The risk of lack of privacy due to data sharing with government, traffic controls, and companies, or even due to cyberattacks to the AVs system, is part of the AV's process. The system's process is the fundamental principles that regulate a system's actions and describe how an automation technology operates (Lee and Moray, 1992). Therefore, the process refers to whether the experience with the system corresponds to the expectations, or the dimensions of predictability (Lee and See, 2004).

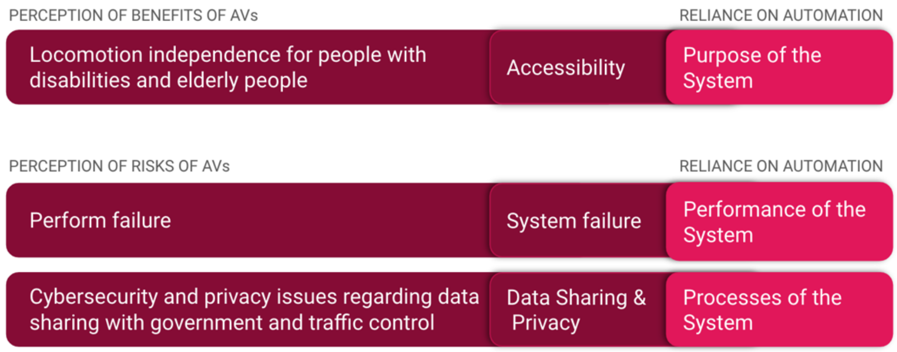

Figure 18: The Relationship Between the Perception of Benefits and Risks and the Elements Forming Reliance on Automation

In summary, results show that the biggest benefits of AVs are those to society, while the biggest risks of AVs are related to individuals. When analyzing the perceptions at the societal and individual level, we found that accessibility is the biggest concern and benefit at the societal level, while the economy is the biggest concern and benefit at the individual one. Finally, the most frequent benefits and risks - accessibility, system failure, and data sharing and privacy – relate to the foundational elements (purpose, performance, and process) relevant to the formation of reliance on automation (Lee and See, 2004).

4.3.3 The Perception of Benefits and Risks of AVs, as External Variables of Situational Trust in AVs, Affects Trust by Influencing Other External Variables (Level of Control) and Internal Variables (Attention Capacity)

According to Hoff and Bashir's model of trust in AS, the perceptions of risks and benefits are external variables of situational trust. They are considered external variables because they relate to the environment and the system itself, and they can change during the user and system interaction.

Understanding the perceptions of concerns and benefits is a wide topic, and it is essential to identify the concerns and benefits. In this study, I identified that, for the participants, the biggest risk of AVs is "performance failure." This external variable is related to other internal and external variables, such as users' attention capacity and subject matter expertise (internal variables) and their level of control (external variable), as shown in Figure 19.

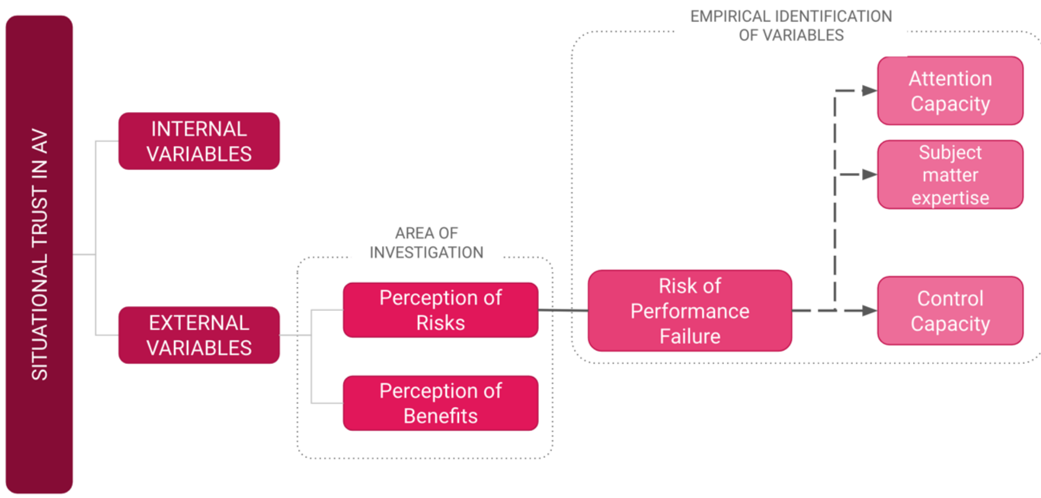

Figure 19: Relationship Between Variables

The quantitative analysis shows that the most significant concern that participants have is consistently the risk of performance failure; this result holds even when asking participants to consider the concern for society or for them as individuals. The in-depth analysis, which used qualitative thematic analysis, provided the following findings on performance failure:

1. Performance failure is related to the increase in accidents with fatalities,
2. The main cause of performance failure is because technology "always fails," and
3. Performance failure is related to a dilemma of lack of human control. The control dilemma posits that in the case of system failure, drivers can either not take control of the AV because they were engaging in other activities and not monitoring the system, and thus be culpable, or prevent the accident my taking control of the system.

Most participants stated that AVs will eventually fail because "technology always fails." Furthermore, participants believe that the consequences of an accident involving an AV are more severe than current traffic accidents, and the number of fatalities will increase. This statement is evidence of how previous knowledge and experiences with technology either mitigate or accentuate the perception of AV risks. Thus, it is important to identify what analogous system experience is an internal variable influencing situational trust in AVs. In Study 2, I investigated an AV's analogous systems (cruise control) and identified the main internal and external situational variables.

For both levels of concerns (individual and societal), participants claimed that the lack of human control over AVs could prevent drivers from intervening when the system fails and consequently prevent them from stopping accidents. Moreover, they also mentioned that over-reliance on the system would make drivers pay less or no attention to the system performance. In the case of a failure, this would mean that drivers would not be able to effectively take back control of the system.

At the individual level, participants who discussed how they would act when riding an AV claimed that they would prefer to have control of the system. No participant stated that they would pay less attention to the system performance because they would be engaging in other activities, even though this is one of their main concerns. However, it is possible that participants would not admit to paying less attention and therefore that this cannot be tested or confirmed by this survey.

Research should further investigate the association between the level of control and (1) how it mitigates risks associated with performance failure and (2) how it increases risks because of the driver's lack of attention to the system performance. In particular, it should identify the internal and external situational trust variables that might affect those two situations. This will clarify how and when participants might pay more attention to the system and in what situations they would take back control of the vehicle. This information is critical for designing a system that integrates human interaction, increasing the calibration of trust in AVs. Study 2, I aimed to fill this knowledge gap, by investigating those two situations with an analogous system.

Another relevant finding is on the relationship between the external and internal variables. By researching one external variable (perception of risks and benefits) in-depth, this study identified other variables influencing trust in AVs for the sample used in this study. Studies should further investigate this, using variables that have been proved to influence trust in AVs to better understand the influence of other variables. Furthermore, this dissertation identified the variables using qualitative analysis of open-ended questions. Further studies should conduct statistical analysis to validate the level of influence of those variables. Study 2 of this dissertation, which uses a qualitative approach, investigated the two variables identified in this study – capacity of control and capacity of attention – to understand their influence in the process of trust in AVs.

4.3.4 The Main Benefit Associated With Participants' Current Vehicles Perceived as One of the Main Individual Risks of AVs

Throughout the analysis of the survey, I found parallels between the participants' perception of benefits and risk of AVs and their current transportation behavior. Hoff and Bashir's (2015) model shows that situational trust relates to the current use context, and it presents internal (related to the user) and external (related to the environment) variables that influence situational trust in AS. However, not many empirical studies have focused on how current behavior, not necessarily related to the system researched, might support the identification and understanding of these variables.

Participants indicated that the biggest benefits of their vehicles and the reason why they purchased them were ties to economic aspects, namely the price paid and fuel economy. Likewise, one of the biggest concerns at the individual level is economic, namely that AVs are too expensive. Hence, the individual concern that participants have regarding AVs aligns with what they have identified to be the main benefit of their vehicles. Based on this finding, In Study Two, I Study 2 will further investigated how the benefits and concerns associated with AVs are related to existing benefits of an analogous system.

4.4 Final Considerations

In this study, I collected data using a survey focused on the situational trust in AVs based on Hoff and Bashir's (2015) model of trust in automation. Situational trust is context-dependent and is influenced by internal variables (the user) and external variables (the system and the environment). The dissertation's goal is to have a better understanding of the internal variables and external situational variables. The survey analyzed two external variables in depth, namely the risks and benefits associated with AVs.

The results provided empirical evidence that helped identify the participants' perception of benefits and risks with AVs and explore why and how participants understood them. When considering the overall benefits of AVs, they tend to perceive benefits on the societal level. When considering the concerns, they tend to be more concerned with individual-level issues. The benefits and risks were identified as having influence on the trust in AVs because of their relationship with reliance formation: purpose (accessibility), process (data and privacy), and performance (system failure). These three variables were not chosen to be investigated a priori.

Its connection with trust was empirically identified during the analysis of the surveys. This is an important finding, corroborating Hoff and Bashir's definition of the perception of benefits and risks as a situational variable as well as Lee and See's perspective (2004) on the basis of trust in automation.

Variables of situational trust are influenced by the context, and they can change during the interaction between the user and the system. This study found a relationship between the external variable, perception of benefits and concerns, and other internal variables such as attention and control levels. Previous studies have not yet understood how the variables relate and influence one another. Thus, in the Study Two I focused on this research gap, which is one of the main contributions of this research for the field of user research in human and autonomous systems interaction.

Finally, investigating systems that are not fully developed is a challenge for user research. The use of prototypes, including low-fidelity ones, is essential for investigating user attitudes and their interaction with a given system. However, the investigation of situational trust is contextual and depends on the environment and other external variables. This research finds that understanding current trusting behaviors, such as the direct relationship between the perception of benefits of users' current vehicles and their perception of concerns with AVs, might open avenues for user research. Particularly, future research can investigate whether users' current behavior with related systems might influence their future behaviors. Therefore, the next study investigates the current trusting behavior in two analogous systems.

Chapter 5. The Interviews

This chapter details the procedures for the semi-structured interviews, including the content analysis process and subsequent results. The outcomes from this phase of the dissertation support the identification of internal and external variables regarding situational trust in AV analogous systems. Moreover, the results reinforce the benefits of the design by analogy framework as a feasible alternative for understanding future interactions with systems that are not yet fully deployed.

5.1 Procedures

The interviews were semi-structured, and all the interviewees were presented with several key questions that were created to define specific areas to be explored throughout the interview process. Asking these questions also allowed me and the participants to diverge and pursue deeper conversations regarding specific topics.

By conducting the interviews, I aimed to better understand the participants' previous experiences with an analogous system—cruise control (CC). CC is a type of automated driving assistance technology that automatically controls the speed of a vehicle. Therefore, I developed the interviews to collect information specifically about the following two aspects:

- Current behaviors towards the adoption of CC: The decision concerning whether to adopt CC can be related to numerous situational factors that also influence users' trust in this type of semi-automated system.
- Monitoring behaviors while using CC: As presented in the research background, monitoring and attention levels highly correlate with trust in AS. Moreover, the lack of monitoring is associated with higher complacency and trust in AS relating to the situational dimension of trust.

5.1.1 Recruitment

Potential participants were recruited through an email invitation that was distributed to the staff mailing list of an American university and word of mouth. Potential participants who were interested in the study contacted me via email. Once the participants demonstrated their interest in participating in the study, I sent them the consent form to review and sign and scheduled an interview session. Due to the COVID-19 pandemic, the interviews were conducted virtually using Zoom conferencing technology and lasted an average of 60 minutes. Each interview was organized into four parts. Part 1 comprised the introduction, in which I reiterated the consent form and used ice-breaking questions to initiate the conversation. Part 2 focused on cruise control adoption and individual preferences, while Part 3 related to the monitoring behaviors of passengers when riding in an Uber or Lyft. Part 4 consisted of the closure of the interview and an explanation of the follow-up survey completion. Each participant received a $20 Amazon gift as compensation after completing the study.

The participants' verbal responses were audio-recorded to be later transcribed and analyzed. They were also encouraged to ask questions and take breaks when needed during the interviews. Once all the parts were completed, I debriefed each participant and presented them with instructions for the follow-up questionnaire, which had to be completed within 36 hours. The questionnaire aimed to assess the participants' demographics, perceived trustworthiness of AV, and intentions of monitoring AV.

