Good Practices for Designing a UI/UX Motorcycle Display: A Systematic Literature Review

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Abstract: - Within the scope of the Mobilizing Agenda for the Development of Intelligent Green Mobility Products and Systems (A-MoVeR), specifically in the second PPS2 defined the presentation of a "new electric motorcycle, with high autonomy, aimed at promoting comfortable, efficient and green urban mobility". In this context, we intend to develop user interfaces (UI) for an electric motorcycle that meet the end-user's expectations by promoting optimal user experience and security. To achieve this goal, this paper provides a preliminary literature analysis, with a compilation of literature related to major aspects for developing an optimized User Interface (UI) and consequently increasing User eXperience (UX), specifying accessibility, adaptability, appeal, and conciseness of motorcycle interfaces in an attempt to determine its constructive qualities. Therefore, it was analyzed studies regarding filtering of displayed information; the controlling of a user's focus and emotions through means of efficient visual representations; the differences in various types of input methods regarding user attention; and, the relevance of dynamic UI as a solution to a variety of problems related to UI/UX design. Therefore, a systematic literature review was performed, which resulted in the finding of various advantageous practices and ideas that are relevant to the design of a motorcycle's UI/UX.

Key-Words: - UI design, UX design, Motorcycle, usability, accessibility**,** Vehicles.

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1 Introduction

The Mobilizing Agenda for the Development of Intelligent Green Mobility Products and Systems (A-MoVeR), presents the creation of 3 PPS (Products - Processes - Services) that must be totally innovative, namely: (1) the Intelligent Antenna Vehicle- to Everything for communication between vehicles and other mobility actors, via modular solutions for 5G; (2) a new electric motorcycle, with high autonomy, aimed at promoting comfortable, efficient and green urban mobility; and (3) secure real-time information collection/management services, which will increase added value for the region's automotive cluster, taking into account the concepts of Smart Manufacturing and advanced manufacturing processes in a "factory of the future" logic to implement.

In this context and focusing on the second PPS, the creation of an electric motorcycle, a team was created, called FRONT-END Displays.

Within this teamwork, two solutions for technological development were defined: (1) a mobile application, being used as a motorcycle display, and integrating information and user interface for viewing functionalities available during motorcycle operation; (2) a mobile application (myFULGORA), for a smartphone, to be used by the operator/owner of the motorcycle, which must include functionalities for configuration, management, and maintenance of the motorcycle.

Recognizing that the optimization of a UI design is done through t a User-Centered Design (DCU) methodology, and that co-design improves interaction and collaboration between the parties, developers, and end users; this work team adopted methodologies, methods, and techniques for the entire development of User Interfaces (UI), as the general objective is to develop user interfaces for electric motorcycles, which meet the end-user expectations, and promoting user experience and security.

Therefore, the first step towards the development of these solutions, from a DCU, co-design, and User Experience (UX) perspective, is to analyze the literature through an extensive systematic literature review.

Overall, with the increasing adoption of more complex User Interfaces (UIs) for a variety of everyday machines to accommodate the increased number of functionalities provided by these

machines, the importance of UI/UX design has likewise increased. The topic is very complex, as there are a lot of aspects to UI/UX design, many of which require an in-depth analysis to be understood and implemented properly. Despite this, during the execution of this study, it was found to be quite difficult to find scientific studies that analyze the diverse aspects of UIs/UXs in general, with most of the found articles focusing on UIs/UXs of specific applications or in an otherwise limiting context. This article intends to help fill this gap of generalized UI/UX studies by compiling various sources that relate to various aspects of their design.
While this study will mainly contain information regarding general practices and problems faced when designing UI/UX, it will adapt this information to better fit in the context of vehicles, specifically motorcycles, and contain fsources that are only relevant in the context of vehicle UI/UX design, specifically.

The structure of this document is composed of an introduction to the methodology that guided its creation, followed by a detailed explanation of how the various steps of this methodology were performed, after which the results of said methodology are presented. The article then presents a discussion and analysis of the obtained results, ending with a brief conclusion and a list of the used references.

2 Research Methodology

A systematic literature review (SLR) is a method of compiling, identifying, and analyzing various scientific research relating to a particular topic, [1].
The method of SLR used in this review was based on the approach presented in [1], which entails a structured research methodology. This review is composed of the following phases: (1) Definition of research questions, in which the questions this article aims to answer are defined; (2) Search strategy, in which the methods used to collect articles that may be relevant to this article are explained; (3) Inclusion and exclusion criteria, where a set of criteria used to filter the collected articles to ensure their relevance to the topic of the research is presented; (4) Data extraction, where select information we want to extract from the article is shown; (5) Document Selection, where the process of document selection and filtering is detailed. The online tool Parsif.al (Parsifal) was used to execute Kitchenham's approach.

2.1 Research Questions (RQ)

For that, two research general questions were defined:

•RQ1: What are some of the important aspects to consider when designing a vehicle UI/UX?

•RQ2: What can be done to ensure the quality of a UI/UX relative to these aspects?

