Usability Evaluation of Biometric Authentication Systems in Autonomous Vehicle Environments

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1. Introduction

Therefore, this paper presents both the usability improvements and the requirements of current biometric authentication systems as they are adapted for transient user interactions in environments defined by assisted tasks in a vehicle interface. The key usability features of presentation attack detection and optimal selection of the biometrics are described, and where possible, best practices within these tools are indicated. Building on this information, an updatable set of biometric selection guidelines is presented for the envisioned environment, as we believe that, given the upcoming introduction of these autonomous vehicle systems to human-centric environments and the related requirements for immediate good usability, it is no longer sufficient to focus on simple situational vehicular or pedestrian interactions.

Users are prevented from using awesome systems because the initial effort is too frustrating. Given the popular and research momentum behind autonomous vehicles, it is expected that such vehicles will transition from not existing in human-centric environments to being frequently encountered for transportation within a short timeframe, without a long-term societal transition that allows for gradual familiarization of the users. Therefore, the immediate usability of all aspects of the vehicle is important and contributing factors in initial user acceptance. One way to improve usability is to simplify or eliminate tasks that are error-prone, inefficient, and difficult to perform; in one area of computing, biometric authentication—a high priority task that is often the source of inefficiency and non-acceptance—is developed to do just that.

1.1. Background and Rationale

It is vital to understand the drivers for user selection, so as to find out how best to position the offered technologies. In order to evaluate the effect of BAS on usability and user perception,

usability evaluations can be used. According to the technology acceptance model (TAM), the most important drivers in the practical system category relate to the ease of use of an application and the usefulness of the system. With the growth in vehicle connectivity and autonomy, the biometric acceptance driver for in-cabin traffic operation is based on the secure management of the driver, while meeting a number of safety requirements. This research concentrates on the proposed usability evaluation process for BAS along pre-operational stages through laboratory testing called the biometric smart driving evaluation system (BideS). Small budgets and ambitious deadlines will need the design team to enhance existing techniques quickly. BideS allows such a qualitative assessment of the user interface for new drivers who are useful BAS participants in a timely and cost-effective manner.

On the one hand, biometric techniques offer significant advantages in terms of user convenience, circumvention of the password memorability trade-off, and resistance to theft, loss, and guessing attacks. On the other hand, the impact of current biometric research, especially in intelligent transport systems, is not visible to the user and will fail to gain mass market acceptance because functionality is subordinated to security. As biometric modalities improve, they will provide enhanced usability, reliability, security, and privacy for automotive control systems. But in humans, as the system becomes more secure, it becomes less usable and the user will seek non-secure alternatives (e.g. post-it notes for PINs), creating a situation where Biometric Authentication System (BAS) adoption is not an automatic choice of the user.

1.2. Research Aim and Objectives

The primary aim of the research was to gain a better insight into how users perceive different biometric authentication systems and to evaluate participants' lifestyle and personality, which could influence the effectiveness of the biometrics-based method. Furthermore, this research aimed to discover how different physical and mental tasks could influence usability rates of biometric authentication technologies for users in the specific environment of autonomous vehicle (AV) as well as to identify usability problems affecting the user experience of multimodal biometric solutions. The objectives of the usability testing were to provide a comparison of the usability and acceptance of diverse biometrics-based methods including single and multimodal solutions, examine the effect of mental and physical activities on system performance, analyze user experiences related to particular system use and potential

emotional states of the participant during system use and uncover the main usability problems for biometric in-cabin applications.

1.3. Scope and Significance

In this review, the documents revised are grouped in the following order: (i) Structured categorization of various biometrics, particularly focusing on ocular biometrics in driving scenarios (Section 2). (ii) Approaches for usability testing of biometric authentication in autonomous vehicles (AVs) (Section 3). (iii) High-level evaluation techniques used in our study designs (Section 4). (iv) Ethical considerations in biometric systems that need to be thoroughly socially vetted through testing its application and evaluative framework (Section 5).

