A novel Usability Framework for Electric Vehicles

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1 INTRODUCTION

Electric vehicles (EVs) have emerged as a promising solution to the challenges posed by fossil fuel-based transportation systems. However, the adoption of EVs has been slower than expected, and one of the reasons for this is the user experience. Based on the McKinsey EV Consumer Survey 2016 and 2019, there is a 24% increase (from 29% in 2016 to 36% in 2019) in consideration of EVs among consumers over the three-years in the United States, although the conversion remains low in single digits [1,2,3]. This indicates that despite the perceived benefits of EVs, the perceived concerns still outweigh them and that there are usability factors that need to be addressed to improve the user experience of EVs and increase their adoption.

Studies suggest that the factors affecting the usability and user experience of electric vehicles are complex and multifaceted [4,5]. Factors such as battery range, charging infrastructure, driving behavior, and in-car user experience can impact the adoption of EVs. Furthermore, the psychological and cognitive factors, such as trust, satisfaction, and comfort, play a crucial role in influencing users' decision-making process. These factors can affect users' perception of the usability and user experience of EVs [5,6].

On the other hand, traditional non-electric cars have been around for over a century and have gone through several iterations of design and engineering, resulting in a refined and comfortable driving experience. Features such as comfortable seats, a well-designed dashboard, and intuitive controls contribute to the user experience of traditional cars.

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The difference in user experience between traditional non-electric cars and EVs highlights the need to develop a comprehensive Heuristic Usability Framework for EVs. This framework should consider the unique characteristics of EVs and address the usability factors that affect the user experience of EVs. By developing such a framework, we aim to improve the user experience of EVs, making them more attractive to potential users and increasing their adoption.

This paper contributes the following to the electric vehicles research:

(1) The paper presents a user survey to understand the factors affecting users' decision to choose traditional non-electric cars over EVs, providing insights into the usability factors that need to be addressed.
(2) Formulates a comprehensive "Heuristic Usability Framework" for Electrical Vehicles, which can be used by researchers, industry professionals, and other stakeholders to evaluate the user experience of existing EVs and establish an industry standard for the design and engineering of future EVs.
(3) Demonstrates how stakeholders can utilize the proposed framework to evaluate and improve the user experience of existing and future EVs.
(4) The paper aims to contribute to the transition towards a sustainable transportation system by improving the user experience and increasing the adoption of EVs.
(5) This paper proposes a valuable tool for designers, engineers, and usability experts to test and evaluate the usability of EVs, improving their overall design and user experience.

1.1 Significance and Broader Impact

The significance of the proposed research lies in the fact that the usability of electric vehicles is a critical factor affecting their adoption and widespread use. Electric vehicles present unique usability challenges that need to be addressed to enhance the user experience and increase adoption. Currently, there is no standardized approach to evaluating the usability of EVs, and this lack of standardization can hinder the adoption of these vehicles. The proposed research aims to address this gap by formulating a comprehensive "Heuristic Usability Framework" that can be used to evaluate the usability of EVs. This framework will help designers, engineers, and usability experts to test and evaluate the usability of EVs, improving their overall design and user experience. Moreover, the proposed framework will be a valuable tool for the industry, academia, and other stakeholders involved in the development and testing of electric vehicles.

The broader impact of this research is that it can contribute to the transition towards a sustainable transportation system by increasing the adoption of electric vehicles. By addressing the usability challenges associated with electric vehicles, this research can make electric vehicles more attractive to potential users and contribute to the growth of this market. This, in turn, can reduce dependence on fossil fuels and help in mitigating climate change.

As an example, the current trend towards electric vehicles in the automotive industry highlights the significance of our work. Many countries and regions are implementing policies to incentivize the adoption of EVs, such as subsidies and tax breaks, to reduce carbon emissions and air pollution. However, despite the benefits of electric vehicles, such as lower emissions and fuel costs, the adoption rate is still relatively low due to various usability challenges, including range anxiety, charging infrastructure, and unfamiliarity with the technology. The proposed framework can help to address these challenges and provide the consumer with confidence in their purchase decision, leading to increased adoption of electric vehicles.

