# Identifying Factors that Influence User Acceptance of Automation in Vehicles

Emily McDonald

Georgia Institute of Technology

## Table of Contents

## Abstract

Automated driving features were developed to improve driver safety and minimize drivers' cognitive workload, but this is only if drivers rely on these systems appropriately. Currently, there is a discrepancy between actual system efficacy and driver acceptance; drivers report preferences for manual control despite research confirming the safety of the automation. This research aims to identify main factors that lead to this lack of user acceptance in automation in vehicles with the intent of later designing a prototype to improve acceptance. This study will expand our understanding of automation acceptance within the driver context and begin to remedy this through improved design.

## Introduction

### *Automation*

Automation is defined as any technology that performs a task that was previously performed by a human (Parasuraman & Riley, 1997), and automation is becoming prevalent in many workplaces because of its ability to extend human capabilities (Lee & See, 2004). Rather than entirely replacing the human, the goal of automation is to change the task structure so that the automated system and the human complement one another in the completion of the task (Ghazizadeh, Lee, & Boyle, 2012). This task structure varies depending on the level of automation; at low levels of automation, there is extensive communication and interaction between the human and the automated system. In this human-automation interaction, the human makes decisions and inputs orders to the system, which then carries out the orders. In high levels of automation, the human's role is to monitor the automated system as it makes decisions with very little required human engagement; instead, the human must be alert for possible automation failures (Kaber & Endsley, 2004). This relationship between the operator and the system is described as the human-technology coagency (Ghazizadeh et al., 2012).

### *Automation in Vehicles*

Automated driving is becoming more common and complex in commercial vehicles, and these varying levels of automation are reflected in these systems. The Department of Transportation and the Society of Automotive Engineers [SAE] International define these features as ranging from level 0 to level 5 automation (SAE International, 2016). At the low end of automation, level 0 defines a car that has little-to-no automated features and is entirely under manual control. Level 0 cars include systems such as automatic transmission and standard cruise control, which are entirely under control of the driver. Level 1 defines vehicles with intelligent alerting systems to help the driver with various monitoring tasks. Levels 2, 3, and 4 automated vehicles have increasing levels of automation such as adaptive cruise control and automated lane keeping, and level 5 automated vehicles are entirely self-driving with little-to-no driver input or engagement (SAE International, 2016). Most available cars on the market are between levels 0 and 3, but there have been recent advancements in upper level automation as can be seen in Google's Waymo and Tesla's Model S self-driving cars.

Standard automation features in this 0-3 range include systems where there is moderate control by both the driver and the system such as lane keeping support [LKS] and adaptive cruise control [ACC]. ACC controls the acceleration and deceleration of a vehicle in relation to the vehicle immediately ahead of it at a specified distance, and as long as the car ahead does not decelerate too suddenly, the ACC system will slow the car to avoid a collision. This leaves the driver responsible for maintaining their lane position within the lane, and as a result reduces cognitive workload. At fast deceleration rates, though, the ACC system may not respond fast enough, and the driver must be alert and take over the system to avoid a collision. LKS, conversely, automates the vehicle's power steering system to maintain lane position and leaves the driver responsible for acceleration and deceleration (Inagaki, Furukawa, & Itoh, 2005).

In the context of driving, a successful human-technology coagency is critical due to the high risk involved with potential misuse and disuse of the system; inappropriate reliance in this situation could be incredibly dangerous for the driver and others around them. (Ghazizadeh et al., 2012). In this type of relationship, the goal of automated driving is not to replace the human in the driving task, but to change the task structure and maintain task-technology compatibility; in higher level automation, the drivers' new task, for example, is to input a destination, maintain alertness, and monitor the road and the automated system in case of a failure. To optimize the relationship between the driver and automated driving system, one must decide the appropriate function allocation between the driver and system in respect to the context. Function allocation defines the decision of which tasks are assigned to the human versus the automation. The function allocation determines the level of automation of a system; the more tasks that are assigned to the system, the higher the level of automation (Inagaki et al., 2005). Often, this function allocation is static, meaning that once the tasks are assigned, the level of automation cannot be changed. The concept of adaptive function allocation argues that the context of automation and the state of the operator should determine the level of automation, and more tasks should be assigned to the driver or system as they are needed, but an intelligent system also can lead to overreliance and complacent drivers (Inagaki et al., 2005). Because automated driving relieves the driver of some engagement, drivers tend to eventually perform worse at high levels of reliance. Automation designed with this in mind encourages appropriate reliance, which is key to a successful human-technology coagency in automated vehicles (Ghazizadeh et al., 2016).