Demographics Questionnaire

The demographics questionnaire was administered to collect information about the participants' general demographic information (e.g., age, sex, and ethnicity), educations, occupational statuses, and types of car ownership.

The Perceived Trustworthiness of AVs

I used a scale that was an adapted questionnaire from Jessup et al. (2019), which was also adopted for the previous phase of this research. In their work, the authors reviewed different peer-reviewed measures of the propensity to trust automation and tested their ability to predict initial perceived trustworthiness and initial behavioral trust against a new measure. Their results demonstrate that their newly proposed and context-specific measure, in comparison to measures such as the complacency-potential rating scale (CPRS), was more reliable and better predicted perceived trustworthiness and behavioral trust. Their proposed measure consists of a 7-point Likert scale that ranged from "completely disagree" to "completely agree" and featured six items comprising the use of automation. Since the present study aims to investigate AV, I adapted the proposed questionnaire from Jessup et al. (2019) to a more situation-based context by changing the items about “technology” to “autonomous vehicles,” as presented in Table 23.

Table 23: Perceived Trustworthy of AV Scale Based on Jessup et al. (2019)

Original Questions from Jessup et al. (2019)	Adapted question for the study focusing on AV
Generally, I trust technology.	Generally, I trust in autonomous vehicles.
Technology helps me solve many problems.	Autonomous vehicles will help to solve different types of problems.
I think it’s a good idea to rely on technology for help.	I think it will be a good idea to rely on autonomous vehicles for help.
I don’t trust the information I get from technology (reverse-scored).	I will not trust the decisions made by an autonomous vehicle (reverse-scored).
Technology is reliable.	Autonomous vehicles will be reliable.
I rely on technology.	I will rely on the technology used in autonomous vehicles.

5.1.2. The Participants

The inclusion criteria for this study including having a valid driver’s license, driving at least twice a week, and having used a ridesharing application in the last 30 days. A total of 17 participants accepted the invitations to participate in the interviews and met the inclusion criteria. I aimed to recruit a similar number of men and women and a diverse variety of professional backgrounds, which was also associated with the possibility of having more or less knowledge about autonomous system functionalities, which related to previous knowledge and influencing levels of trust.

For age, 58.8% (n = 10) of participants were between 24 and 38 years old; 29.4% (n = 5) were 39 to 53 years old, while 5.9% (n = 1) were either from 54 to 72 years old or more than 72 years old. Approximately 58.9% (n = 10) of the participants were female. For education, 47.1% (n = 8) had an advanced degree (either a master’s or doctorate); 35.3% (n = 6) had a bachelor’s, and 11.8% (n = 2) had some college experience. No participant had only a high school education or less. As for car ownership, 94.1% (n = 16) owned a car, and only 5.9% (n = 1) did not own a car; one participant shared a car with another household member. Detailed information on each participant is provided in Tables 24 and 25.

Table 24: Frequency of the Sample's Demographic Characteristics

Description		Frequency
Gender	Female	58.9% (10)
	Male	41.1% (7)
Age	18–23	0% (0)
	24–38	58.8% (10)
	39–53	29.4% (5)
	54–72	5.9% (1)
	>72	5.9% (1)
	High school or less	0
	College	11.8% (2)
	Bachelor's	35.3% (6)
	Advanced (master's or doctorate)	47.1% (8)
Car Owner	Yes	94.1% (16)
	No	5.9% (1)

Table 25: The Participants' Characteristics

	Gender	Age	Ethnicity	Education	Occupation	Car Ownership	Level of trust in AV
P01	Female	37	Asian	Grad	Student	Yes/Shares car with partner	Low
P02	Female	29	Latina	Undergrad	Marketing manager	Yes	High
P03	Male	65	White	Undergrad	Retired	Yes	High
P04	Female	26	White	Undergrad	Student	Yes	High
P05	Female	35	White	Undergrad	Stay-at-home mom	Yes	Low
P06	Female	50	Black	Grad	Sales	Yes	Low
P07	Male	45	White	Grad	Researcher	Yes	Median
P08	Female	32	Latina	Grad	CEO	No /Shares driving app (Zipcar)	Median
P09	Male	35	White	College	Technology manager	Yes	High
P10	Female	34	White	Undergrad	Music teacher	Yes	High
P11	Male	53	White	Grad	Professor	Yes	High
P12	Female	48	White	Grad	Data analyst manager	Yes	High
P13	Male	72	White	Grad	Retired	Yes	High
P14	Female	43	White	Grad	Professor	Yes	Low
P15	Female	28	Black	College	Retail supervisor	Yes	Low

Table 25 (cont.)

P16	Female	45	Black	Under	Customer relationship manager	Yes	Low
P17	Female	33	Asian	Grad	Student	Yes	Low

5.2 Data Analysis Process

I divided the process of analyzing the interviews into two main phases. The first phase related to the analysis of the questionnaire, and the second phase related to the analysis of the interviews.

The data collected from the questionnaires were analyzed using descriptive statistics (e.g., frequencies, ranges, means, and the standard deviation) to describe the demographics characteristics of the participants and their AV perceived trustworthiness scores, which are detailed in Table 44. I transcribed the audio files that were recorded during the interviews using machine learning software, Ottis.ai, and then checked them for accuracy. I analyzed the transcriptions using the thematic analysis approach as described by Braun and Clarke (2006). Their approach allows for a systematic way of seeing and processing qualitative information and is organized into five steps, as used in this research. Table 43 details the categorization process.

Step 1: Data familiarization: This includes the transcription and review of the interviews. Throughout this process, the researcher becomes familiar with the data, and it is possible to identify initial ideas after reviewing each transcript.

Step 2: Generating initial code: This step includes the first and second time that the researcher reads the transcribed data after reviewing the transcription. During the reading and re-reading process, the researcher starts "Coding interesting features of the data in a systematic way across the entire data set, collecting data relevant to each code" (Braun and Clarke, 2006, p. 87).

This initial coding process followed a deductive approach, which related to a predefined set of interests (Palys and Atchison, 2014, p. 304). The process of deductive coding begins by using specific or pre-defined interests to identify relevant pieces of information to develop a set of preliminary codes. I defined the pre-defined areas of interest in relation to the goals of the study: the use of cruise control, no use of cruise control, monitoring behavior, situations that might demonstrate trust in automation, situations that might demonstrate distrust or mistrust in automation, and situational variables that might influence the participants' behaviors and decision-making, including their perceptions of benefits and concerns.

Step 3: Searching for themes across the data: This phase follows the interpretative coding approach; the researcher elaborates on the preliminary codes by making finer distinctions within each coding category (Palys and Atchison, 2014, p. 304). Braun and Clarke, (2006, p. 87) also claimed that this step resembles "collating codes into potential themes, gathering all data relevant to each potential theme." During this phase, I re-read the transcripts several times to narrow down the number of codes and categorize them into identifiable themes. I then analyzed the codes and grouped them into four central themes: trust, internal variables, external variables, and monitoring behavior.

Step 4: Reviewing themes: During this phase, the complete interview data are re-read to validate the codes. By "checking if the themes work in relation to the coded extracts at the first level and second level" (Braun & Clarke, 2006, p. 87), this step also provides the opportunity to pattern coding as process associations become apparent. Here, it is possible to start identifying trends within the data, and these were used to identify behavioral patterns related to the internal and external variables that influenced situational trust.

Step 5: Reporting: This step comprises the final analysis, which also consists of developing compelling examples that represent the data. Such examples were extracted to showcase the resulting outcomes both as statements in the form of ideas and feelings, and "visual representations are drawn using interconnections between codes" (Braun & Clarke, 2006, p. 87).

5.3 Analysis

This section aims to answer the following question: "How does the perception of benefits and risks regarding an AV's analogous system (cruise control) act on situational trust in CC?" This section is organized in two subchapters: one presents the results of the trust-in-AVs questionnaire, and the other presents the analysis of the results of the interview thematic analysis.

5.3.1 Trust in AV Questionnaire Results

After the interviews, the participants answered the trust-in-AV questionnaire. The scores ranged from 7 to 42; the *mean* score was 26.17, the *mode* was 30, the *median* was 27, and the *SD* was 7.7. Participants who had scores above 27 were classified as highly trusting AV, and participants who had scores lower than 27 were classified as lowly trusting AV (Table 26). It is important to acknowledge that the categorization of high and low trust, using the median, presents limitations because low trust can be connected to distrust situations, while high trust scores can be connected to overtrust situations. Both, distrust and overtrust are levels that can caused the misuse of the AS.

Table 26: Participants' Categorizations Based on Their Perceptions of AV Trustworthiness

#	Total Score	Trust in AV category
P01	15	Low
P02	31	High
P03	36	High
P04	32	High
P05	26	Low
P06	24	Low
P07	27	Median
P08	27	Median
P09	30	High
P10	35	High
P11	30	High
P12	30	High
P13	37	High
P14	18	Low
P15	14	Low
P16	13	Low
P17	20	Low

5.3.2 The Analysis of the Interviews

By conducting the interview analysis, I aimed to achieve the five goals listed in the following paragraph to understand situational trust in CC and how the perception of benefits and concerns, as well as other internal and external variables, influence the adoption of cruise control.

1. Identify the participants' levels of knowledge and interest in car technology.
2. Identify the participants' perceptions of benefits regarding their vehicles and whether CC relates to that.
3. Identify the perception of CC benefits.
4. Identify and understand the situational variables influencing the adoption of CC.
5. Identify and understand the situational variables influencing the non-adoption of CC.

Table 27 presents the initial categorization of the interviews. As previously mentioned, the analysis started with predefined areas of interest. The next step involved the identification of themes and, finally, the categories within the themes. This initial categorization was essential for the subsequent analysis and achievement of the five key objectives of this study.

Table 27: Thematic Analysis Categorization

Theme	**Category**	**Fragment of Text**
Decision for choosing the vehicle / benefits Understand the main reason for purchasing the current vehicle they own.	Economy	*"[...] the value for money, it's really good. Basically, the things that I most look for a car which is economic and technology, it's there."*
	Technology	*"[...] is a 2011, one of the first vehicles that had a backup camera. It's a black and white backup camera."*
	Size	*"[...] little more family friendly like a van or a little bigger car.*
Perception of safeness Identify which features relate to a car's reliability and safety and if those features relate to perception of trustworthiness of cruise control and its use.	Airbags	*"So, it has like seven airbags. So, it's a really reliable and secure, safety car."*
	New car	*"I rely my car 100%. Like I said, it's a brand-new car."*
	Tires	*"The tires must always be good"*
	Backup camera	*"[...] backup camera [...] especially pulling out of my driveway, when there's tons of kids running around, not just mine"*
Control of cruise control: Identify the trusting behaviors during the use of CC	Control with automation (the cc keeps on)	*"If I'm just, like open highway, and I've got cruise control on and I'm not really concerned about anything around me, I just use the buttons on...my steering wheel."*
	Manual control (the cc is turned off)	*"I use the pedals because it's faster."*
Monitoring behavior Increased monitoring behavior might show less trust in automation. This theme identifies how participants demonstrate monitoring behavior and attention to the system performance	Attention to the speedometer	*"[...] I know how it works and I know my car... is just I don't check very often yeah"*
	Attention to the route	*"I, you know, so I pay attention to where I am, I don't think I would ever consider paying attention to like the speedometer. [...] I'm paying attention to where I'm going [...]."*
External variables The external variables that influence the adoption of CC, and if these variables can change how participants behave during a ride, and its relation with trust.	Weather	*"Even if it's raining, I use it. [...] doesn't really bother me and doesn't make any difference."*
	Road conditions	*"Anytime there's gravel, I've already been going slow because it's usually just a slower road anyway."*
	Daylight	*"[...] night time the same, I always put on because I think it's more, even more safe, safer."*

Table 27 (cont.)