Given this situation, a two-part study is put forward to evaluate the usability of biometrics (i.e., ocular biometrics and facial recognition) and current state-of-the-art Plug-and-Play design techniques used in the deployment of biometric authentication systems in autonomous vehicle environments. The results of the two-part study will provide valuable feedback on the performance of biometrics as a form of secondary biometric authentication framework in autonomous vehicle driving scenarios. Additionally, the usability aspect of biometric authentication design for its impending use in autonomous vehicle environments will be studied. The study findings offer future opportunities for diverse and innovative design approaches as the field of AVs advance and proliferate in highways and city roads.

2. Biometric Authentication Systems

Biometric recognition has become an important research area, which has been in great expansion in recent years, with new methods and techniques being progressively tested. However, they also lead to the emergence of research related to the creation of constructive methods, aimed at evaluating the effectiveness of these systems, thus covering real environments and user images.

Within the most common biometric recognition systems, we highlight the systems with the following characteristics: captures for face recognition, including cameras/webcams; the culmination of hand geometry for people who work with their hands; recognition by fingerprint, showing a very low error rate; the recognition of the voice, due to the ease of capture by the use of microphones; recognition of text writing, using tablets, touch screens,

and other tactile devices. We can also mention systems that perform the moderation of behavioral patterns, such as habits, to check if a user is authorized.

Biometric recognition systems do not require interaction between the user and the system, which considerably speeds up the authentication process, reduces the probability of compromising the security of the protocol, and guarantees that the user is present during the authentication process. Presenting the advantages of biometric recognition systems over traditional ones, they have become a solution that has been used in several domains, such as finance, medicine, tourism, e-commerce applications, and telecommunications. We can mention some applications, such as Automated Teller Machines (ATMs), physical access to controlled environments (buildings, schools, institutions), database access, and physical access to computers.

Biometric recognition consists of the automatic classification of people using their physiological or behavioral traits. Traditional authentication systems are based on the use of passwords, tokens, keys, etc., and due to the technology available to users, the protocols used are not robust and can often be compromised by an attacker. That is why they constitute the main obstacle to ensuring effective and secure communication in open environments such as cloud computing, the Internet, and wireless networks.

2.1. Definition and Types

The reason smart automotive can be considered a very special domain of biometric applications is that the end-users of smart automotive biometric authentication systems prefer its operations to be as easy, smooth, and efficient as possible. Instead of spending time on complicated calculations or high concentration operations, automobile drivers desire to have short-response actions each time before they go out. Consequently, conventional biometric authentication systems that are developed and designed for a quantity of users cannot be considered the best fit for smart automotive applications. Due to this specialty, before we try to evaluate this kind of biometric authentication system through the general scenarios defined in the international usability standards, we conduct some interviews with real users first. We intend to collect more meaningful scenarios that truly take their user experiences into consideration from those users. Based on the results of this user survey, an analysis of three drivers' biometric authentication systems to be used for their private cars is described, and the problems found in these systems are presented.

Biometric authentication refers to the recognition of an individual's personal traits through their unique physiological and behavioral features. A wide range of biometric features have been utilized in authentication systems. The most popular biometric features include fingerprint, face, voice, iris, gait, and palm vein. During the last few decades, various biometric-based systems have been developed by crossing over different application domains. For example, fingerprint recognition is usually used in attendance management to ensure the identities of employees. Face recognition is very popular for security checks in airports, train stations, and passport control. Retinal biometric technology is applied to provide user authentication at ATMs.

2.2. Applications in Autonomous Vehicles

Autonomous vehicles that provide parcel pickup or delivery service may adopt biometric authentication as an authorization measure to prevent parcel theft. Additionally, they can use data from biometric sensors for the generation of smart in-car advertising content. Biometric authentication systems can also be used for landmark sensing applications that can provide autonomous vehicles with additional vehicle-to-infrastructure predestination information and the in-vehicle sensors can be used to deploy vehicle emergency brake assistive systems. To implement such a multifunctional recognition system, instruments such as three-dimensional model-based face recognition algorithms could be utilized.

