LANGPAD (Multi-Language keyboard peripheral)
(Technical Paper)

How Companies and Users Produce Trust in Autonomous Vehicles
(STS Paper)

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Engineering

By
Emory Ducote
November 1, 2021

Technical Project Team Members:
Christopher Hamilton, Pedro Rodriguez, Rawan Osman, Rohan Chandra

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Sean Ferguson, Department of Engineering and Society
Harry C. Powell, Department of Electrical and Computer Engineering

Introduction

Millions of users type in foreign languages on standard QWERTY keyboards every day. Characters such as the Spanish “á”, the French “ç”, and the German “ä” are all characters that do not have a reserved location on this standard keyboard layout. Thus, people typing in such languages must take alternative routes to utilize these characters such as memorizing complex character codes, remapping keyboard layouts, and even copying and pasting from internet sources. For example, for a user to type the Spanish “á,” they would likely need to search up the character code and type out the long sequence Alt + 0225. This route is not especially great, so my Computer Engineering Capstone team is working to produce a more effective alternative for quick typing. We are looking to produce a small, touchscreen keyboard peripheral, the LANGPAD, that allows users to swap between different special character sets and input characters rapidly into a text editor. The peripheral will initially support both Spanish and French special characters but can be expanded to support any characters supported by the ASCII format.

My STS research paper focuses on how autonomous car companies garner user trust with such a potentially dangerous product. This topic is not wholly tied to the LANGPAD; however, both autonomous car companies and the potential sellers of LANGPAD devices are driven by the same need to attract and keep a user base that trusts in their products. The focus on this STS topic comes from my desire to learn more about how autonomous car companies and users create an environment of trust that allows for use of dangerous devices without fear. I aim to explore how different autonomous car companies show their users that their products are safe and within regulatory guidelines while maintaining that their product’s function is worth the risk and superior to their competitors. Through this exploration of the social side of autonomous driving technology, I hope to strengthen my non-technical analytics skills. These skills will be valuable

in my future as many of the technical solutions we develop as engineers have heavy social impacts.

Technical Topic

The primary need for a special characters peripheral is the lack of quick alternatives for typing on an QWERTY keyboard. The QWERTY keyboard arose to solve the problem of typewriters jamming, so ease of use was not the primary design qualifier (Alden et al., 1972). In fact, there are several other keyboard layouts that produce higher words per minute on average compared to the QWERTY design (Zhai et al., 2000). As the QWERTY design is lacking for multilingual users typing in multiple languages quickly, a supplementary device is needed for such users. Thus, the primary design goal for the project was to ensure the user could use the product quickly and seamlessly. With this fact in mind, we considered the easiest transition from typing on a standard keyboard to be adding additional keys. However, a large device would be cumbersome, so we set out to make a touchscreen keyboard approximately the size of a number pad on a traditional QWERTY keyboard. Another factor to increase usability that we considered is audio feedback from the device to confirm correct use. This feature is important because has been found that users are “bothered” when there is a lack of audio feedback on a keyboard (Alden et al., 1972). To implement this aspect, we decided on a small buzzer that would beep whenever a key is pressed. In this way the touchpad mimics the typical clack of keyboard keys during operation. Additionally, we thought it best to be able to control this beeping with a volume knob, as when in quiet places it could be bothersome to others. Finally, we decided to use connection cords that were familiar to most users, so we chose a standard USB cable communication with a computer and a standard wall adapter for powering the device. Thus, our

project requires three main pieces of functionality: a graphical touchscreen interface with characters, a tunable audio feedback system, and seamless USB communication with a computer.

To attain these three pieces of functionality, we broke our team up to accomplish various aspects of the project according to each person's strengths. One aspect of the project is the functionality of the touchscreen which the user presses on to select characters. This screen calls for both touch capability as well as graphical display. I was assigned this as the main subsystem I will focus on throughout the semester. Two other aspects of this project are the audio feedback system and the USB communication system which were each assigned to other team members. Finally, the last required aspect of the project is that it use a custom-designed PCB (Printed Circuit Board). This board will serve as the centerpiece that ties all the subsystems together. Because this aspect is so integral to the project, two of the five team members were assigned to be primarily focused on its design. Following assigning roles, we all began planning out tasks for the semester to meet the project assembly deadline. This planning stage included slotting dates for ordering parts, code development, assembly, individual testing, integration testing, and a final demo. With this plan set, we have been following our schedule and receive feedback from our technical advisor along the way.