It does not intend to delve deeply into specific topics of UI/UX design but rather intends to compile and give a brief synthesis of various aspects of said design, the use of these rather generalized questions was considered ideal.

2.2 Search Strategy

Regarding the search strategy, the initial selection of articles proceeded as follows:

To collect articles to be considered for this research, three digital libraries were used:

•ACM Digital library, [2]

•ScienceDirect, [3]

•Scopus, [4]

These libraries were selected because they provided a vast amount of peer-reviewed articles and tools that made it easy to extract relevant data from said articles.

Furthermore, the following search strings were used on ACM Digital library and Scopus:

• ("Car" OR "Motorcycle" OR "Vehicles" OR "Websites") AND ("UI" OR "User Interface" OR "digitalUI" OR "digital User Interface") AND ("Accessible" OR "Common practices")

• ("How to develop a" OR "What to consider when developing a" OR "Developing a clean") AND "UI" AND "digital" AND ("UI" OR "User Interface")

• "User" AND "Interface" AND "Vehicle"

And the following search strings were used on ScienceDirect:

• ("How to develop a" OR "What to consider when developing a" OR "Developing a clean") AND "UI" AND "digital" AND ("UI" OR "User Interface")

• ("Car" OR "Motorcycle") AND ("UI" OR "User Interface" OR "digital UI" OR "digital User Interface") AND ("Accessible" OR "Common practices")

• "User" AND "Interface" AND "Vehicle"

2.3 Inclusion and Exclusion Criteria

The following inclusion and exclusion criteria were used to filter the initially selected articles:

Inclusion criteria:

•Studies focus on UI/UX design, interface-related related-tecnhology and motorcycle security.

•Peer review articles.

•Systematic review articles.

•Studies published between 2014-2024

The first inclusion criterion was selected to guarantee that the analyzed articles are relevant to this SLR.

The second and third inclusion criteria were selected to ensure the legitimacy of the analyzed articles.

The relevance of the fourth criterion is explained later in this article.

Exclusion criteria:

•Presented information irrelevant to motorcycle UI/UX design.

•No access to the full paper version.

•Differ from English, Portuguese, or German language.

The first exclusion criterion was selected to ascertain that the information exposed in the selected articles would be in some way relevant to motorcycle UI/UX design.

The second and third exclusion criteria were selected to guarantee that the selected articles were readable by the researcher (without relying on tools such as digital translators, which could produce incorrect results) by ensuring they were written in a language they understood (English, Portuguese or German) and accessible to them through their institution, the university UTAD.

2.4 Data Extraction

The following questions were settled on to identify the filtered articles:

Data extraction question (DEQ) 1:

Which of these options is it most related to?

• Accessible UI/UX design (UI/UX design that can be effectively and efficiently used by people suffering from limiting physical or mental conditions)

• Adaptable UI/UX design (UI/UX design whose parts can be altered to better fit its users' needs and wishes)

• Appealing UI/UX design (UI/UX that is appealing to its intended users)

• Concise UI/UX design (UI/UX design that is organized to provide fast access to the functionalities that are currently relevant to its user)

DEQ 2:

Which demographic is it most relevant to?

• Older adults

• People with hearing disabilities

• People with mental disabilities or developmental disorders

• People with visual impairments

• None of the listed demographics

2.5 Document Selection

Using the search strings on the digital libraries, 631 studies from ACM Digital Library, 491 studies from ScienceDirect, and 411 studies from Scopus were selected (Figure 1).

Post-filtering using the inclusion and exclusion criteria there remained 46 studies from ACM Digital Library, 40 studies from ScienceDirect and 15 studies from Scopus. The main problem that led to selected studies being filtered out was their irrelevance to motorcycle UI/UX.

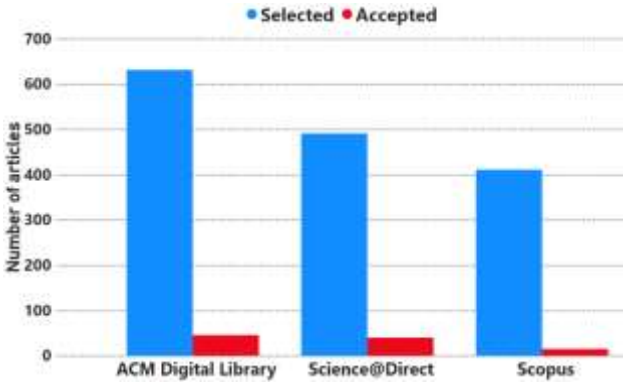

Fig. 1: Number of accepted and selected articles per digital library

Evaluating each of the 101 filtered studies using a set of quality assessments that assigned each article a score between 0 and 4 based on said articles' relevance to the study and discarding the articles whose score was lower than 2.5, 33 articles remained.