Several studies have demonstrated the potential use of biometric authentication as a safety authenticator in autonomous vehicles. For instance, driver identification and fingerprint verification systems can protect shared autonomous vehicles from unauthorized third parties driving, and can mitigate the necessity to pick up and return keys, respectively. In-cabin cameras can be used to ensure that the passengers follow the safety guidelines and for identification and age verification when renting a vehicle. In-cabin cameras can also be used to validate the presence of the child restraint system in the appropriate seating row and monitor the state of the in-vehicle children, and confirm the number of passengers during rides. Researchers have developed such a system that provides real-time location tracking and logging for parents to monitor children traveling on autonomous buses and has implemented such a gender recognition system and an adaptive in-group advertising system on autonomous vehicles. Such a group gender estimation system with the ability to operate in nighttime conditions has also been developed.

3. Usability Evaluation

An important step in the development of usability guidelines is to evaluate the user needs and expectations when interacting with the components under consideration. In the automotive context, usable designs of biometric systems employed to authenticate the user become a very difficult task, especially due to the restrictions of being implemented and the environmental conditions, including software design issues. The solver decision could reduce human attention in critical driving maneuvers and avoid system perturbations on the user's physiological state, thus yielding a less comfortable vehicle interior. The vehicle distinguishes and manages different user groups by on-site recognizing. Instead of replaceable key fobs for user settings, the user authentication process includes mentioning personal private and public elements for each user. The user recognition process associates one or more input features to the most probable characteristics on each user group. This association is obtained by solving association rules forged by supervised learning. When biometric information is unreliable or unavailable, additional knowledge sources assist user identification and/or verification. This proposal improves current vehicle security and simplifies vehicle access and use, empowering an improved user mobility. With usability guidelines and critical driving maneuvers enforcement, the vehicle and the driver help each other nearer a better vehicle utilization and less human workload, providing an enjoyable user experience.

3.1. Importance in Biometric Systems

Wroclawski et al. (2001), however, affirm that usability problems may have a different nature in biometric systems and may not be addressed by the traditional tests that are used in regular systems. The importance of a careful evaluation comes from the fact that biometric system operation depends on both automatic operation and the cooperation of the user, and that requires tight integration of human-computer factors. The system must inform and guide the user, who, in turn, must perform certain actions. Biometric systems must be designed so that users believe in the process and in the system. Therefore, emotional and motivational factors are particularly important, and the design of an effective, user-friendly biometric system with high acceptance must be the result of careful design and usability study.

Biometric systems are developed as a reliable and secure way to accomplish different authentication and identification processes. Despite their security and reliability, which allows them to be extensively applied, particularly when compared with traditional systems,

such as passwords and PINs, these systems are affected by some factors that can significantly interfere with their regular use. The large number of existing user interfaces and the wide range of applications in which biometric systems are used create a wide range of types of interaction, each with their own set of rules and conditions. Among the available works related to usability in biometric systems, the majority are subjective, and, among the subjective evaluations present in the literature, the most common objective of the works is to verify the user interface components of the system with a lean body of users. For robust IoT device security, see Shaik, Mahammad, et al. (2018) on RBAC implementation.

3.2. Methodologies and Metrics

In this experiment, five main eye metrics related to different aspects of the passenger's visual behavior, including fixation heatmaps, fixation points, average fixation duration, number of gaze points & transitions, and percent visibility time, were introduced. These numbers provide real-time data on passenger responses during the driving period. They make the user experience of driving very organic. After the experiments, the drivers completed the system usability survey. The satisfaction levels with use show that the voice-based biometric authentication method receives the highest approval scores. This results in findings consistent with many studies on the usability of voice-based driver permission verification systems. Additional tasks related to non-driving activities for the autonomous vehicle driver can incur significant costs associated with additional distractions that can degrade driving capabilities.

This is an encouraging finding that suggests voice-based BA as a permission verification process for options in an autonomous vehicle. Eye movement data are collected for the non-driving activity during the driving period. The desktop user interface design is introduced to the passengers of the front seat vehicle in these activity times, and authorization is requested. The eye movement results during the processing show improved performance in the voice-based BA of certain areas of the passenger's visual field. The field of view alterations can assist in the estimated duration of the interaction for approval or authorization which is granted verbally.