	Traffic	*"[...] except in super heavy traffic and or in construction zones a lot of times, uh, if it's, you know, bumper to bumper."*
Internal variables The internal situational variables (related to the user) that can change how participants behave during a ride, and its relation with trust.	Tiredness	*"When I'm tired, that is the one that I get a bit unsure of what to do, because if I'm tired, if I'm relying on 100% of my car, I may fall asleep, and this is not really safe.*
	Stress	*"I never use CC if I'm stressed or angry. Yeah, I want to have control of the way that I'm driving."*
Accuracy Trust relates to performance and how accurate the system is. This category explores the perception of accuracy and what are the trusting behavior associated	CC speed is accurate	*"I only slow down if I see that the traffic is also slowing down or there is an accident. Otherwise, I won't change the speed."*
	Reduce cc speed for certainty	*"I always, always, slow down a few miles of the speed limit just to make sure that it's right."*
Mistrust Identify if there are situations of mistrust where participants do not trust the system because of a suspicion or intuition, but without any previous bad experience that could lead to that.	Suspicious, Intuition	*"it's just I feel more safe and I don't feel secure to just go and rely on technology. I rather to do it physically."*
Distrust Identify if there is any type of distrust evidence related to cc or ridesharing. Distrust could be bas on previous experience.	Initial knowledge	*"You know that you hear about those nightmare stories where an Uber driver picks somebody up and then takes them into wherever and kills them or whatever [...] And I always have my phone out, ready to call somebody"*

5.3.2.1 Experiences with Automobile Technology

I began the data analysis and categorization with a general understanding of the participants' interest in, knowledge of, and previous experiences with automobile technologies. The premise is that participants with higher interest in car technology, as well as technology in general, exhibit higher levels of CC adoption. This relates to previous findings that higher levels of perceived trust in technology are linked to more favorable perceptions and the decision to adopt a technological innovation (Arnott, 2007; G. Kim et al., 2009; Venkatesh et al., 2012).

The majority of the participants exhibited a similar level of knowledge related to driving technologies, and none of them demonstrated a high level of interest in cars (e.g., they did not follow specialized automobile news, were not car collectors, etc.). Although the participants stated that they did not follow any specialized media, six out of 17 participants stated that they did online research before buying their current vehicles, such as searching for other owners' reviews online and car safety ratings on the National Highway Traffic Safety Administration

(NHTSA). P05 said, *"Before buying this car, I searched for information about safety on the NHTSA and on the internet to help me with my decision"* (P05, 35 years, stay-at-home mom).

The results demonstrate that five out of 17 participants who owned cars with advanced technological features, such as lane-keeping alerts and automated braking systems, were more comfortable using CC and wanted to use it more if this were possible. Usually, environmental variables such as weather and traffic conditions prevented them from "being in cruise control mode" for long periods, as mentioned by P5. This topic is further investigated in Section 5.3.2.4.

> *I use [CC] every time that I know I can speed up a little and there isn't traffic… You know Illinois, everything is flat! And my car also breaks if I'm too close from another car, which makes [me] even more comfortable, and I want to use it more.* (P5, 65 years old, retired)

For the next step, I investigated the relationship between the participants' ownership of cars with more or less technology and their trust scores. Although the sample size was small and no conclusions could be made in terms of causal relationships, this information relates to the participants' expertise and experience with automation in an analogous system.

Table 28 presents the trust categorization and the information concerning whether the participants owned cars with advanced technological features. Here, I defined advanced technological features as any type of automated system in the vehicle that is more complex than cruise control, such as automatic braking systems, line-keeping, distance keepers, and automatic parking. All five of the participants marked with an (*) were categorized as having high trust in AV and also owning a car with advanced technology.

Table 28: Participants' Perceptions of AV Trustworthiness Classifications and Advanced Autonomous Technology in Their Cars

#	Trust in AV	Car with Technology
P01	Low	No tech
P02*	**High**	**High tech**
P03*	**High**	**High tech**
P04*	**High**	**High tech**
P05	Low	No tech
P06	Low	No tech
P07	Median	No tech

Table 28 (cont.)

P08	Median	No tech
P09	High	No tech
P10	High	No tech
P11*	**High**	**High tech**
P12	High	No tech
P13*	**High**	**High tech**
P14	Low	No tech
P15	Low	No tech
P16	**Low**	**High tech**
P17	Low	No tech

In this sample, the participants' familiarity with advanced technology (more developed than CC but analogous to AVs, such as automated braking systems) minimized their perception of risk and uncertainties related to AVs and maximized their perception of AVs' performance and benefits, which consequently increased the perception of AVs' trustworthiness, as illustrated by P02 comment.

> *I went to a trip last week and I barely drove. The car was doing everything for me, controlling the speed, breaking and lanes. I try to use cruise control and all features of my every time that I can.* (P02, 29 years, marketing manager)

It is important to highlight that only Participant 16 did not present a high level of trust despite owning a "high tech vehicle." One of the possible reasons for this might be that this participant mentioned that the main reason for purchasing the vehicle was its size and the fact that it is a luxury car:

> *I always wanted to have a big car, and a Cadillac Escalade was my dream choice. This is why I bought this car. Also, it is luxury... there are many cool features, like window defrosting, but some of the things I don't even know how to use*. (P16, 45 years, customer relationship manager)

In summary, the analysis of the results demonstrates that participants who own cars with "high tech" appeared to be more comfortable when using the technologies. This relates to the development of learned trust, as well as expertise on the subject. When verifying the participants' levels of trust, I observed that they had high levels of trust in AVs. This analysis is illustrated in Figure 20. This finding indicates that the act of trusting an AV's analogous systems can support the understanding of trust in AVs. However, further research must investigate this hypothesis.

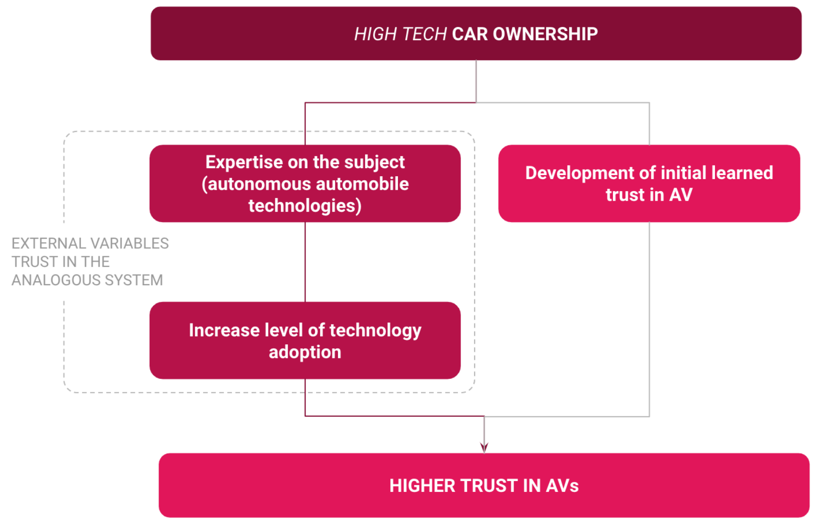

Figure 20: The Use of Technology and Its Relationship with Trusting Behavior and Trusting AVs

5.3.2.2 Perceptions of Vehicles' Benefits

Regarding the perception of benefits that influenced the participants' decisions to purchase their current vehicles, the participants mentioned three main reasons: the economy (12 out of 25 statements), technology (9 out of 25), and size (4 out of 25). Some participants referred to more than one benefit when explaining why they purchased their cars.

The participants' main reason for purchasing a vehicle related to economic aspects. When analyzing each of the responses that mentioned an economic benefit, I identified two main points: purchasing price and fuel economy. Eight out of 12 statements mentioned the price that the participants paid when purchasing their vehicles, such as the statement that was made by P01: *"My Honda Civic is not a very expensive car, and it was a very good deal... I also know that it will be easy to sell this car" (P01, 37 years, student)*. However, four out of 12 statements mentioned that the participants' vehicles' fuel economy was an important benefit that influenced their purchasing decisions.

This finding corroborates with Study One, which observed that the main reasons the participants purchased their cars related to economic aspects. Moreover, this finding also relates to the individual benefits and concerns about AVs, which also related to economics.

5.3.2.3 Overall Perceptions of the Benefits of Cruise Control

When asked about what are main benefits of using CC, all the participants expressed having positive perceptions of CC, regardless of their level of trust in AV. I began the analysis grouping all responses to this question and generating a word cloud to create an overview of participants' responses. Figure 21 illustrates the top 30 words that the participants mentioned when talking about their general perceptions of CC. The word cloud was created using SPSS and was excluded from counting the most frequent stop word. The words that were commonly associated with the benefits of CC include "speed," "highway," "easier," and "foot."

The next step was the content analysis of the responses. The words from the word cloud were used as the initial theme of the thematic analysis process. The final categorization is presented in Table 29.

Figure 21: The Word Cloud with the Top 30 Words Related to the Perception of Benefits of CC

Table 29: Categorization of the Benefits of Using CC

Theme	Category	Subcategory	Statement	Count
Perception of benefits The variables related to the benefits of CC	Level of effort	Comfort/ease to use	"I think it is easier to drive using CC. I feel more relaxed and get less tired..."	9
		Speed control	"It's easier to drive because you don't need to control the speed all the time."	15
	Physical comfort	N/A	"I can stretch my legs"	5

Participants mentioned that the biggest benefits of using CC are comfort and speed control. Although the participants focused on these two different characteristics, the main attributes of these benefits are the same as they relate to the driver's level of effort. Fifteen out of 17 participants stated that the main benefit of CC usage is the speed control, as stated by P07: *"… that's probably the main reason why I use it. It is to just keep my speed steady…*" (P07, 47 years, researcher).

Participants also mentioned that the capacity of keeping the speed constant makes easier to drive as claimed by P08 *"It is just easier. I mean, it makes driving much more, you know… it's just easier. You don't need to speed up or slow down… and braking and navigating"* (P08, 32 years, CEO). Moreover, nine out of 29 statements mentioned that in addition to make driving easier, CC also makes driving more comfortable and relaxing, as mentioned by P02 *It is really comfortable… I set the car's cruise control, I basically don't even drive anymore. But because, like I said, my car turns the wheel by itself and also breaks"* (P02, 29, marketing manager), and P10 *"It makes [it] easier to drive, and I feel more relaxed."* (P10, 34, music teacher). In summary, by automating the maintenance of speed, the effort levels of driving are reduced, since there is one less task to be done. Consequently, participants feel more comfortable.

Comfort was related to the driver's physical comfort, as stated by P06: *"What I like about it is that it can give your leg a break."* Therefore, CC was mostly frequently identified as a benefit when associated with long distance driving.

This finding demonstrates that the main benefits of CC, just like the benefits of AVs, present elements of system reliance: the purpose of the system (comfort) and process (speed control). Moreover, the perception of speed control as a benefit reveals that the participants relied on automation to control their cars.

5.3.2.4 The Adoption of CC

As a preliminary step in the analysis of why the participants chose to adopt CC in their vehicles, I developed a word cloud image to visualize the top 30 words that the participants related to the use of CC. The process of creating this image involved multiple steps that involved stop-words elimination (e.g., "I," "think," "car," "yes," "ok," and others) using the SPSS software. I discovered that "helps" was the most recurrent word, which was followed by "night," "speed," "weather," and "traffic." These words exhibited three main external variables that are situational to the context of use: the environment (the weather, the time of day, and traffic) and process (speed control). Furthermore, this preliminary analysis also revealed that external variables seemed to more strongly influence the adoption of CC.

Figure 22: Top 30 Most Recurrent Words Related to the Use of Cruise Control

External variables are situational factors that relate to the environment and specific characteristics of the context of use (e.g., the environment, the weather, and road conditions) or characteristics of the system (e.g., process and performance, ease of control, complexity, and workload). Internal variables are situational attributes of the driver, such as their mood, attentional capacity, stress level, and other factors. These are situational states because they might change over the course of a single interaction or multiple interactions with the system. For instance, a driver can become drowsy over the course of a long drive, which may reduce their attentional capacity and concentration.

The next step of the analysis, which also involved thematic analysis, focused on statements in which the participants mentioned when and why they use CC. With the identification of those statements, I initiated the categorization using the variables identified in the word cloud organized. I focused on the categorization of what factors influenced the participants’ decisions and to determine whether these were internal or external variables. The results of the analysis are presented in Table 30. In addition, the Figure 23 illustrates the organization and relationship of the categories identified.