Overall, the proposed framework can help significantly to improve the user experience of existing and future electric vehicles, leading to an increased adoption of electric vehicles, which is crucial for achieving a sustainable future for transportation.

2 RELATED WORKS

2.1 Usability in Electric Vehicles

Usability is essential when creating interfaces for automobiles, particularly for electric vehicles. Usability testing can assess the effectiveness of features in navigation systems, which now include real-time traffic updates and routing to nearby charging stations. The importance of battery management system and charging station usability has also been emphasized. To improve the user experience, electric vehicle makers and charging station suppliers should focus on building intuitive and user-friendly systems. A recent study found that charging station instructions and user interfaces significantly affected the utility of range estimation devices for electric car drivers. To deliver a seamless driving experience, navigation systems must provide accurate and relevant information to drivers. A usability testing framework for electric vehicles is needed to evaluate these components [1, 2, 24].

2.2 Safety and distractions

Vehicle safety features such as ESC, automatic collision avoidance, and lane departure warning are critical. Automatic collision avoidance systems employ sensors and cameras to recognize objects and apply brakes if a collision is near, whereas ESC detects and decreases skidding. Lane departure warning systems notify drivers when their vehicle begins to drift out of its lane, assisting in the prevention of accidents caused by driver distraction or drowsiness. A study identified visual, cognitive, tactile, and aural distractions from car screens. Bright colors, complex interfaces, and manual or aural distractions can distract drivers. To ensure safety, designers must address these issues while building car screens. [10] The safety of electric and hybrid vehicles was evaluated through collision warning system testing and crash tests. Electric vehicles performed well and had sufficient safety features. Future research may lead to further safety improvements. [11,12]. The study investigated the safety benefits of vehicle-to-vehicle communication systems and the risks associated with high-voltage electrical systems in electric and hybrid vehicles. Sharing information can prevent collisions, while high-voltage electrical systems pose electrocution risks. More research is needed in both areas to improve safety[11,13].

2.3 User Experience and Interface

Two distinct studies were carried out to investigate various areas of driving technology. The first study concentrated on the use of automated experience sampling techniques for gathering data on driver behavior and preferences. The study gave special attention to the design of the user interface as well as the data collection methods used. The second study looked at how augmented reality displays could improve driver safety by delivering real-time information about road risks and obstructions[12,14]. Some of the studies focus on different aspects of electric vehicle user experience: driving distance, range displays, and user interfaces. The studies emphasize the importance of considering user feedback in the design of electric car technology[15,16]. The article discusses two studies on in-car technology user experience and interface design. One study found that multi-finger interaction on touch screens improved user satisfaction. The other study highlighted the importance of user-centered development for electric cars as mobile devices. Both studies emphasize the need for user-focused design to improve user experience and adoption of in-car technology[13,17].

2.4 Connectivity

The study looked into the feasibility of over-the-air (OTA) upgrades, which allow for remote software upgrades and feature additions, which prolong the lifespan of the vehicle and improve the customer experience[13]. The project studied V2G methods that allow electric vehicles to supply energy back to the grid, giving benefits to both the user and the utility provider[18]. The research examined how infotainment technologies in electric vehicles, such as touchscreens and mobile device integration, can provide drivers with entertainment, communication, and navigation services. It also looked into the impact of mobile applications that enable drivers to control and check their electric vehicles, such as tracking battery levels and charging to the maximum capacity of the car.

2.5 Usability Evaluation Methods

2.5.1 Questionnaires and Surveys. Surveys and questionnaires were used in this study to collect customer input on several aspects of the electric vehicle experience, such as range anxiety, charging infrastructure, and driving dynamics. The obtained data can be used to identify areas for improvement and to lead the development of electric vehicle technology that meets the demands and expectations of consumers[25].