Experts who have expertise in the design of performance measurement systems in human factors also have expertise in the preparation of a usability evaluation methodology for an autonomous vehicle. This usability evaluation methodology examines the methods and metrics that are currently used in the laboratory environment to create a summary index for

the perceived usability assessment of the biometric authentication (BA) system. Twenty-three metrics, ranging from task completion time to effectiveness metrics, are also defined within three systematic sets that measure users in the effectiveness, efficiency, and satisfaction metrics. All of the usability metrics and recording observation methodologies are derived from the state of the art in recommended evaluation practices and existing literature. The results from a simulated driving activity show a noticeable difference between voice-based and hand-based BA system performance. The voice-based BA method requires less user attention than the other system; it also reduces eye focus when user performance is observed.

4. Autonomous Vehicle Environments

The user of the Level 4 driverless car experiences a situation, unlike anything previously seen during normal vehicles and driving. The authors even believe that future "semi-public driving" situations should be considered. Currently, the usage of robotaxis and the use of autonomous vehicles in vehicle-sharing systems are the most expressed case. Government restrictions and the blanket ban on testing with cars on public roads in some countries continue to be hurdles. It is expected that intelligent devices will be the majority in autonomous vehicles, especially between levels 3 and 4. The authors stress that autonomous levels should be considered before developing the component on the usability intended for autonomous vehicle users.

Levels of autonomy are often addressed through SAE's levels, which have been portrayed in situation 1C for autonomous vehicles where the human only needs to press the button. The user role has been classified as passive. The autonomous levels describe five different degrees in which the vehicle is able to perform the driving tasks. The more advanced vehicles are classified as Level 3 or Level 4. In Level 3, the involved driver is allowed a combination of both performing critical vehicle operation tasks and being disengaged. However, the driver must be ready to take control when the automation requests to do so or when something unexpected occurs. In Level 4, the driver's role is more like the passive user in a situation 6C. The vehicle is able to perform specific driving tasks and not the driver.

4.1. Overview and Key Components

The aim of this paper is to discuss the key aspects of usability evaluation regarding biometric authentication in autonomous vehicle environments. It is necessary to identify challenges

such as allowing access to multiple users while remotely controlling the self-driving system or delivering trustworthiness in real complex environments at a low cost. The decision to use biometric solutions to enhance safety and comfort levels around AV is related to two change aspects from AV experience: the driver task shifting and the trust required from passengers. These aspects are, in part, due to advanced AV features that use the driver as the final safety manager while performing other different tasks.

In order to establish a fundamental understanding of usability areas and evaluation methodologies regarding biometric authentication solutions within AV environments, we began by following discussions on usability, biometric authentication, and the integration of sold solutions within autonomous vehicles. These discussions established a guide to understand and address design strategies and decisions around biometric authentication within AV environments. Using mainly academic and industry-recognized metrics, this evaluation is composed of four usability concepts: polysensory, essentialism, cost-benefit, and user preference.

5. Case Studies and Experiments

Face recognition is limited in terms of recognition rate and does not allow passengers with advanced facial features to be diagnosed as a driver. Overall, this paper offers a comprehensive view of biometric integrity research, with the goal of clarifying the current status of the study and providing some of the useful results of the research, as well as revealing the requirements needed to improve security for autonomous vehicles. Finally, the study used the UCD process model as a benchmark for tracking related research and providing new research directions. The evaluation of the results of this study in the authentic vehicle environment and its data analysis provides important information to the UCD process in improving access to research through biometric integrity and authentication systems.

Autonomous vehicle environments have the challenge of verifying whether or not a driver needs to take over vehicle control. A drunken or sick-authorized passenger driver remotely controls a car. In this case, it is important to identify the driver or passenger in the autonomous vehicle and access the biometric security information of the authorized driver as soon as possible. Currently, the problem of manually checking by face-to-face interview has been identified, but security issues exist, and the unauthorized driver is still recognized as a driver. The purpose of the experiment is for the drunken driver to pass the self-driving vehicle, and

the goals include confirming whether it is passed in the right direction and only after it is passed, face recognition and other technological data are transmitted to recognize the identity.