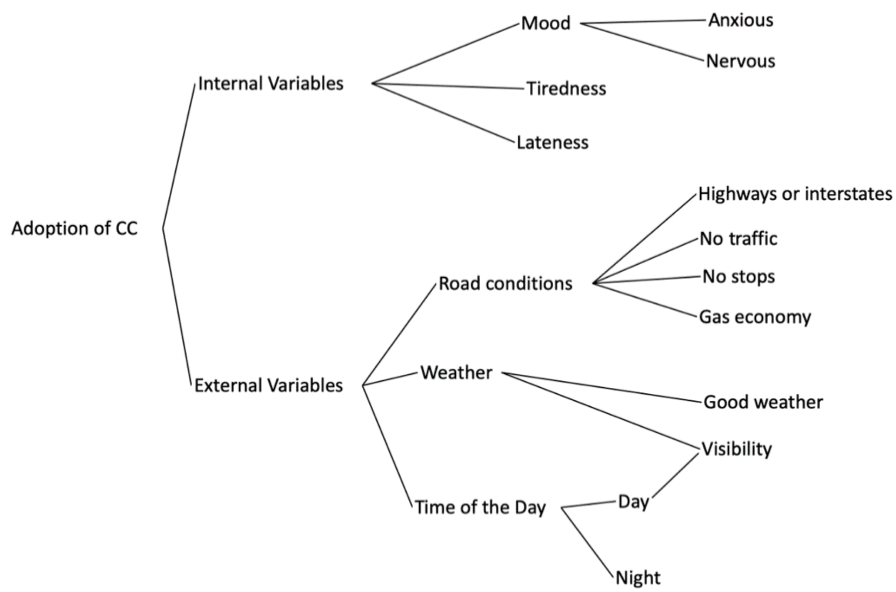

Figure 23: Categories and Subcategories of Situational Variables Related to the Adoption and Non-adoption of CC

Table 30: Categorizations Related to the Use of CC

Theme	Category	Subcategory	Quotation	Count
External variables: Environmental conditions that interfere with the adoption of CC	**Weather**	Good weather	*"If the weather is almost good, I have control, like I can see in front of me easily… I use the cruise control."*	8
	Time of day	Night	*"…that's nighttime the same, I always put on [CC] because I think it's more, even more safe, safer."*	3
	Visibility	N/A	*"If the situation is, like clear. If I can see what's happening in front of me, and then I can take charge as fast as possible."*	13
	Road condition Not necessary to change speed	Highway or interstate	*"I just use it when I'm on highways. I don't use it inside the city."*	16
		No traffic	*"…where it's just… you're driving the same speed for a long time."*	11
		No stops	*"Even if I have a couple of miles to go and I know there are no stop [streets], stop signs, or traffic lights, [then] I would put on cruise control."*	10

Table 30 (cont.)

	Economy	Gas	*"I would think that my gas mileage would be worse if I was like constantly pressing the gas."*	4
Internal variables	**Mood**	N/A	*"If I'm stressed out and I'm running late, I'll put cruise control higher… like, I'll go faster in the cruise control."*	3
	Tiredness	N/A	*"I think that I have, let me think, um, I think I have it on because then I do turn, like, the music up and roll the windows down to try to stay awake."*	2

These results demonstrate that external variables had a greater influence on the participants' decisions to use CC than internal variables. The condition of the roads was the most influential variable. Its categorization allowed me to identify three subcategories related to what conditions are favorable to the use of CC: highway or interstate (16), no stops (11), and no traffic (10).

Highways and interstates are the preferred type of road because the traffic flows better, which reduces the need of changing the speed. In this type of environment, since the speed is constant, the driver does not need to control and monitoring the performance of the CC. This corroborates with the correlated subcategories of stops and traffic, because in both situations, the driver needs to brake and speed up constantly. Therefore, it is possible to state that road conditions must involve the necessity to maintain a steady speed, as mentioned in P01 speech: *"Even if the weather is good and I'm driving on the interstate to Chicago, for example, and there is too much traffic, I don't use cruise control"* (P01, 37 years, student); and P13: *"I don't like to use CC when there is too much traffic because you always need to brake or speed up, and I need to keep turning on the cruise control" (P13, 72 years, retired).*

Some participants also stated that the visibility of the road, as mentioned by P17, influenced their adoption of CC:

> *I always use CC when I don't need to change speed soon, but I must have a good view of the road, and I can see that the road is clear, that there is no construction.* (P17, 33 years, student).

Visibility was connected with the category of weather and time of the day. Seven participants stated that they preferred to use CC during the day because it is easier to see.

Although not directly mentioned in the participants' statements, good weather (8 mentions) also connected with the visibility of the road, which is reduced in rainy and snowy situations.

Internal variables such as mood (3) and exhaustion (2) were conditions for use only in a few statements. Only three statements mentioned that in situations where the participants' moods were affected, such as if they were stressed or angry, they would adopt CC because this made driving easier for them. Additionally, participants who mentioned that they would adopt CC when tired thought that they could focus on other things to make them feel "more awake" than driving. In these situations that involved the participants' feelings, I observed that they exhibited a decreased desire to drive and control the vehicle and switched to a different focus.

> *If I'm tired, I usually stop somewhere, get a coffee. I open the windows or turn on the AC, and I use the CC if the road conditions are good. So… you know, I don't need to think about if I'm above the speed limit, and I can focus only on the road conditions and the other cars.* (P04, 26 years, student).

The relationship between traffic conditions and the adoption of CC relates to the process of the system. This external variable (traffic conditions) requires more or less monitoring behavior of the environment from the participant than the system itself does (e.g., changing the speed more frequently). The decreasing monitoring behavior consequently relates to the purpose of the CC system—that is, to support the driver in controlling the speed of the vehicle.

The Non-adoption of CC

The analysis of the variables that influence the non-adoption of CC followed the same strategy. I identified all the statements related to situations in which the participants did not adopt CC and completed the categorization and subcategorization regarding when and why CC is not used. When comparing the roles of internal variables as motivators for whether to adopt CC, I observed a higher presence of internal variables such as stress, exhaustion, and nervousness.

In situations that involved exhaustion, the participants tended to not use CC (13). Their statements demonstrated that the use of CC made them feel less engaged in driving, which made them even more tired. They believed that they needed to focus and be engaged in driving to try to feel less tired: *"If I'm on a long drive, for example, and I start to get sleep, I don't use CC. I feel that I will fall asleep. I need to drive to try to wake up."*

I observed the same in situations in which the participants felt stressed or angry or were in a negative mood. In these cases, the participants claimed that they wanted to be able to control something. Therefore, in both situations (feeling tired and stress), the participants desired to have control of the vehicle to make them feel "better."

However, the external variables were more associated with adopting cruise control. All the participants affirmed that they would not drive using CC when it is snowing or if the roads are icy. Rain, in a majority of the cases, was a concern only if the rain were heavy. Moreover, several participants mentioned visibility limitations as a consequence of the weather in relation to both inclement weather and road conditions.

Table 31: Categorizations Regarding the Non-adoption of CC

Theme	Category	Subcategory	Quotations
External Variables	Weather	Icy/Snowy	*"... **really icy**, then generally, I won't use cruise control because, uh, I need to change speed..."*
		Rain	*"... raining really heavily, then I don't think you can count on that. And so, I would rather have complete control of the car myself..."*
		Visibility	*"... any situation that I cannot have a clear vision of what is happening in front of me. I will never use it."*
	The time of day	Night	*"I am more cautious during the night when I'm driving, and I never use cruise control probably."*
	Road conditions	Highways or interstates	*"If I know that I'm getting off the interstate soon or maybe [if] I'm on a highway and I know that I'm going to need to turn, I'm more likely not to use [CC]."*
		Heavy traffic	*"... if it's, um, heavy traffic, like even if I'm on the interstate and the traffic starts to pick up, whether I'm going through a city or by a city or, um, just heavier traffic..."*
		Curvy roads	*"... curved roads, like hilly, where I can't see around the bend... a lot of blind spots."*
		Construction areas	*"If there's construction on the road, or just, um, I would say, like, anytime I'm paying more attention to my surroundings.*
Internal Variables	Stress levels	N/A	*"I don't think when I am angry or sad or, you know, like when you are... I don't think it's a good idea to use cruise control because you can just forget what you're doing."*

Table 31 (cont.)

Anxiety	N/A	*"…if I'm having to be on mentally for other people in the car or getting ready to go someplace important, rather meeting or something, I generally am not using cruise control..."*
Exhaustion	N/A	*"If I'm really really fighting sleep, I will turn the cruise control off so that I at least just have to push the pedal."*

The Adoption of Cruise Control Scenarios

For the next step of the analysis, I explored when both internal and external variables were questioned together and their relation to the participants' levels of perceived trustworthiness (high or low trust in AV). I asked the participants to describe what they would do if they were driving on an interstate at night and feeling very tired. For the majority of participants (14 out of 17), including all the participants who were classified as having high trust in AV, nighttime was not a factor that affected their decision to adopt CC because (i.) nighttime is not a concern if road visibility is good and (ii.) nighttime is a better time to use CC because there is less traffic. All three participants who would not adopt CC during the night were classified as having low trust in AV.

The internal factor "exhaustion" had more influence on the participants' decisions to adopt CC in comparison to the external factor "the time of day". Only three participants (two with high trust and one with low trust) stated that using CC when they are tired helps them to concentrate more on the road instead of the speed of their vehicles. However, six out of eight participants who highly trusted AV claimed that they would not adopt CC in the given scenario because driving on manual mode would make them feel more engaged with the car and, consequently, more awake. The statements of participants 05 and 08 illustrate this conclusion.

> *I do think CC can be dangerous if you're tired because with cruise control, you're doing less things by not taking control of the speed. Then you have less physical contact with the car, and I think this makes you even more sleepy.* (P05, 35 years, stay-at-home mom)
>
> *I don't mind if it is night or day. As long as there is not too much traffic and the road is good, I will use CC. But if I am tired, I think cruise control will make me more sleepy, you know… because I will be more relaxed, I don't need to pay attention to the speed. So, if I am tired, I won't use it… doesn't matter if it is night or day.* (P08, 30 years, CEO)

Moreover, the participants' decisions to use CC also related to their perceptions of personal reaction time. For example, some participants said that they use the buttons on the steering wheel to control the speed when it is necessary to adjust speed by only a few miles per hour. The majority of the participants (14 of 17) claimed that when they need to brake, they immediately use the brakes instead of the control buttons, as stated by P06: "*... usually… to slow down, I brake and then reset it."* This action was also associated with the reaction timing of the car: *"...because slowing down with the buttons takes a lot longer time than slamming on the brakes"* (P03, 65 years, retired). In addition, P17 also claims that the reaction time of the car if a decision factor on how to calibrate the CC speed.

> *… if I could stop suddenly, like, I'll press the brake, you know, if I really have to slow down fast, but if someone in front of me is just going like, you know, few, few miles per hour like slower, then I'll just slow the cruise… I'll stay on cruise control, just slow down.* (P17, 33 years, student)

When they the participants controlled the speed with the pedals instead of the buttons, even though doing so turns off the cruise control, they associated this with an automatic reaction and no rationale:

> *I think part of it is habitual, right? Like, you're just used to going faster using the pedals, and I feel like you have to think less about doing it right like because I don't use the accelerate button on my cruise control very much. I feel like I'm less likely to do that even when I do need to go faster.* (P05, 35 years, stay-at-home mom)

Furthermore, some participants stated that using CC can influence their levels of monitoring and, consequently, how quickly they can take back control of the speed. Most of the participants (10 out of 17) stated that using CC does not change their attention capacity but rather allows them to fully monitor their surroundings instead of monitoring their speed levels. However, seven out of 17 participants believed that using CC would interfere with their attention capacity. They claimed that they feel more comfortable and relaxed when using CC and, because of that, they would pay less attention to their surroundings and, consequently, have a slower reaction time.

5.4 Study Discussion

This study aimed to investigate AVs' analogous systems—mainly, cruise control. An improved understanding of why and how the participants have used CC has provided information on the internal and external variables that relate to situational trust in the analogous system, which can also influence trust in AVs. I conducted semi-structured interviews with 17 participants and used a questionnaire to measure the participants' levels of trust in AVs.

Based on the analysis of the semi-structured interviews, the results indicate that the participants' familiarity with the analogous systems (CC), as an internal variable, related to their trust in AVs. Participants who owned cars with more developed autonomous technology (e.g., automated braking systems and lane-keeping) than the system under investigation (in this case, the CC system) presented a higher perception of AV trustworthiness. Familiarity has an important role in situational trust processes that support humans in framing unknown situations before interacting with autonomous systems. Moreover, the participants tended to prefer to act in ways that were familiar to them. For example, when the participants had to decide between automating the speed control with the use of buttons on the steering wheels or manually controlling the speed with the pedals, they tended to choose the pedals because this is what they felt "used to." Familiarity also increased their levels of comfort, which could have led to scenarios that involved a lack of situational awareness and over-trust. As previous researchers have found, when drivers feel comfortable, it is easier for them to feel safer and engage with other activities, which can increase their propensity to become distracted (Rudin and Parker, 2004) and adopt more hazardous driving behaviors (Hoedemaeker and Brookhuis, 1998).