*User Acceptance*

For users to rely on a system, they must first accept the system. User acceptance of a system is a key aspect that determines appropriate reliance and use of a system (Walker, Stanton, & Salmon, 2016), and it is often difficult to introduce new technology and information systems due to a lack of user acceptance (Davis, 1993). Research has shown that inappropriate acceptance of a system can lead to user misuse and disuse of the technology, and in certain situations, can lead to serious safety concerns (Parasuraman & Riley, 1997). In situations of inappropriate acceptance, the user misuses the technology by relying on it too heavily and becoming complacent and nonreactive to potential risks. Disuse might occur when the user instead relies too little on their technology and fails to use systems that could improve efficiency or safety during the relevant task (Parasuraman, Sheridan, & Wickens, 2008). One key aspect of appropriate user acceptance is the operator's trust in the system. Therefore, driver trust is essential to understanding how drivers use and interact with their systems (Walker et al., 2016) and how to employ proper function allocation between the human operator and the automated system (Parasuraman et al., 2008). To design a system that encourages appropriate trust and reliance, one must consider the function of the system in relation to the context that one will operate it in (Lee & See, 2004).

There has been a recent spike in interest in user acceptance specifically in automation in vehicles in response to rapidly developing vehicle technology (May, Noah, & Walker, 2017); it is not yet well understood how drivers decide to use, misuse, or disuse their automated vehicles. Modern vehicles display advancing technology that drivers are expected to use but may not fully understand; this expectation requires drivers to either use technology they are not comfortable and familiar with or to neglect to use it at all (Walker et al., 2016). Acceptance and trust of the automated vehicle systems can lead to vital changes in driver workload and performance, which subsequently affect driver use, misuse, and disuse of the system. Automated systems such as automated cruise control effectively reduce drivers' cognitive workload, but drivers have also been shown to brake harder, more often, and later as well as fluctuate position within a lane more frequently when using automated cruise control (Kazi, Stanton, Walker, & Young, 2007).

Prior research into the underlying mechanisms of user acceptance has yielded models such as the Technology Acceptance Model (TAM) proposed by Davis (1989) and extensions of TAM such as the Automation Acceptance Model (AAM) proposed by Ghazizadeh et al (2012). TAM's standout features that influence user acceptance, among others, are perceived ease of use

(PEOU) and perceived usefulness (PU). Davis defines PU as “the degree to which a person believes that using a particular system would enhance his or her job performance,” and defines PEOU as “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989). The AAM expands on these concepts by adding a feedback mechanism that asserts that acceptance of automation is a dynamic and bidirectional process; the users’ attitudes affect the user experience, and their experience influences their trust and attitudes of the system. This feedback loop includes trust in the system and task-technology compatibility, which explains acceptance in automation as an ever changing and evolving concept based on beliefs and experience with the system (Ghazizadeh et al., 2012).

Despite this research into the roots of user acceptance and our understanding of the importance of acceptance of automated systems, the current issue is that users do not accept automation in vehicles even when drivers are presented with data that confirms that automated control of the vehicle is safer and more effective than manual control (Ghazizadeh et al., 2012). The specific cause of this lack of acceptance in automated driving has not yet been documented. It is not enough that automation in vehicles functions effectively - drivers must also be willing to accept it in order to complete the human-technology coagency.

Researchers have theorized that a lack of acceptance of automated systems may come from automation related accidents due to poor system design, organization factors, software and hardware failures, environmental interference, or operator abuse/misuse/disuse (Hoff & Bashir, 2015). Failures in automation, specifically, have been identified to decrease trust and reliance in the system, especially when the user perceived the failed task as easy (Madhavan, Wiegmann, & Lacson, 2006). Hoff and Bashir (2015) also claim that formation of trust in automation can be negatively affected by inconsistencies in the operator, environment, and system; it is also possible that the lack of acceptance stems from people's tendency to be skeptical about unfamiliar technology (Walker et al., 2016).

*Current Study*

This discrepancy between system function and user acceptance is the key question and motivation behind this work, and by better understanding the human-technology relationship, we can work to integrate new technologies seamlessly into people's lives. Because there are so many facets of automation and theories of acceptance, the goal of this work is to identify the specific aspects of automated driving that explain drivers' lack of acceptance and to use these aspects to create a design the improves user acceptance.

This study aims to answer the following research questions:

(1) Which feature(s) of automated driving lead(s) to users failing to accept the system?

(2) How can the feature(s) be improved to increase user acceptance?