2.5.2 User testings and Prototype Testing. The study conducted comprehensive user testing to examine the intelligent in-car system and AR head-up displays. The evaluation of AR HUDs, including their impact on driving performance, safety, and usability, was a crucial aspect of the research. Additionally, the validation of results through further user testing ensured the study's outputs' validity. Prototype testing of the intelligent in-car system provided critical insights on its accessibility, engagement, and satisfaction. However, the study's small sample size and lack of diversity may limit the generalization of its findings. Future studies should address these limitations to improve the accuracy and predictive ability of the conclusions[20,21].

2.5.3 Heuristics and Expert Evaluations. To assess the efficiency of the assessment framework, the study used expert evaluation approaches such as heuristic evaluations and usability testing. The researchers contrasted heuristic evaluation approaches with the MALTU model for assessing the usability of ubiquitous systems, highlighting their different strengths and drawbacks[22]. Furthermore, expert evaluation methodologies were used in to examine the usability of non-visual controls, such as cognitive walk-through[23, 24].

2.6 Other Perspectives

When building human-machine interfaces, the study's primary focus was on the user's perspective (HMI). Understanding the demands and opinions of both taxi drivers and passengers was required. In addition, the study looked into customers' perspectives of the societal benefits and drawbacks of electric automobiles. They included concerns about infrastructures and societal standards, as well as reduced dependency on oil, which might lead to greater public health[26,27]. These studies looked at users' opinions of the economic benefits and drawbacks of electric vehicles, such as lower gasoline prices but also concerns about upfront expenses and range limits. The study also investigated economic impediments to electric car adoption, such as upfront costs and range constraints. According to the research, while many consumers appreciate the potential cost savings associated with electric vehicles, worries about upfront costs and range limits continue to be significant hurdles to wider adoption[26,28].

3 PROBLEM STATEMENT

3.1 Research Question(s)

The use of Electrical Vehicles (EVs) has been growing in recent years, driven by the need to transition to sustainable transportation systems. Despite the increasing demand for EVs, there are still usability challenges that need to be addressed to enhance the in-car user experience and increase adoption[1,2]. As mentioned in the "Related Work" section, different research works to address different aspects of the devices like ubiquitous devices or mobile computing or electric vehicles but there is a need to develop a dedicated novel Heuristic Framework that just focuses on the complete experience of electric vehicles. So that by using that framework, engineers, designers and industry experts can use that framework to test the usability of experience of EVs and thus they can improve the experience which can lead to more increase the more trust and adaption to EVs. And that's why, this study aims to answer the following research question: *What are the key usability factors that need to be considered in developing a comprehensive Usability Framework for Electrical Vehicles, and how can this framework be designed to enhance the in-car user experience and increase the adoption of Electric Vehicles?*

To answer this research question, the study will first identify the key usability factors that are essential for developing a comprehensive Usability Framework for Electrical Vehicles. The key usability factors that are important to consider include controls, displays, infotainment systems, charging, climate control, etc[29]. Once the key usability factors have been identified, the study will develop a comprehensive Usability Framework for Electrical Vehicles that addresses these factors.

3.2 Hypothesis or Expected Outcomes

The hypothesis for this study is that developing a comprehensive *"Heuristic Usability Framework"* for Electrical Vehicles will improve the usability and in-car user experience of Electric Vehicles, leading to increased adoption of these vehicles. The rationale for this hypothesis is that EVs present unique usability challenges that need to be addressed to enhance the user experience and increase adoption. Currently, there very few standardized approach to evaluating the usability of EVs, and this lack of standardization can hinder the adoption of these vehicles. By developing a comprehensive Usability Framework that addresses the key usability factors, the study expects to improve the usability and user experience of EVs, making them more attractive and adaptive to potential users. Furthermore, the study expects that the Usability Framework will be widely accepted and used by the industry, academia, and other stakeholders involved in the development and testing of Electrical Vehicles. This widespread adoption will further improve the usability and user experience of EVs, contributing to the growth of this market and the transition to a sustainable transportation system.

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