Figure 24 illustrates the importance of the concept of technological familiarity as an internal factor that must be considered when researching situational trust since it relates to other variables and the performance and process of the system. Both performance and process are important aspects of trust in automation formation, as described by Lee and See (2004). Although this study utilized a limited dataset, the participants' familiarity with other types and more developed analogous technologies seems to support their decisions to use CC. Therefore, this finding indicates that interactions with analogous systems may influence trust as a situational factor.

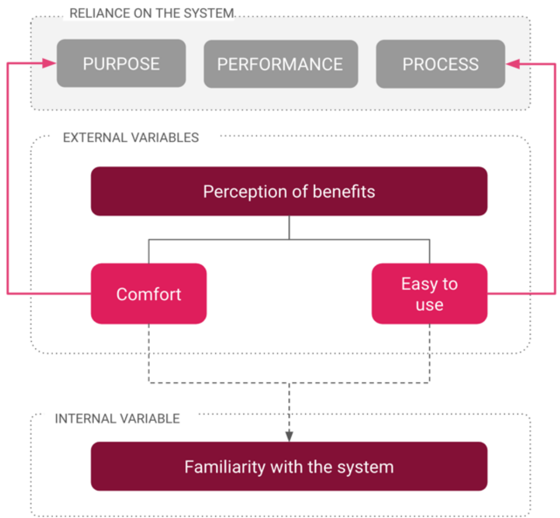

Figure 24:Familiarity with the System

Situations that involve over-trust have been identified as a major reason for AV incidents due to drivers' failures to monitor systems and interventions with the control of AVs (Frison et al., 2019; Kundinger et al., 2019). By corroborating previous findings, my results demonstrate that the perception of the time available for intervention is one of the main reasons why the participants would or would not adopt CC. This relates to both the performance of the system and the performance of the user. For instance, some participants stated that they would not use the CC system if they thought they were in a situation where they would need to quickly take back control of the vehicle (such as driving under poor conditions that involve inclement weather or too much traffic). However, other participants who were more engaged and comfortable with the use of CC (i.e., they had a higher perception of AV trustworthiness) were also less worried about their reaction time that related to taking control back. This is an important research finding regarding current interactions with analogous systems since it provides insight for the calibration of situational trust in AVs.

5.5 Final Considerations

I attempted to gain a better understanding of how situational variables influence the situational trust dimension during the qualitative phase of this dissertation and explored a new direction by investigating users' current behaviors with an AV's analogous systems (cruise control). While AVs are not completely accessible to society, people tend to refer to previous experiences with and familiar topics that concern other technologies when explaining their thoughts and opinions about AVs, such as "computers make mistakes" and "technology improvement" (Rousseau, 1998). Therefore, the investigation of users' current reliance on technology and behavioral patterns with analogous systems supports a better understanding of situational trust in AV and its variables. These current behaviors may become a support mechanism for future human and AV interactions in which participants anchor their behaviors based on previous experiences with analogous systems.

I analyzed the interviews following the thematic analysis approach and organized the analysis process into three main phases: participants' interest and knowledge in vehicles' technology, the perception of benefits of participants' vehicle's and benefits of CC, and the identification of internal and external variables that would interfere in the adoption or non-adoption of CC.

The results demonstrate that the participants who owned vehicles with developed autonomous systems such as lane-keeping and automatic brakes felt more comfortable using CC and presented higher scores on a questionnaire that was designed to assess their levels of trust in AVs. This relates to one of the variables of formation of trust in AS, which has already been investigated. This is initial learned trust and the development of subject matter (which is an internal variable of situational trust).

Regarding the benefits of vehicles, the participants perceived economic attributes as the main benefits provided by their vehicles and cited this as their reason for purchasing them; these attributes are the same benefits and reasons that were mentioned by the participants from Study 1. This demonstrates that although technological and societal aspects can also influence an individual's decision to purchase a vehicle, economic factors are always going to be a concern. This is why economic attributes are the main individual concern about AVs.

The main variable that has influenced the adoption of CC is the monitoring of vehicle performance. Some participants adopted CC in situations where traffic and roads were constant and when they did not need to control the vehicle's speed, which increased their use of CC. In situations where there was traffic or hazardous road conditions, many participants regulated their speed by braking and accelerating. In this situation, where it is necessary to highly monitor the vehicle and the environment, most of the participants preferred to not use CC.

Additionally, visibility was another external variable capable of influencing the use of CC. In situations where there was less visibility, the participants tended to not use CC because they needed to pay more attention to the road and have more reaction time in case something appeared on the road. This represented another situation in which the participants had to have more control and monitor the vehicle, so CC was not used.

Both road conditions and visibility are external variables that influence situational trust. In these situations, I observed a decrease in CC adoption and less reliance on the system to perform in these conditions.

These results demonstrate that external variables impact situational trust in CC. Although the participants trusted that CC would be able to maintain their speed correctly, in certain situations, they thought that the system would not support driving and that they would need to regain total control of the vehicle, which would require them to have a quicker reaction time.

Although this study was affected by limitations regarding its methods (as previously mentioned, my initial goal was to conduct an in-person contextual inquiry), the interviews provided information that allowed me to understand the participants' perceptions of CC benefits, as well as the variables that influence trust in CC (visibility in the driving environment, conditions of the environment, and mood). Future researchers should investigate whether these external variables interfere with situational trust in AV. The goal is to understand how to calibrate trust in these situations so users can maintain their required levels of monitoring.

Chapter 6. Final Discussion

This chapter discusses the main findings of each study and identifies possible relationships among them. The research followed a qualitative approach, and the findings presented require further investigation, especially through the use of quantitative methodologies, to better understand how humans interact with AVs and their analogous systems.

6.1 Control and Monitoring in Trusting Behavior

Control and monitoring are behaviors that have been extensively investigated in studies about trust. In 1993, Parasuraman et al. found that participants who had the poorest failure-detection abilities, in other words, they performed poorly at correcting monitoring systems, presented the highest levels of trust in automation. While numerous studies have adopted simulation and prototypes to investigate AVs, the research conducted for this dissertation corroborated patterns of trusting behavior found in previous studies by investigating CC as an analogous system of AVs. Although more research is necessary to investigate monitoring in CC, the dissertation's results demonstrate the efficiency of using analogous systems to understand trusting behaviors toward automobile automation.

Researchers in both academia and industry have intensively investigate the "issue" of control in AVs because of the inherent ethical risks, namely, determining fault in an accident when the driver is not in control of the system performance. The research conducted for this dissertation found that in addition to being perceived as a risk of AVs, the control of the system also influences users' adoption of the analogous system (CC) and their trusting behavior.

Study 1 found that the AV's performance failure is one of the biggest risks. This related not only to technical issues but to the fact that drivers, when riding an AV, will engage in different activities and pay less attention to the vehicle's performance. Consequently, if the vehicle fails to perform correctly, the driver will be slower to intervene and resume control of the vehicle. This concern was reflected in the response that their primary activity while riding in an AV would be the observation of the road and the monitoring of the system performance.

On the other hand, Study 2 found that when using CC, participants tended not to monitor the performance of the system, in this case the speed. They mentioned that they trust the system and believe that, while using CC, the speed is accurate and constant regardless of external factors. This finding contributes important information regarding how people are likely to behave after becoming familiar with AVs. It also shows, that the use of CC does not represent a risk related to performance failure. Although CC has been widely adopted, it is important to take this finding into consideration and further investigate this topic in real-life environments, since new variables might be discovered during these investigations.

Participants in Study 2 stated that the use of CC slowed their reaction time in situations where they needed to resume control of the vehicle's speed. In situations considered "riskier," participants expressed the desire to remain highly attentive to the environment in order to react quickly should they need to resume control of the vehicle.

The findings highlighting situations where participants increased their monitoring levels and desired more control of the vehicle due to the influence of situational external variables represent a contribution to the literature on AV, specifically relating to user experience. Designers of AV systems should take into consideration that users' trust changes in situations perceived as risky-heavy, such as rain and snow, reduced visibility, and high-traffic conditions. For example, the trusting behavior change, increasing the level of attention toward system performance and the desire to resume control of the system. The changes on participants' trusting behavior was demonstrated by them not allowing the system to perform in adverse conditions, overriding CC when it was raining. However, differently from CC, fully AVs systems capable to identify risky environmental conditions would be able to calibrate the level of trust and avoid changes on users' trusting behavior.

6.2 Individual Risks

This study identified economy as the main reason of why participants purchased their currently vehicles (low purchasing price) and their main benefit (fuel economic and low maintenance costs). Economic factors were also considered big one of the biggest risks of AVs, and the biggest one when analyzing only in the individual level. This provides insights on the influence of benefits of an analogous system (CC) to the perception of both risk and benefits of the AVs. Thus, participants' trust of the analogous system provides important clues about how trust will be influenced by the same situational variables.

Moreover, economic factors, are important to be consider as external variables influencing trust in AV. Future studies should further investigate the benefits and costs of AVs, both on the individual and societal level. This study investigated a small sample size and focused on the economic factors in the individual level. However, a larger study using a quantitative approach would be able to better identify a correlation between perceptions of benefits and costs as well as other aspects of trust including dispositional trust. Therefore, future studies should also focus on the investigation of participants' portrait value profiles (dispositional variable), because it tends to reflect their individual and societal views of benefits and risks (situational variables) of AVs. This would fill one of the biggest theoretical gap regarding the different layers of trust in automation, identifying the relationship between dispositional and situational trust.

6.3 The Trust Score

Participants classified as having high trust in AV are more influenced by internal variables (e.g., tiredness) than external ones when deciding whether to use CC. On the other hand, external variables (e.g., time of day and traffic) appear to be less influential in the decision of high-trust participants than they do in participants classified as having low trust in AV. This provides insight for future studies, which should consider how different situational variables influence levels of trust in different ways.

AVs are affected by situational variables of interaction with analogous systems. Overall, the majority of the participants perceived CC as trustworthy. Not comprehending the technology behind these systems does not appear to represent a risk or a reason for not trusting the systems investigated. Instead, participants' fear of other drivers on the same road and internal situational factors (e.g., attention and capacity to quickly react when necessary) seem to be the greatest influence in their decision to not adopt these systems.

Participants with high levels of trust in AV demonstrated a familiarity with other types of advanced automated technology. Thus, familiarity with analogous systems may be a critical internal variable for situational trust by supporting humans in framing unknown situations prior to interaction with automation. Although Hoff and Bashir's model already indicates that expertise is an internal variable, further investigation should be undertaken to understand the role of familiarity and validate it as a situational variable.

Furthermore, as expected, participants with high trust in AV also tended to rely more on the systems, monitoring and interfering less in its functionality. Monitoring behavior was a consequence of the environment. Results also indicated that high trust participants are highly impacted by internal variables (e.g., mood, stress, attention, and tiredness) when associating these variables with risky situations and the reduction in the capacity to control the vehicle. On the other hand, participants classified as low trust are highly influenced by environmental variables (e.g., time of the day and road and weather conditions). While establishing these associations is a major contribution of this study, further research should be conducted to more fully investigate the role of these environmental variables.

Although the results presented in Study 2 present limitations in terms of sample size, diversity, and methodology, the investigation of behavior with analogous systems proved to be a valid approach, providing important qualitative insights for understanding human and AV interactions. Further research should focus on investigating the correlation between trust levels and different situational variables. Since trust in AV is a dynamic and multidimensional process, future studies should also investigate the relationship between current behavior with analogous systems and dispositional trust in AV using data triangulation to verify the results of the situational trust dimension.

Finally, results of this investigation reveal that situational factors involve complex cognitive processes that deeply influence users' perceptions and judgments. Therefore, understanding users' current behavior with analogous systems can provide useful insights for the design of parameters calibrating different levels of trust in AV. In turn, this may influence whether individuals adopt AV technology and their successful interaction with this technology.

Chapter 7. Conclusion

Today's society is rapidly advancing toward an increased use of autonomous systems (AS) that not only interact and collaborate with humans but also are cognizant of their interaction with each other and the environment. The safety-critical nature of these systems requires successful interactions that depend on the performance of the system as well as the performance of users and their behavior toward the system. Therefore, one of the essential components in the design of trustworthy autonomous systems is to better understand the relationship between users and AS.