## Methods

To investigate how to improve user acceptance of automated driving, I will conduct research in three phases. In phase 1, I will conduct semi-structured focus group interviews to investigate attitudes and opinions towards automation in vehicles. Based on the results of the focus groups, in phase 2 I will create a survey to identify a specific factor of automation that leads to the lack of user acceptance. In phase 3, I hope to have identified a specific factor that I can redesign and prototype to then test experimentally with users to see if it leads to improved acceptance over the current model. Phase 1 is currently in progress; the following section discusses phase 1 in more detail, and phase 2 and 3 will be addressed in the discussion.

*Phase 1 Procedure:*

This phase is exploratory research to help me identify factors of user acceptance in automated vehicles. I began with pilot tests to refine my interview, and then I conducted a series of five focus groups asking questions about attitudes and opinions of driving, automation, and driving with automation. Questions in the automation section was focused on navigation systems for reference because it is a form of automation most people are familiar with. Each focus group was scheduled for a maximum of an hour and half, but each of them lasted around 45 minutes, and each focus group was audio recorded in order to be transcribed later. Each focus group consisted of between one and five Georgia Tech students who fit the inclusion criteria. I used the Automation Acceptance Model as a framework for my questions to help me identify a specific characteristic that is a detriment to user acceptance. My questions were formatted in the structure of Perceived Ease of Use [PEOU], Perceived Usefulness [PU], trust, and compatibility, and I asked these questions in relation to three categories: driving, automation, and driving with automation. I believe using a known, broad model of acceptance (AAM) as guidelines will help me identify more specific factors, and splitting the questions into three sets will help me locate discrepancies between categories. The focus group recordings were transcribed, and I have developed a coding scheme to analyze the data.

*Participants*

Participants for phase one were all Georgia Tech psychology students who were recruited using the SONA participant recruitment system, and they were each awarded one and a half credits for their participation in the focus groups. In total, there were fifteen participants; this sample included 13 men and 2 women all between the ages of 18 and 22. The inclusion criteria to participate in this study included: participant must be at least 18 years old, must have a valid drivers' license, have had their driver's license for at least two years to eliminate potential novice effects, must drive at least once a week, and have the ability to speak and understand English. Due to difficulties recruiting enough participants, the requirement to drive at least once a week was dropped after the first focus group.

## Results

To analyze the focus group transcripts, I developed a coding scheme (Figure 1) using both top-down and bottom-up themes; due to time constraints, I was only able to code one transcript, and the other transcripts appear to contain similar themes because each group was composed of nearly identical demographics. I blocked the transcript to code into the three sections (driving, automation, and driving with automation) so I could compare results between blocks. Because I am investigating factors that lead users to accept automation, I divided my coding scheme into Accept and Reject, and within each of these categories, I divided the factors into Internal factors and External factors. All of the data can be found in Figure 1 along with the coding scheme, but the most notable discrepancies between blocks seem to be the differences in trust in own ability [Accept, Internal], effort [Accept, Internal], independence [Accept, Internal], complacency [Reject, Internal], morality [Reject, Internal], and maintenance [Reject, External]. From what I can tell looking over the data, it appears that the majority of people's opinions and tendency to accept or reject stem from their own personal, internal qualms about the system. Users seem to have inaccurate or under-formed mental representations of autonomous systems which might lead to uncertainty and therefor rejection in using the system.

Trust in own ability appeared multiple times in the driving section, but there were no instances of this factor in either automation or driving with automation, which leads me to believe that users may overestimate the abilities of the system and disregard their own role in the human-automation relationship. Independence was another factor that appeared in the driving block but not the driving with automation block; participants frequently mentioned that they liked driving because of the freedom it allowed them in going where and when they choose, but this was never mentioned in automated driving. Participants also cited car maintenance many times as something they don't like about their own cars or driving, but was never mentioned in the automation or driving with automation section. A common theme I've found is that participants often forgot "regular" things about operating a car like trusting their own ability to drive, the freedom that driving allows, the fact that they still have to maintain their car – it's not immune from ordinary car damage and maintenance, and waiting in traffic. Referencing back to the previously mentioned inaccurate mental representation, automation in cars seems to be such an unreal concept that users forget aspects of everyday cars that they already manage with their current cars.

Participants voiced major concerns about automated driving such as control and complacency; they were worried about forfeiting their control while driving to the car, and they were worried that automation would allow people to pay less attention while driving and become complacent. The concerns about control only appeared in the automated driving section, but not in the automation section. This leads me to believe that users were more willing to give up control in the navigation rather than driving context because of the increased risk, and that the trust in their own ability was rarely questioned in the driving with automation section. Complacency though, was mentioned in the automation (navigation) and driving with automation sections; participants often said that they believe technology is making people lazy, so I am not surprised to see this in automation and automated driving.