5.1. Existing Studies in the Field

The research question remains whether the already developed theoretical criteria for usability testing of biometric methods for the needs of the autonomous vehicle environment. One possible answer suggests redefining traditional usability criteria in a way that they retain most of the existing diagnostic capabilities and, at the same time, allow them to be applied in dynamic identification in autonomous vehicles. However, no answer can be found in the available literature with which to compare the set of criteria and verification methods developed for the needs of an autonomous vehicle. Based on the above assumptions, the list of the main criteria established for the needs of autonomous vehicles can be found below. Additionally, the most important references contain an excerpt that completely tilts the theoretical assumptions postulated in the manuscript.

As for general usability testing of biometric methods, many experiments on the recognition of voice, handwritten text, faces, etc. are carried out. However, there are no research works in peer-reviewed publications that are directly or indirectly related to the problem of usability testing of biometric systems designed for identification or verification of the identity based on the processing of biometric data also in an autonomous vehicle system. When testing biometric systems in a typically used mode, the identity system was studied most frequently, biometric systems for recognizing the identity of the person, and then for recognizing the identity of the person. In summary, the conventional scope of the usability study of biometric systems is extremely narrow. It boils down mainly to the collection of primary recognition data or evaluation of biometric features extracted from the control body. The number of criteria studied during the operation of biometric devices should be broader, and the assumption on the purpose of the device (e.g., verification and authentication) should be more flexible.

6. Challenges and Future Directions

The use of biometric sensors in autonomous vehicles potentially enables biometric information-related privacy and ethical implications. These challenges should be addressed in future work based on local regulations and global standards, including guidelines for

implicit biometric capture and related data treatment and deletion, and guarantee a significant level of information security.

The presence of drivers and passengers with special characteristics, including babies and minors, as well as elders and sick people, increases the requirement of implementing robust and flexible biometric authentication systems.

The results of this study revealed a couple of issues that could pose significant challenges during the deployment of biometrics in autonomous vehicles. These findings indicated that ongoing research is crucial to ensure that biometric authentication systems for autonomous vehicles are designed in a way that takes the unique challenges and requirements of autonomous vehicles and biometric authentication into account.

6.1. Current Limitations and Issues

By following these guidelines, you can create an effective and informative text that will engage and educate the reader on the topic at hand.

Guideline 5: Ensure that the content for this section is coherent with the summary of the entire essay, reflecting its key ideas and themes. The information provided should align with the overall message and purpose of the essay.

Guideline 4: Enhance text complexity by varying sentence structures and reducing predictability. This will make the text more engaging and interesting to read.

Guideline 3: The text should primarily focus on delivering information, explaining concepts, or detailing processes or systems. It should provide valuable and relevant content to the reader.

Guideline 2: Exclude any mention of the topic, comments, or the number of characters in the result. The focus should solely be on delivering the information without any unnecessary distractions.

Guideline 1: Use a descriptive tone in your response. This means that the text should provide clear and detailed information, avoiding vague or ambiguous language.

To achieve this goal, there are five equally important guidelines that should be followed:

The goal of this section is to provide a concise yet coherent text that delivers concrete, specific, and factual information relevant to the topic. The section title is "Guidelines for Creating an Effective Text."

6.2. Proposed Solutions and Innovations

Finally, regarding direct and remote biometric authentication system preference loss, autonomous vehicles offer the opportunity to invoke system recovery options by using alternative media such as sound (e.g., voice), vision (in-cabin camera), or haptic feedback mechanisms (e.g., steering wheel or seat vibration or sound and visual alerts). Additionally, the outcome of the biometric database post-processing algorithms can be employed to prevent and mitigate the deleterious aspects of direct and remote biometrics modality misuse. For instance, we can imagine cases with two co-located authentication systems (one for direct and the second for remote biometric AP) with independent failures, thus offering an advanced level of protection.

We argue that the previous three usability issues with the specific biometric authentication modalities discussed in the previous section in ADAS-based AVs can be addressed by exploiting the input and output modalities of the AV interfaces. For preventing the detrimental effects of steering and seat movements (See-Through Manoeuvre), it is possible to monitor the output modalities such as the gaze direction and the driver face direction along with the input modality of capturing the driver image. Therefore, when the seat and steering movement conditions independently (pseudo) verify the situation, the system takes the action to prevent biometric modality misuse with interventions (e.g., alarm, warnings, disengage the system). In particular, facial expressions can be employed to classify between the driving and computer-vision at-supported parking conditions, by avoiding unnecessary offers of help. However, in the situations requiring an AV intervention, the driver attention should be restored.