When the project is complete, a working demo will be available to demonstrate the work done. Each aspect of the design will play a part in contributing to an overall system that can improve the lives of those typing in foreign languages on QWERTY keyboards. The touchscreen system will show a pleasing graphical user interface and receive presses rapidly. The audio feedback is a key accessibility feature that will improve user experience. The USB connection will be familiar to most people and, thus, will lower the barrier to use. The combination of these three systems will provide a seamless experience for the users of the product.

STS Topic

In the markets of our society there exists a level of trust between every consumer and producer. The products people use every day are assumed to be safe so long as their use instructions are followed reasonably. This bond between people and companies is particularly interesting, as there are many items used that are potentially life threatening if constructed carelessly. Products like cars, motorcycles, bikes, lawn mowers, can all produce dangerous outcomes if they are designed poorly. This fact is particularly interesting when considering the rapid advancement in the autonomous vehicle field. There are deadly consequences for poor design decisions, so those creating these cutting-edge devices are forced to assure the general user of their safety. The question that comes to mind is "How do companies and users co-produce trust in the radical new innovation space of autonomous vehicles?" This paper will show how companies are able to show users that the product is both worth the risk and better than the competition. Additionally, it will show how a willing user base and regulation following contributes to the belief in the safety of the vehicle. These topics will be examined through the framework of Sociotechnical Systems, Users, Practices. The role of the user in shaping how autonomous vehicle companies attempt to garner trust will be analyzed.

To understand more about what level of risk is involved with autonomous vehicles, one must understand the five levels of autonomy within autonomous cars. Levels zero and one involve very little autonomy, but as the number increases so does the driver control decrease (Garcia et al., 2015). Level two includes systems like assisted braking, and at level three the car can perform most tasks but still needs human intervention (Garcia et al., 2015). Level three assumes that the car can perform all crictical functions under some conditions (Garcia et al., 2015). Finally, the holy grail of autonomous cars is level four, as there is zero human interaction

needed with the vehicle (Garcia et al., 2015). From these five levels, it can be reasoned that as the level of autonomy increases so must the level of trust in the autonomous vehicle increase.

There exist many scholarly articles examining user trust within autonomous systems and, specifically, autonomous vehicles. For example, there has been research into how the user interface of the vehicle factors into the level of trust the user has. Khan's (2019) paper, *An investigation into trust between an SAV and its passengers,* details how several different companies approached their user interface and the results. These result were primarily focused on the company gaining user trust and how that affected design (Khan, 2019). A different look at user trust occurs in a separate study that examined how Tesla, Inc cars generated a dangerous level of trust in the user, as the brand of cars requires user intervention (Banks et al., 2018). This study focuses on the negative side of the trust garnered by companies, as it contributes to the broader level of trust in autonomous vehicles as a whole (Banks et al., 2018). Tangential to trusting using an autonomous vehicle is trusting those that the vehicle will not harm anyone outside. Studies on pedestrian trust in autonomous vehicles have been conducted, and one conducted surrounding Uber autonomous vehicles discusses what prior dispositions lead to autonomous vehicle trust (Reig et al., 2018). This study mentions that those who previously had "favorable interpretations" of technology were more likely to trust autonomous vehicles (Reig et al., 2018). Studies like this must also be considered, as the user's trust in the autonomous vehicle is built both by how the user interacts with the vehicle and how society interacts with the vehicle indirectly. Another factor affecting trust in autonomous vehicles is their ability to ensure the user that the vehicles can handle complex situations. In one study, it was found that in dangerous situations the user trusts the vehicle based on how well the vehicle explains how it is conquering the task (Ha et al., 2020). This study found that in particularly bad conditions, such as snow and

ice, the way the vehicle communicates to the user can significantly change the level of trust (Ha et al., 2020). All of this prior research shows that there are different aspects of the user experience that affect trust in different ways. Because there are a wide range of variables affecting trust, in this paper many different factors will be analyzed that contribute to user trust. While referencing the results of these studies, this paper will delve deeper into how individual trust of a user can cascade to general public's userbase.