The most unexpected result was the discussion about the morality or automated cars. Participants voiced their concerns that whoever programs and designs the automation in cars is also the one making moral decisions for the driver in certain situations; for example, one participant proposed a hypothetical situation of a car coming across an intersection with a mother with a baby, an old woman, and a group of children, and the car has to decide which it must run into. While situations like this are incredibly unlikely and implausible, it poses a dilemma in whether the decisions made by the car align with the users' morality. This seemed to be an important factor for some participants to be able to accept automation in cars. These results are based on assumptions and have no statistical significance, and therefore should not be generalized to a larger population, but they represent interesting findings to pursue in the future.

## Discussion

Based on my findings, it appears to me that a main concern to address in the acceptance of automation in vehicles is addressing and improving users' mental models of automated driving. With better understanding of the available technology, users will be able to learn and gain more experience with automation. These improvements, based on the results of what people liked in automation/navigation and what they didn't like in automated driving, should focus on the system providing accurate, real-time feedback and information back to the driver about the progress and actions of the system. Another recommendation for improving users' acceptance is implementing clear structures and understanding of the control dynamic while driving; giving the users a sense of control while driving seems to be important for acceptance. In addition to control, I would recommend elements to ensure adequate situational awareness while driving to reduce driver complacency, which is a known common problem in any automated system. I believe one of the most valuable findings to be addressed in future work is how to address the morality dilemma presented by my participants; how should technology make decisions for the user?

*Future Work*

The results of this study have the potential to be furthered into phase 2 and 3 as discussed in methods. Phase 1 should be completed by coding the other focus group transcripts and perform statistical analysis with the composite data. The results of phase one will lead directly into the construction of phase 2; this frequency data will help me find emergent themes that I can use to construct a survey. Based on phase 1, I would like to further pursue users' understanding and trust in technology, users' control and complacency, and their belief in the system's morality. The survey will be based on these concepts that had the highest frequency and discrepancies in the focus group data, and it will be formatted in the same structure as the focus groups (driving, automation, and driving with automation), but it will ask about more specific features and will be dispersed to a much larger sample than the focus groups. With this survey, I will identify a specific discrepancy in acceptance between driving, automation, and driving with automation and how this feature or concept should be improved. The results of this survey will provide the basis for phase three of this study.

In phase 3, after identifying a specific factor that leads to users' refusal to accept automation in vehicles, I will work to change the design or implementation of this feature in accordance with the indicated user preferences. Once the prototype based on this design is complete, I will test the prototype compared to the current model. This phase will be within subjects, and I will collect feedback based on participants likely completing a driving task using both models.

Participants in this phase will compete a driving course on a simulator; the test drive will include some currently undetermined level of automation. Participants will complete two baseline drives and two test drives; each baseline drive will be a manual drive using either the control feature or the prototype, and each test drive will be automated and use either the control feature or prototype. After each drive, participants will complete a NASA-TLX workload survey and an acceptance survey. The independent variable in this phase is the design (prototype or control), and the dependent variables will be driver performance, workload, and acceptance.

*Conclusions*

I expect that improving the design of a feature will improve performance, decrease workload, and improve acceptance. If successful in improving user acceptance through this design, the next step would be to integrate this new design into a car or driving simulator and test reliance and performance compared with the current model. It is expected that improved user acceptance of the system will lead to appropriate reliance on automation features in cars to ultimately increase driver safety. Driver safety has always been a priority, but modern developments in vehicle automation has brought greater attention to drivers' interaction with these systems and how this relates to safety. This work has the potential to improve our understanding and execution of automation in vehicles in relation to user acceptance, and this understanding will help us with user design as technology continues to advance.

**References**

Davis, F.D. (1989) Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Q*. 13:319-340.

Davis, F.D. (1993). User acceptance of information technology: system characteristics, user perceptions and behavioral impacts. *International Journal of Man-Machine Studies, 38,* 475-487.

Ghazizadeh, M., Lee, J.D., & Boyle, L.N. (2012). Extending the technology acceptance model to assess automation. Cognition, Technology & Work. 14, 39-49 10.1007/s10111-011-0194-3

Hoff, K.A. & Bashir, M. (2015). Trust in automation: Integrating empirical evidence on factors that influence trust. *Human Factors, 57*(3), 407-434.