Just like with all human interactions, trust is a key component of the relationship between humans and AS. Moreover, trust has been growing as a central topic of investigation in Human Computer Interaction (HCI) field and autonomous systems research. HCI and human factors literature provide a lens for viewing interactions between humans and AS, focusing on the understanding of specific characteristics of the user and the system and how these characteristics contribute to the formation of trust in autonomous systems. However, contributions from both fields still lack sufficient attention to the dynamics of trust.

In this dissertation, I attempted to overcome this limitation by understanding how internal and external variables might influence the formation of situational trust in AVs. To this end, I conducted two studies: identifying and understanding the influence of users' perception of benefits and risks of AVs and its relationship to situational trust (Study 1), and understanding how internal and external variables in analogous systems influence situational trust (Study Two).

This research found that the perception of benefits correlates most closely with societal attributes (greater accessibility), while the perception of costs correlates most closely with individual attributes (financial impact). Nevertheless, the primary benefit cited by participants, both in Study 1 and Study 2, related to an individual attribute—namely, the financial impact of operating an autonomous car. Despite the importance of perception of the benefits of AV use, participants' decisions to adopt this technology hinged most closely on how it would affect them on an individual level.

This study also contributed to research on trust by providing insights on how to investigate the variables of situational trust. For example, the research determined that performance failure is connected to the capacity of control and attention, both external variables. This demonstrates that situational variables, especially external ones, are related and they have the capacity to influence each other.

For the purpose of this dissertation, the investigation of current behavior with analogous systems proved to be a valid research approach, providing important qualitative insights for understanding trust in human and AVs interactions. The research on participants' ability to trust an analogous system provided information on how current trusting behavior—as demonstrated by participants' need to intervene and their attention level—can also influence trust in AVs. (Both control and attention were found as perceived risks of AVs.)

Because autonomous systems have not been deployed on a large scale and are difficult to access, the use of analogous systems to investigate trust might be a feasible alternative. Data from the research of current behavior with analogous systems can support design research methodologies, especially in the area of speculative design. Speculative design is primarily concerned with possibilities, that is, expanding the user-centric approach to emphasize human preferences in designing the future and the ways in which system design facilitates or hinders this goal.

Understanding the implications of people's current interaction with this technology can facilitate the socio-technological challenge of successfully modeling complex autonomous systems, such as AVs. For autonomous systems to trust humans, they must proactively "sense" the individual person, extract meaning and cues during sensing, manage identity to ensure they are interacting with the correct human, estimate and manage human intent, and make an informed judgment on the level of trustworthiness of the human in a particular context in time and space. Moreover, such investigation facilitates the transition from technology adoption and technical issues toward aligning technology with human values as their societal and individual needs.

7.1 Future Directions

The principal limitations of this study concern the research methodology procedures: sample composition, data collection, and measurements. In addition to providing strategies to overcome these limitations, this section proposes ways to address the gaps and summarizes areas of further investigation.

Participants from Study 1 were recruited using Amazon Mechanical Turk (MTurk). Users of this platform tend to exhibit greater-than-average familiarity with technology, thereby biasing the results of this dissertation. Although multiple recruitment sessions were conducted to ensure a diverse sample in terms of age and gender, the majority of the participants were white males, ranging from 25 to 45 years old. Participants from Study 3 were selected through a variety of methods, including mailing lists and social media; however, participants from this group were exclusively from the Midwest region of the United States. This decreased study diversity in terms of demographic data as well as environmental factors, such as road and weather conditions. Therefore, future research should recruit a larger sample of participants who are more diverse in age, geographical region, and demographics. The latter can be achieved by cross-cultural data collection methods. To further expand the study population, it is recommended that some participants be recruited offline, instead of solely through MTurk, thereby minimizing bias related to familiarity with technology.

The research methodology for this dissertation used a combination of surveys and interviews in which participants recounted their past experiences. This is a limitation because when recounting past experiences, important details can be forgotten and or may be incorrectly remembered. Even though the quantitative methodology (surveys) proved efficient in answering the research questions, certain limitations in the use of surveys exist, particularly regarding understanding the motivations, emotions, feelings, and opinions of participants. Therefore, future work must triangulate data from the surveys and interviews with observations and think-aloud protocols, thereby minimizing the gap between what participants' words and actions.

In Study 2, participants were classified as low trust or high trust based on their median score on the measurement used to access trust in AV. This generic procedure was followed because there are no standards or guidelines for how trust-related measures should be scored or categorized. While this categorization supported our analysis and guided our investigation, it is important to note that this type of procedure may pose limitations, such as only providing a high or low trustworthiness classification, despite trust being a very complex trait with multiple ways to interpret the scores. Hence, we recommend that researchers investigating trust in automation consider developing more valid measures and guidelines on score classification. This is especially important when assessing user experience in research and design, developing user profiles, and establishing behavior models.

Trust in AVs is a dynamic and multidimensional process. Future studies should consider correlating the investigation and analysis of the different dimensions of trust, triangulating data from dispositional and situational dimensions. This might provide a better understanding of the variables and how the different dimensions of trust influence one another.

7.2 Final Thoughts

The work presented in this dissertation represents a step toward integrating ideas from HCI and formal methods to address issues in the design of trustworthy and human-centered autonomous systems. As discussed in this chapter, challenges that need to be addressed remain. This research demonstrates that humans vary in how they handle situations, how they interpret and react to environmental influences, and how they perceive automation. Therefore, because it is impossible to fit humans into a single data-driven behavior model, it is essential to understand and identify the individual differences among users for AVs to be successful.

By exploring the model of trust in automation proposed by Hoff and Bashir, this dissertation has shown that the investigation of individual differences is an essential factor in understanding the mechanisms governing users' trust in AVs. Human operators make sense of automation by using different interpretational lenses related to their situational factors, thereby building different theories and hypotheses about how the system will work. This work informs HCI and User Experience researchers and practitioners by providing them two research approaches: (1) the use of societal and individual factors to understand the perception of risks and benefits, and (2) the use of analogous systems to investigate the situational variables of trust. Furthermore, the results provide practical contributions for the design of more supportive and personalized "trustworthy automation" based on situational variables.

References

Arnott, D. C. (2007). "Trust–current thinking and future research." *European Journal of Marketing.*

Bainbridge, L. (1983). "Ironies of automation," in *Analysis, design and evaluation of man–machine systems*. Elsevier, pp. 129–135.

Begg, D. (2014). "*A 2050 vision for London: What are the implications of driverless transport, transport times.*" London, UK. [Online] Available http://www.transporttimes.co.uk/Admin/uploads/64165-transport-times_a-2050-vision-for-london_aw-web-ready.pdf.

Biondi, F., Lohani, M., Hopman, R., Mills, S., Cooper, J, & Strayer, D. (2018). "80 mph and out-of-the-loop: effects of real-world semi-automated driving on driver workload and arousal". *In Proceedings of the human factors and ergonomics society annual meeting*, vol. 62, no. 1. SAGE Publications Sage CA: Los Angeles, CA, pp. 1878–1882.

Braun, V., & Clarke, V. (2006). "Using thematic analysis in psychology." *Qualitative research in psychology*, vol. 3, no. 2, pp. 77-101.

Capgemini. (2019). "The Autonomous Car: A Consumer Perspective." [Online]. Available: https://www.capgemini.com/wp-content/uploads/2019/05/30min-%E2%80%93-Report.pdf

De Visser, E., Parasuraman, R., Freedy, A., Freedy, E., & Weltman, G. (2006). "A comprehensive methodology for assessing human-robot team performance for use in training and simulation," in *Proceedings of the human factors and ergonomics society annual meeting*, vol. 50, no. 25. SAGE Publications Sage CA: Los Angeles, CA, pp. 2639–2643.

Dzindolet, M. T., Peterson, S. A., Pomranky, R. A., Pierce, L. G., & Beck, H. P. (2003). "The role of trust in automation reliance," *International journal of human-computer studies*, vol. 58, no. 6, pp. 697–718.

Ferronato, P., & Bashir, M. (2020, July). "Does the Propensity to Take Risks Influence Human Interactions with Autonomous Systems?." *In International Conference on Applied Human Factors and Ergonomics* (pp. 23-29). Springer, Cham.

Flemisch, F., Winner, H., Bruder, R., & Bengler, K. (2016). "Cooperative guidance, control and automation". *Handbook of driver assistance systems*, pp. 1471-1481.

Fishbein, M., & Ajzen, I. (2011). *"Predicting and changing behavior: The reasoned action approach".* Psychology press.

Frison, A. K., Wintersberger, P., Liu, T., & Riener, A. (2019, March). "Why do you like to drive automated? a context-dependent analysis of highly automated driving to elaborate requirements for intelligent user interfaces." *In Proceedings of the 24th international conference on intelligent user interfaces* (pp. 528-537).

Fu, K., Chan, J., Cagan, J., Kotovsky, K., Schunn, C., & Wood, K. (2013). "The meaning of "near" and "far": the impact of structuring design databases and the effect of distance of analogy on design output." *Journal of Mechanical Design*, vol. 135, no. 2.

Gentner, D., & Markman, A. B. (1997). “Structure mapping in analogy and similarity”. *American psychologist*, vol. 52, no. 1, pp. 45.

Gkartzonikas, G., & Gkritza, K. (2019). “What have we learned? a review of stated preference and choice studies on autonomous vehicles,” *Transportation Research Part C: Emerging Technologies*, vol. 98, pp. 323–337.

Goel, A. K. (1997). “Design, analogy, and creativity.” *IEEE expert*, vol. 12, no. 3, pp. 62-70.

Hancock, P. A.; Billings, D. R.; Schaefer, K. E.; Chen, J. Y. C.; de Visser, E., & Parasuraman, R. (2011). A Meta-Analysis of Factors Affecting Trust in Human-Robot Interaction. *Human Factors*, vol. 53, no. 5, pp. 517–527.

Hohenberger, C., Spörrle, M., & Welpe, I. M. (2017). “Not fearless, but self-enhanced: The effects of anxiety on the willingness to use autonomous cars depend on individual levels of self-enhancement.” *Technological Forecasting and Social Change*, vol. 116, pp. 40-52.

Hoedemaeker, M., & Brookhuis, K. A. (1998). “Behavioural adaptation to driving with an adaptive cruise control (ACC).” *Transportation Research Part F: Traffic Psychology and Behaviour*, vol.1, no. 2, pp. 95-106.

Hoff, K. A., & Bashir, M. (2015). “Trust in automation: Integrating empirical evidence on factors that influence trust,” *Human factors*, vol. 57, no. 3, pp. 407–434.

Hoffman, R. R., Johnson, M., Bradshaw, J. M., & Underbrink, A. (2013). Trust in automation. *IEEE Intelligent Systems*, vol. 28, no. 1, pp. 84-88.

Howard, D., & Dai, D. (2014). “Public perceptions of self-driving cars: The case of Berkeley, California”. *In Transportation research board 93rd annual meeting*, vol. 14, no. 4502, pp. 1-16.

Hulse, L. M., Xie, H., & Galea, E. R. (2018). “Perceptions of autonomous vehicles: Relationships with road users, risk, gender and age,” *Safety Science*, vol. 102, pp. 1–13.

Hung, Y. T., Dennis, A. R., & Robert, L. (2004, January). Trust in virtual teams: Towards an integrative model of trust formation. *In 37th Annual Hawaii International Conference on System Sciences, 2004*. Proceedings of the (pp. 11-pp). IEEE.

Jessup, S., Schneider, T., Alarcon, G., Ryan,T., & Capiola, A. (2019). “The measurement of the propensity to trust automation,” Virtual, Augmented and Mixed Reality. *Applications and Case Studies Lecture Notes in Computer Science*, p. 476-489.

Kim, G., Shin, B., & Lee, H. G. (2009). “Understanding dynamics between initial trust and usage intentions of mobile banking.” *Information Systems Journal,* vol. 19, no. 3, pp. 283-311.

Kundinger, T., Wintersberger, P., & Riener, A. (2019, May). “(Over) Trust in automated driving: The sleeping pill of tomorrow?.” *In Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-6).

Kyriakidis, M., de Winter, J., Stanton, N., Bellet, T., van Arem, B., Brookhuis, K., Martens, M., Bengler, K., Andersson, J., Merat, N., et al., (2019). “A human factors perspective on automated driving,” *Theoretical Issues in Ergonomics Science,* vol. 20, no. 3, pp. 223–249.

Kyriakidis, M., Happee, R., & de Winter, J. (2015). “Public opinion on automated driving: Results of an international questionnaire among 5000 respondents,” *Transportation research part F: traffic psychology and behaviour,* vol. 32, pp. 127–140

Lee, J. D., & Kolodge, K. (2020). “Exploring trust in self-driving vehicles through text analysis,” Human factors, vol. 62, no. 2, pp. 260–277.