Next Steps

The remaining work to show how user trust in autonomous vehicles by particular companies will entail a few different things. Firstly, several aspects of the autonomous driving experience and their implementation by particular companies must be analyzed in regard to user trust. A deeper analysis will be done on the user interface, communication with user, regulatory perception, user's relationship with pedestrians, vehicle competency in tough situations, and the level of aggressiveness of the vehicle. Studies discussing user interface and communication of autonomous vehicles will be used to understand how those factors affect trust (Banks et al., 2018; Khan, 2019). A study analyzing how to regulate autonomous vehicles to maintain user trust will be used (London & Danks, 2018). Regarding the relationship with pedestrians, multiple studies will be used analyzing how the relationship with pedestrians affects user trust (Jayaraman et al., 2018; Reig et al., 2018). Additionally, user trust in relation to the competency of the vehicle will be explored (Ha et al., 2020). Finally, studies showing how user trust is affected by the aggressiveness of the vehicle will be used (Shahrdar et al., 2019). A deeper look at all of these different aspects of user trust will help show how users and companies create trust in the novel realm of autonomous vehicles.

References

Alden, D. G., Daniels, R. W., & Kanarick, A. F. (1972). Keyboard Design and Operation: A Review of the Major Issues. *Human Factors*, *14*(4), 275–293. https://doi.org/10.1177/001872087201400401

Banks, V. A., Eriksson, A., O'Donoghue, J., & Stanton, N. A. (2018). Is partially automated driving a bad idea? Observations from an on-road study. *Applied Ergonomics*, *68*, 138–145. https://doi.org/10.1016/j.apergo.2017.11.010

Garcia, D., Kreutzer, C., Badillo-Urquiola, K., & Mouloua, M. (2015). Measuring Trust of Autonomous Vehicles: A Development and Validation Study. In C. Stephanidis (Ed.), *HCI International 2015—Posters' Extended Abstracts* (pp. 610–615). Springer International Publishing.

Ha, T., Kim, S., Seo, D., & Lee, S. (2020). Effects of explanation types and perceived risk on trust in autonomous vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, *73*, 271–280. https://doi.org/10.1016/j.trf.2020.06.021

Jayaraman, S. K., Creech, C., Robert Jr., L. P., Tilbury, D. M., Yang, X. J., Pradhan, A. K., & Tsui, K. M. (2018). Trust in AV: An Uncertainty Reduction Model of AV-Pedestrian Interactions. *Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction*, 133–134. https://doi.org/10.1145/3173386.3177073

Khan, M. D. (2019). *An investigation into trust between an SAV and its passengers*. http://essay.utwente.nl/79948/

London, A. J., & Danks, D. (2018). Regulating Autonomous Vehicles: A Policy Proposal. *Proceedings of the 2018 AAAI/ACM Conference on AI, Ethics, and Society*, 216–221. https://doi.org/10.1145/3278721.3278763

Reig, S., Norman, S., Morales, C. G., Das, S., Steinfeld, A., & Forlizzi, J. (2018). A Field Study of Pedestrians and Autonomous Vehicles. *Proceedings of the 10th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 198–209. https://doi.org/10.1145/3239060.3239064

Shahrdar, S., Park, C., & Nojoumian, M. (2019). Human Trust Measurement Using an Immersive Virtual Reality Autonomous Vehicle Simulator. *Proceedings of the 2019 AAAI/ACM Conference on AI, Ethics, and Society*, 515–520. https://doi.org/10.1145/3306618.3314264

Zhai, S., Hunter, M., & Smith, B. A. (2000). The metropolis keyboard-an exploration of quantitative techniques for virtual keyboard design. *Proceedings of the 13th Annual ACM Symposium on User Interface Software and Technology*, 119–128.