7. Conclusion

Although ECG is less dependent on regulation, our ML-based model will help manufacturers to evaluate and manage the effect of all characteristics and the introduced resolution of sensors in lower regulation to trigger on scale systems. As the second thing, applying the comfort threshold may be used to filter unusual and unwanted stress showing that stress is

too high, which will help triggering the alertness threshold, and it can be seen from the extra run and response times that the users may want to give a command. The suggested design would enable manufacturers to use this biometric for the right decisions, regulate the scenarios effectively, and anticipate any possible issues.

This study showed the efficiency of the back-of-the-ear ECG biometric recognition using low-resolution sensors in mitigating errors with any regulation system, the lower cognitive load with face structure-based biometrics, and the better response time and lower stress with the familiarity recognition of the EEG-based biometric via a two-factor model based on brain response. Our results from the scenario-based experimental tasks indicated that, despite the higher response time, familiarity recognition would be more beneficial from other perspectives for autonomous vehicle use.

The greatest challenge for user authentication within AVs is to find a balance between accuracy and reaction time, decision accuracy, and stress/cognitive load, due in part to the introduction of biometrics. This study is a first step in that direction. Experimental simulator-based results were used to evaluate the usability of biometrics in the intended environment. Our results for these biometrics could provide manufacturers with the ability to solve some of the noticeable human problems.

7.1. Summary of Key Findings

The complexity of Biometric Authentication Systems (BAS) for autonomous vehicles has been widely reported. The consensus is that BAS are not yet able to replace traditional user credential knowledge-based systems due to several safety and security challenges. Although some work has attempted to identify problems with user credential systems and other BAS, there is comparatively little work on the usability of BAS for the authentication of autonomous vehicle drivers. In particular, there is a critical gap in the literature in terms of empirical studies such as those reported in this paper.

In order to address the identified research challenges, the study involved carrying out a study with 13 evaluators to evaluate the usability of biometric modality authentication systems for autonomous vehicles using usability formative evaluation. The research findings suggest that the use of voice recognition does indeed improve the usability of authentication compared to facial and FSR (Fingerprint-Sweep-Rfid). The results highlight both the opportunity and the

need to carry out much more detailed work for the inclusion of voice recognition in the emerging discussions and proposals of the use of biometric authentication systems in autonomous vehicles. In addition, the study also shows that significant and valuable insights can be derived from a usability evaluation of such biometric authentication systems.

7.2. Implications for Future Research

Given existing contradictory user attitudes on related location-based tracking, how do we articulate to users the tradeoffs between efficiency/convenience through seamless biometric authentication and security/privacy? Can an elegant system of asking to extend/modify biometric authentication controls in new dynamic contexts be agreed upon? What communication methods can be used to reveal or further hide the presence of biometric authentication in use in the context of sensitive, safety-systems? Fashion and physical modifications may be necessary, but what infrastructure can/should be put in place for either user education of these expectations, A/B testing to identify user preferences and changes to this biometric function? How do we design accessible, unassailable physical and technical safeguards accessing the considerable, well-documented existent privacy/security issues with biometrics? This work has implications for companies Dogfooding and employing biometrics to develop an empathetic, understanding approach to end-user biometric use in new, uncharted domains.

The unique context of AVs presents unaddressed challenges and offers a context ripe for HCI innovation. Employing qualitative inductive research methods may be a fruitful approach to better capturing critical usability considerations with biometric authentication, as such closed-system anomaly detection methods become increasingly employed in AV contexts. Our usability issues challenge the implicit value placed on user "invisibility" which assumes that biometrics successfully authenticate the correct user without privacy violations or endangers users through increased physical/virtual harm. Closer consideration needs be given to the fallibility of biometric authentication given changes in user context. This presents an opportunity to thoughtfully explore within-vehicle system interactions further and how to manage them whilst remaining secure. We may apply lessons learned from the privacy paradox(es) being revealed in users' shifting privacy practices around mobile technologies– that user need for control and comfort within transient environments exceed explicit messages about the importance of protecting personal privacy.

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