Lee, J. D., & See, K. A. (2004). “Trust in automation: Designing for appropriate reliance,” *Human factors*, vol. 46, no. 1, pp. 50–80.

Lewandowsky, S., Mundy, M., & Tan, G. (2000). The dynamics of trust: comparing humans to automation. *Journal of Experimental Psychology: Applied*, vol. 6, no. (2), pp. 104.

Linsey, J. S., Tseng, I., Fu, K., Cagan, J., Wood, K. L., & Schunn, C. (2010). *A study of design fixation, its mitigation and perception in engineering design faculty*.

Lewis, J. D., & Weigert, A. (1985). “Trust as a social reality,” *Social forces*, vol. 63, no. 4, pp. 967–985.

Lynberg, M. (Apr, 2020). “Automated vehicles for safety,”. [Online]. Available: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

Lyons, J., & Stokes, C. (2012). “Human–human reliance in the context of automation”. *Human factors*, vol. 54, no. 1, pp. 112–121.

Marinik, A., Bishop, R., Fitchett, V., Morgan, J. F., Trimble, T. E., & Blanco, M. (2014). *Human factors evaluation of level 2 and level 3 automated driving concepts: Concepts of operation (No. DOT HS 812 044*). United States. National Highway Traffic Safety Administration.

Marsh, S., & Dibben, M. R. (2003). “The role of trust in information science and technology,” *Annual Review of Information Science and Technology*, vol. 37, no. 1, pp. 465–498.

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). “An integrative model of organizational trust,” *Academy of management review*, vol. 20, no. 3, pp. 709–734.

McBride, S., Rogers, W., & A. Fisk, A. (2014). “Understanding human management of automation errors”. *Theoretical Issues in Ergonomics Science*, vol. 15, no. 6, pp. 545–577.

Merritt, S. M., & Ilgen, D. R. (2008). “Not all trust is created equal: Dispositional and history-based trust in human-automation interactions,” *Human Factors*, vol. 50, no. 2, pp. 194–210.

Milakis, D. (2019). “Long-term implications of automated vehicles: An introduction.” *Transport Reviews,* vol. 39, no.1, pp. 1-8.

Mitzner, T., Boron,J., Fausset, C., Adams, A., Charness, N., Czaja, S., Dijkstra, K., Fisk, A., Rogers, W., & Sharit, . (2010). “Older adults talk technology: Technology usage and attitudes,” *Computers in human behavior*, vol. 26, no. 6, pp. 1710–172.

Moorman, C., Deshpande, R., & Zaltman, G. (1993). “Factors affecting trust in market research relationships.” *Journal of Marketing*, vol. 57, no. 1, pp. 81-101.

Muir, B. M. (1994). “Trust in automation: Part i. theoretical issues in the study of trust and human intervention in automated systems,” *Ergonomics*, vol. 37, no. 11, pp. 1905–1922.

Palys, T. S., & Atchison, C. (2014). “*Research decisions: Quantitative, qualitative, and mixed method approaches.”* 5th ed. Toronto: Nelson Education.

Parasuraman, R., & Riley, V. (1997). “Humans and automation: Use, misuse, disuse, abuse,” *Human factors*, vol. 39, no. 2, pp. 230–253.

Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). “A model for types and levels of human interaction with automation,” *IEEE Transactions on systems, man, and cybernetics-Part A: Systems and Humans*, vol. 30, no. 3, pp. 286–297.

Parke, B., Hobbs, A, & Kanki, B. (2010). “Passing the baton: An experimental study of shift handover”. *In Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 54, no. 5. SAGE Publications Sage CA: Los Angeles, CA, pp. 502–506.

Payre, W., Cestac, J., & Delhomme, P. (2014). “Intention to use a fully automated car: Attitudes and a priori acceptability,” *Transportation research part F: traffic psychology and behaviour*, vol. 27, pp. 252–263.

Penmetsa, P., Adanu, E., Wood, D., T. Wang, T, & Jones, S. (2019). “Perceptions and expectations of autonomous vehicles–a snapshot of vulnerable road user opinion”. *Technological Forecasting and Social Change*, vol. 143, pp. 9–13.

Perkins Coie (2019). “Autonomous vehicle survey report.” [Online]. Available: https://www.perkinscoie.com/images/content/2/1/v3/216738/2019-Autonomous-Vehicles-Survey-Report-v.3.pdf

Petersen, L., Zhao, H., Tilbury, D. M., Yang, X. J., & Robert, L. P. (2018). “The influence of risk on driver trust in autonomous driving systems*.” In Autonomous Ground Systems Technical Session of the Ground Vehicle Systems Engineering and Technology Symposium (Novi, MI).*

Peterson, D., Adams, A., Sanders, S., & Sanford, B. (2018). “Assessing and addressing threats and risks to cybersecurity.” *Frontiers of health services management*, vol. 35, no. 1, pp. 23–29.

Plungis, J. (2020) “Tesla driver in fatal march crash was using autopilot, ntsb says.” [Online]. Available: https://www.consumerreports.org/car-safety/ tesla-driver-in-fatal-march-crash-was-using-autopilot-ntsb-says/.

Robert, L. P., Denis, A. R., & Hung, Y. T. C. (2009). Individual swift trust and knowledge-based trust in face-to-face and virtual team members. *Journal of management information systems*, vol. 26, no. 2, pp. 241-279.

Rasmussen, J. (1990). “Human error and the problem of causality in analysis of accidents,” *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, vol. 327, no. 1241, pp. 449–462.

Rempel, J. K., Holmes, J. G., & Zanna, M. P. (1985). “Trust in close relationships.” *Journal of personality and social psychology*, vol. 49, no. 1, p. 95.

Rousseau, D. M., Sitkin, S. B., Burt, R. S., & Camerer, C. (1998). Not so different after all: A cross-discipline view of trust. *Academy of management review*, vol. 23, no. 3, pp. 393-404.

Rotter, J. B. (1967). “A new scale for the measurement of interpersonal trust 1,” *Journal of personality*, vol. 35, no. 4, pp. 651–665.

Rudin-Brown, C. M., & Parker, H. A. (2004). “Behavioural adaptation to adaptive cruise control (ACC): implications for preventive strategies.” *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 7, no. 2, pp. 59-76.

Sanchez, J., Fisk, A. D., & Rogers, W. A. (2006). “What determines appropriate trust of and reliance on an automated collaborative system? effects of error type and domain knowledge,” in *2006 9th International Conference on Control, Automation, Robotics and Vision*. IEEE, pp. 1–6.

Satterfield, K., Baldwin, C., de Visser, E., & Shaw, T. (2017). "The influence of risky conditions in trust in autonomous systems," *in Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 61, no. 1. SAGE Publications Sage CA: Los Angeles, CA, pp. 324–328.

Siegrist, M., & Cvetkovich, G. (2000). Perception of hazards: The role of social trust and knowledge. *Risk analysis*, vol. 20, no.5, pp. 713-720.

Solhaug, B., Elgesem, D., & Stolen, K. (2007, April). "Why trust is not proportional to risk." *In The Second International Conference on Availability, Reliability and Security (ARES'07)* (pp. 11-18). IEEE.

State of California Department of Motor Vehicles (2019). Testing of Autonomous Vehicles with a Driver. Available from: https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/testing. Accessed Jun. 25, 2020.

Strayer, D., Drews, F., & Crouch, D. (2006). "A comparison of the cell phone driver and the drunk driver," *Human factors,* vol. 48, no. 2, pp. 381–391.

Suchman, L. A. (1987). *Plans and situated actions: The problem of human-machine communication*. Cambridge university press.

Thomopoulos, N., & Givoni, M. (2015). "The autonomous cars blessing or a curse for the future of low carbon mobility? an exploration of likely vs. desirable outcomes," *European Journal of Futures Research*, vol. 3, no. 1, p. 14.

Titchener, K., White, M., & Kaye, S. (2009). "In-vehicle driver distractions: Characteristics underlying drivers' risk perceptions," in *Proceedings of the 2009 Australasian Road Safety Research, Policing and Education Conference*: Smarter, Safer Directions.

Venkatesh, V., Thong, J. Y. L., & Xu, X. (2012). "Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology." *MIS Quarterly*, 3vol. 6, no. 1, pp. 157–178.

Ward, C., Raue, M., Lee, C., D'Ambrosio, L., Coughlin, J.F. (2017). Acceptance of automated driving across generations: the role of risk and benefit perception, knowledge, and trust. *In Kurosu, M. , (Ed.), Human-Computer Interaction: Proceedings of HCI International 2017* (pp. 254-266). Basel: Springer International Publishing AG.

Welch, D., & Behrmann, E. (May, 2018). "In self-driving car race, waymo leads traditional automakers." [Online]. Available: https://europe.autonews.com/article/20180508/ANE/180509829/in-self-driving-car-race-waymo-leads-traditional-automakers.

Westenberg, B., Kolodge, K., Georgiva, T. & Boor, L. (2018). "Automated vehicles: Liability crash course. Mcity—affiliate law research program." [Online]. Available: https://www.millercanfield.com/assets/htmldocuments/JDP_Miller%20Canfield%20MCity%20White%20Paper_2018_Final.pdf

Wicks, A. C., Berman, S. L., & Jones, T. M. (1999). "The structure of optimal trust: Moral and strategic implications." *Academy of Management review,* vol. 24, no. 1, pp. 99-116.

Woods, D., & Dekker, S. (2000). "Anticipating the effects of technological change: a new era of dynamics for human factors," Theoretical issues in ergonomics science, vol. 1, no. 3, pp. 272–282.

Zhang, T., Tao, D., Qu, X., Zhang, X, Lin, R., & Zhang, W. (2019). "The roles of initial trust and perceived risk in public acceptance of automated vehicles," *Transportation research part C: emerging technologies*, vol. 98, pp. 207–220.

Appendix A - IRB Approval

ILLINOIS

OFFICE OF THE VICE CHANCELLOR FOR RESEARCH

Office for the Protection of Research Subjects
805 W. Pennsylvania Ave., MC-095
Urbana, IL 61801-4822

Notice of Exempt Determination

September 23, 2019

Principal Investigator	Masooda Bashir
CC	Priscilla Boff Ferronat
Protocol Title	*The formation and calibration of trust in human and autonomous system interaction*
Protocol Number	20182
Funding Source	Funded
Review Category	Exempt 2 (i)
Determination Date	September 23, 2019
Closure Date	September 22, 2024

This letter authorizes the use of human subjects in the above protocol. The University of Illinois at Urbana-Champaign Office for the Protection of Research Subjects (OPRS) has reviewed your application and determined the criteria for exemption have been met.

The Principal Investigator of this study is responsible for:

- Conducting research in a manner consistent with the requirements of the University and federal regulations found at 45 CFR 46.
- Requesting approval from the IRB prior to implementing major modifications.
- Notifying OPRS of any problems involving human subjects, including unanticipated events, participant complaints, or protocol deviations.
- Notifying OPRS of the completion of the study.

Changes to an **exempt** protocol are only required if substantive modifications are requested and/or the changes requested may affect the exempt status.

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Appendix B - Survey

I. Autonomous Vehicle Perceptions

A. Propensity to Trust in Autonomous Vehicles

As you may know, Autonomous Vehicles (AVs) are being researched and developed in the US and around the world and we are interested in learning more about your views, opinions and comfort level with AVs. Please use the following rating scale to indicate your overall views on AVs: (1) Strongly Agree (2) Agree (3) Agree and Disagree (4) Disagree (5) Strongly Disagree

1. Generally, I will trust in autonomous vehicles.
2. Autonomous vehicles will help to solve problems.
3. I think it will be a good idea to rely on autonomous vehicles for help.
4. I won't trust the decisions made by an autonomous vehicle.
5. Autonomous vehicles are reliable.
6. I rely on the technology used in autonomous vehicles.

B. Overall Benefit Perception

Instructions: In your opinion, what are the pros and cons related with the development and adoption of autonomous vehicles? Please, select all the items that you would consider to be the main benefits.