Inagaki, T., Furukawa, H., & Iroh, M. (2005). Human interaction with adaptive automation: Strategies for trading of control under possibility of over-trust and complacency. *1st International Conference on Augmented Cognition.*

Kaber, D.B., & Endsley, M.R. (2004). The effects of level of automation and adaptive automation on human performance, situation awareness and workload in a dynamic control task. *Theoretical Issues in Ergonomics Science, 5*(2), 113-153.

Kazi, T., Stanton, N., Walker, G.H., & Young, M.S. (2007). Designer driving: Drivers' conceptual models and level of trust in adaptive cruise control. *International Journal of Vehicle Design, 45*(3). 339-361.

Lee, J.D. & See, K.A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors, 46*(1), 50-80.

Madhaven, P., Wiegmann, D.A., & Lacson, F.C. (2006). Automation failures on tasks easily performed by operators undermine trust in automated aids. *Human Factors*, *48*(2), 241-256.

May, K., Noah, B.E., & Walker, B.N. (2017) Driving acceptance: applying structural equation modeling to vehicle automation acceptance. AutomotiveUI '17 Adjunct

Parasuraman, R. & Riley, V. (1997). Humans and automation: use, misuse, disuse, abuse. Human Factors. 39(2), 250-253

Parasuraman, R., Sheridan, T.B., & Wickens, C.D. (2008). Situation awareness, mental workload, and trust in automation: viable, empirically supported cognitive engineering constructs. Journal of Cognitive Engineering and Decision Making. 2(2), 140-160. 10.1518/155534308X284417.

SAE International (2016). U.S Department of Transportation's new policy on automated vehicles adopts SAE International's new levels of automation for defining driving automation in on-road motor vehicles.

Walker, G.H., Stanton, N.A & Salmon, P. (2016). Trust in vehicle technology. International Journal of Vehicle Design. 70. 157. 10.1504/IJVD.2016.074419

# Appendix

## Figure 1: Coding scheme/frequencies

| | | | Definition | Driving | Automation | Driving with Automation |
|---|---|---|---|---|---|---|
| Accept | | | | | | |
| | Internal | | | | | |
| | | Trust in system's ability | The user trusts the system to perform as it's supposed to | 2 | 3 | 2 |
| | | Trust in own ability | The user trusts that they are able to correctly operate the system | 2 | 0 | 0 |
| | | Effort* | The task does not require too much cognitive load | 0 | 0 | 4 |
| | | Experience | The user has had positive experiences or feels that prior experience with the system has helped to accept | 0 | 0 | 2 |
| | | Independence* | The user feels independent using the system | 3 | 2 | 0 |
| | External | | | | | |
| | | Safety | Using the system does not make the user feel unsafe | 2 | 0 | 1 |
| | | System compatibility | The system fits the needs of the user (i.e. user only wants the system if it's a pick-up truck) | 3 | 5 | 3 |
| | | Feedback/information | System provides adequate real-time, updated feedback and information to the user | 0 | 2 | 0 |
| | | Accuracy | The system performs its tasks correctly | 0 | 3 | 2 |
| | Other | | | 2 | 1 | 2 |
| Reject | | | | | | |
| | Internal | | | | | |
| | | Control | The user feels uncomfortable with the amount of control while using the system | 0 | 0 | 6 |
| | | Complacency* | The user believes that using the system will lead to complacency | 0 | 3 | 4 |
| | | Experience | The user has had negative experiences with the system or has not had engagement with the system | 0 | 0 | 3 |
| | | Trust in own ability | The user does not trust that they are able to correctly operate the system | 1 | 0 | 1 |
| | | Trust in system's ability | The user does not trust the system to perform as it's supposed to | 2 | 2 | 3 |
| | | Effort | The task requires too much cognitive load | 2 | 2 | 0 |
| | | Morality* | The car's ability or inability to make moral decisions for the driver | 0 | 0 | 3 |
| | External | | | | | |
| | | Traffic | User believes heavy traffic is a deterrent for using the system | 3 | 0 | 1 |
| | | Accessibility | The user believes the technology to be inaccessible due to things like price, access to charging stations, low production… | 1 | 0 | 2 |
| | | Maintenance* | The user is frustrated with the amount of maintenance required. | 5 | 0 | 0 |
| | | Feedback/information | The user would like the system to provide more real-time feedback and information | 0 | 2 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Accuracy | The system does not perform it's tasks correctly | 0 | 2 | 3 |
| | Other | | | 2 | 1 | 1 |