1. Increase free time for family, entertainment, and work while traveling or commuting.
2. More locomotion independence for people with disabilities or elderlies.
3. Greater access to healthcare with improved patient mobility.
4. Greater access for people living in areas with limited public transportation or remote areas.
5. Improve safety for pedestrians and bikers
6. Reduce traffic accidents.
7. Improve safety for pedestrians and bikers

8. The companies in charge of the development of autonomous vehicles are liable which will prevent technology failures to happen.
9. Lower insurance premiums because is the autonomous vehicle that will be insured not the "driver".
10. Lower insurance premiums because in case an accident the claim will be against the autonomous vehicle's manufacturer and not the "driver".
11. Driverless car will be easier to use and driver licensing won't be required anymore.
12. Vehicle registration will be easier and faster.
13. New laws and legislation should regarding autonomous vehicles' operation should be led by the U.S. Department of transportation instead of manufacturer and technology companies.
14. Decrease the expenditure on fuel
15. Reduce the energy consumption
16. Less dependence on foreign oil
17. Higher vehicle flow rates on existing roads (increased lane capacity)
18. More parking spaces and farthest from urban areas.
19. Reduce the numbers of cars on the cars.

D. Overall Risk Perception

Instructions: In your opinion, what are the pros and cons related with the development and adoption of autonomous vehicles? Please, select all the items that you would consider to be a risk related to AVs development and adoption. .

1. Cybersecurity/data privacy risks.
2. Infrastructure issues (i.e., roads, bridges).
3. More dependence on technology.
4. Failures on the system performance.
5. The technology that operates the autonomous vehicle is not reliable.
6. The companies in charge of manufacture autonomous vehicles are no liable.
7. Privacy issues regarding data sharing with other vehicles.
8. Privacy issues regarding data sharing with car and technology companies.
9. Privacy issues regarding data sharing with government and traffic control.

10. Price of investment, it will be too expensive.
11. Fully autonomous vehicles might not deliver high safety benefits until high penetration rates of these vehicles are realized
12. Autonomous vehicle won't have enough capacity to interact with other cars controlled by humans or when encountering an animal on the roads.
13. Users will have less control and freedom.
14. Issues related to car ownership.
15. Even Though the vehicle is fully automated and capable of driving without any type of human control, law requires drivers to be present at the wheel at all times and ready to intervene at the first sign of tech failure
16. Driver license won't be mandatory anymore
17. Lack of a regulatory framework.
18. There will be issues for the reconciliation of federal and state regulatory jurisdiction
19. Road conditions will not be good enough for autonomous vehicles drive safely.
20. It will be necessary investimet on smart technology for road signs, traffic lights and merge lanes
21. Loss of jobs related to transportation.
22. Increase the numbers of cars on the roads.

E. Individual vs Collective Benefits and Risks of AVs

E1. Instructions: Using the benefits and concerns that you selected above, please indicate how them are related to and individual or to the society as a whole. Please, drag and drop the selected item in the table. You may place the same benefit/risk item for both levels (individual and society). In addition, the items must be ranked in descending order, in which number 1 represents the biggest benefit/risk and number 6 represents the smaller benefit/concern.

Society		Individual	
Benefits	Risks	Benefits	Risks
1-	1-	1-	1-
2-	2-	2-	2-
…	…	...	...
Other, please specify	Other, please specify	Other, please specify	Other, please specify

E2. We would like to hear more from you! Please, write a few sentences to describe how do you think *[topic chosen as #1 concern]* might be the biggest concern regarding autonomous vehicles for the society.

E3. We would like to hear more from you! Please, write a few sentences to describe how do you think *[topic chosen as #1 concern]* might be the biggest concern for an individual.

F. Expectations

F1. Recent research claim that although self-driving cars are closer to become reality, we are still far from being able to buy a fully autonomous vehicle. However, we are already able to experience different types of automations in our daily lives, like personal assistants, coffee machines, and cleaner robots, as well as automation in our cars, like cruise mode, parking assistant, and lane changing. From, fully autonomous vehicle that doesn't require the presence of humans to none automation at all, what kind of automation technology from the following options do you think is your preferred one and you would like to have available on your car? Please, choose only one option.

1. Driver assistance systems such as warnings, alerts, automatic lights, and cruise control.

2. Partial automation, which means that minimal actions are required from the driver besides supervision. Autonomous systems include, lane keeping, speed control and brake control.
3. High automation without any actions required from the driver. No human is required to supervise the function of the vehicle and passengers are allowed to sleep.
4. None automation. I want to drive myself in every type of driving situation and have complete control of all tasks.

F2. If you were to ride in a completely autonomous vehicle, what do you think you most likely would use the extra time doing instead of driving? Please select your preferred option from the list below.

1. Text or talk with friends/family
2. Read
3. Sleep
4. Watch movies/TV
5. Do things to improve my health, like meditation and exercises
6. Play games
7. Work
8. Watch the road even though I would not be driving
9. Watch out the performance of the vehicle in case something wrong might happen
10. I would not ride in a completely self-driving vehicle

II. Current Transportation Habits

A. Mode of transportation alternative to driving

Instructions: Different modes of transportation like Uber and electric bike rentals are becoming more popular. What are the modes of transportation that have you used in the past year as an alternative to driving? Please use one of the options in the following rating scale that best matches with you.

(1) I’ve never used this type of transportation

(2) I rarely use this type of transportation

(3) At least one or twice a month

(4) I use it every week

(5) I use it more than once per week

(6) I use this type of transportation every day

1. Car sharing (e.g. Zipcar)
2. Ride sharing, such as Uber or Lyft
3. Bike sharing
4. Electric scooter sharing
5. Bike from the city rental service
6. Electric bike from the city rental service
7. Public Bus
8. Taxi
9. Subway or train
10. Ride
11. Company private transportation for employees
12. Car or Motorcycle
13. Other. Please, specify what alternative to driving have you used in the past year.

Open question: We would like to hear more from you! Please, tell us why did you decide to use a transportation different than cars and motorcycles? What were the reasons and motivations?

B. Timing

B1. How many hours per week do you stay on traffic (either using public transportation or driving)? Please, choose the option that best matches with you.

1. Less than 1 hour
2. From 1 to 3 hours
3. From 3 to 5 hours
4. From 5 to 7 hours
5. From 7 to 9 hours
6. More than 9 hours

B2. Please indicate from the list below the regular reasons why do you spent *[number of hours]* in the traffic.

1. Work
2. School
3. Drive children to school
4. Grocery
5. Gym
6. Shopping
7. Do you have any other regular activity that was not mentioned in the list? Please, specify.

C. Ownership

C1. Instruction: We would like to know if you own a vehicle. Please, indicate the type(s) of vehicle do you have by choosing the best options from the list below.

1. Passenger car (any type or size)
2. SUV (sport utility vehicle)
3. Minivan / van / MPV (multipurpose vehicle)
4. Pickup truck
5. Motorcycle / scooter
6. Other, please specify what type of vehicle do you own
7. I do not drive
8. I had a vehicle in the past but I don't own one anymore

C2. Open Question: What made you choose this vehicle?

C3. **[If own a car]** Instruction: We are curious to know if you are aware about any autonomous technology that you might have used. Please, choose from the options listed below the options indicate your previous experience with vehicles' autonomous technology.

1. Automatic lights
2. Automatic wipers
3. Cruise control

4. Engine automatic turn on and turn off when stopping the vehicle
5. Automatic heating system for winter days
6. Lane keeping assistance (lane centering)
7. Automated parking system (self-parking)
8. Speed control
9. Automated braking system
10. I’ve never used any of these automation systems before
11. I’ve used a different type of automation.
    - Please specify the type of automation

III. Scenario based behavior (Deb et al, 2017)

Instructions: Imagine that you are walking home from shopping. On your way, you need to cross multiple crosswalks, both signalized and unsignalized. As you prepare to cross at an unsignalized crosswalk, you find that a driverless vehicle is approaching the crosswalk (with no one sitting in the driver's seat). Based on the given scenario, please select the choice that best indicate your behavior for each question.

What will your response at the crosswalk be, with the driverless vehicle approaching if you are alone?

1. I will not cross the road at the crosswalk to avoid crossing in front of the driverless vehicle.
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.

What will your response at the crosswalk be, with the driverless vehicle approaching if you are if your 5 years old child walking by your side and your 2 years months baby in the stroller?

1. I will not cross the road at the crosswalk to avoid crossing in front of the driverless vehicle.
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.

What will your response at the crosswalk be, with the driverless vehicle approaching if you are if you are walking with your dog?

1. I will not cross the road at the crosswalk to avoid crossing in front of the driverless vehicle.
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.

As a pedestrian, how will you accept the presence of driverless vehicles in your area?

1. I will be angry to see driverless vehicles in my area; I think they will cause more problems.
2. I will feel anxious about the presence of driverless vehicles in my area; I don't trust them.
3. I will be indifferent to the presence of driverless vehicles in my area; it doesn't matter to me.
4. I will have no problem with driverless vehicles in my area; I trust the technology.
5. I will feel excited to see driverless vehicles in my area; I believe they will make my area safer.

Appendix C - Interview Guideline

Table 32: Semi Structured Interview Guideline

PHASE	TOPIC	MAIN QUESTION	LIST OF SUPPORTIVE PROMPTS
PART I. ICE BREAKING	Introduction	Greetings, introduction, and consent agreement	
	Contextualization	How social isolation and the restrictions imposed by COVID-19 pandemic has changed the way you move around?	
	Current vehicle ownership	Do you own a vehicle?	How satisfied are you with your car? What are the reasons why you are satisfied/not satisfied? What are the reasons that make you want this car? What are the reasons that make you decide for not wanting a car? Is there a specific reason why r you don't have a vehicle?
	Safety definition	In your opinion, what makes you consider a car safe and reliable?	
PART II. CRUISE CONTROL	Vehicle technology experience and interest	What is the latest or coolest type of driving technology you have encountered and would like to experiment in case you haven't had yet?	Where did you learn about it? Regarding your own car, a car that you rented, or any car that you have driven, what type of driving technology you have already experienced that impressed you? It can be both positive or negative. Can you tell us a little about your experience? What made you like / dislike this technology?
	Assessment of previous experience	Do you remember how your latest experience using CC was? Or the most recent experience that you remember? Can you talk a little bit please about how that experience was and any detail that you remember?	Where were you driving to? How were the road conditions (e.g. highway)? What type of trip (e.g. business or leisure)? How was the weather? Was it during the night or day?
	Adoption level	In general, how much do you use CC when you are driving?	What makes you use CC [often/ sometimes/….]?
	Initial experience with CC	Do you remember how your first experience with CC was? Or one of your first experiences? How did you learn how to use the CC? Can you tell us about this experience?	How was the overall experience? Was that how you imagined?

Table 32 (cont.)

	General experience	What about your general experience? What are the reasons that make you generally decide to use CC?	Where generally are you driving to? How are the road conditions (e.g. highway)? What type of trip (e.g. business or leisure)? How is the weather? What time of the day?
	Preferences on CC adoption	What would make you use CC more frequently and for a longer period of time? When do you prefer to use CC?	What makes you prefer [this type of situation] than [...]? What about you? Is there any specific [mood] that would make you adopt it or not? What about [stress level / tiredness]? How would it change the way you use CC?
		Can you please describe the type of situation where you would prefer TO NOT use CC and drive manually?	Can you please describe the type of situation where you don't use CC because you don't feel safe?
PART III. RIDE SHARING	Preferences towards the decision of ridesharing	What are the factors and situations in which you will decide by a U/L than a taxi? What makes you decide by public transportation, like bus and metro, instead of U/L? Generally, what are the situations where you use U/L?	
	Situations of monitoring	What do you generally do when riding a U/L?	What do you do differently when you are alone from when you are with coworkers and when you are sharing U/L with friends?
		How much attention/monitor do you pay to the U/L driver behavior?	What are the different situations that will make you more conscious of driver behavior than others? Can you please talk a little about them? What are the factors that make the situation [...] more comfortable with the services and the U/L driver than [...], like you just mentioned?
		What do you generally pay attention to? How do you do that? What about [*prompts*]	Following the rules of the transit Respecting pedestrians Respecting the speed limit Respecting the transit signs Use cellphone while driving Following the route displayed on the app

Table 32 (cont)

	Use of features provided by the app	What do you usually do while you are waiting for your ride to arrive?	How do you confirm if the car is the one that you ordered? Do you use any features provided by U/L to check the driver? How important is the driver rating? How important is the number or rides, or type of car, driver's picture…
		What do you usually do when the U/L arrives? What do you generally do when the ride is over and you arrive at your destination?	
		What are the features that you know that are available but you haven't used yet?	Have you ever taken a ride and the driver did not take you to the right destination? What did you do? What would you do in a situation like this?
PART IV. CLOSURE	Thank you	Information about next steps, gift card and thank you.	