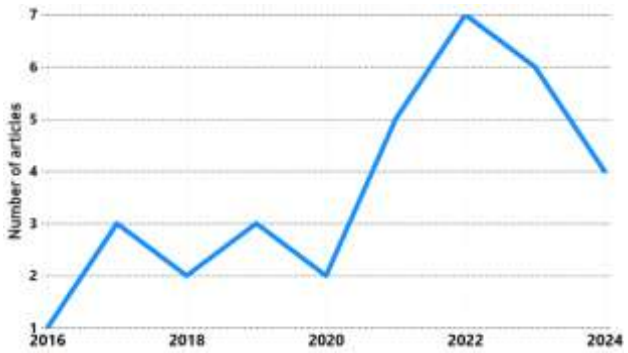

Fig. 2: Publication year distribution of accepted articles

Of these 33 selected articles, the oldest one stems from 2016, with a majority of the sources being from 2022 (Figure 2). This distribution in publication time is expected considering one of the quality assessments was dependent on the article's age, a choice made because of the rapid rate at which the digital landscape, and consequently the area of UI/UX design, is evolving, which renders older articles potentially obsolete due to the possibility of these articles relying on information that has been rendered irrelevant or made incorrect by advancements in technology to justify their conclusions. (An article may exclude certain possibilities due to technical restrictions that were relevant when the article was written, but no longer apply because of more recent technological advancements, for example.)

These articles' origin varies greatly, including Australia, China, the UK, France, and Brazil, showing that this topic is of interest to many parts of the world.

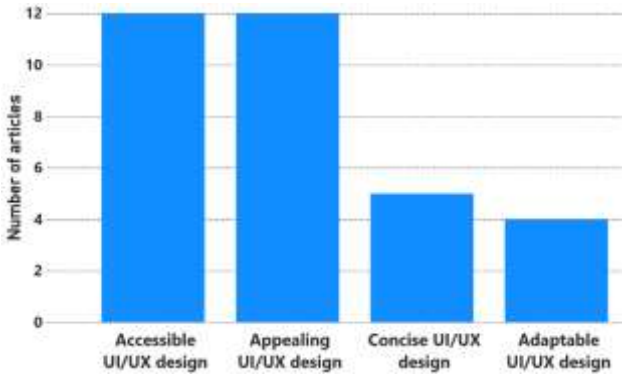

Fig. 3: Data extraction question 1 (DEQ 1) results

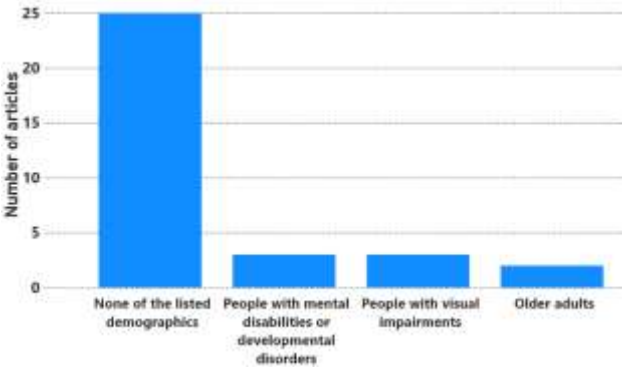

Fig. 4: Data extraction question 2 (DEQ 2) results

As can be seen, most of the articles were related to either appealing UI/UX design or accessible UI/UX design (Figure 3) and didn't target any of the listed demographics (Figure 4).

Only two of the analyzed studies were specifically related to private vehicles, being [5] and [6]. However, all the studies provided some information that could be applied to motorcycles.

3 Results

The analyzed studies revealed important aspects of graphical UI/UX design for motorcycles demonstrating, for example, the varying effectiveness of control methods in regard to the execution of commonly performed vehicle tasks, where it has been determined that, for basic tasks, the use of knob and button or steering wheel button controls results in less time spent observing the UI, while these same control methods resulted in more fixation counts when used for more complex tasks. Regarding medium tasks, voice control was found to be the most suitable, while combining touchscreen controls with voice controls was overall found to be the best method to tackle advanced tasks, [7]. Concerning the aforementioned touchscreen

controls, implementing tactile feedback for the users' inputs can be beneficial to user experience and performance, [8]. [9], analyzed the use of gestures performed by the driver as input methods but found that in that context drivers tend to prefer voice inputs over gestures. The importance of feedback resulting from user inputs in UX was also stated, [7], [10]. Many of these studies based their criteria for accessibility on the W3C (World Wide Web Consortium), which provides a variety of standards and rules to create accessible UIs for websites, of which many can be applied to designing user interfaces for motorcycle UI, [11], [12].

Reference [5] presented an interesting approach to personalization of a UI/UX based on data collected by that same UI, suggesting the use of neural networks to analyze user patterns and alter the UI accordingly.

It is not feasible to design a single UI that appeals equally to everyone, as many factors, such as a user's personality, can lead to a sizeable difference between what attributes two different users consider to be more attractive. User preferences are often contradicting, and as such cannot be simultaneously incorporated into the same interface, [13]. Personalization and customization, if implemented correctly, can help minimize these conflicts, [14].

An important aspect that is relevant mainly to vehicles is that of possible accidents relating to fatigue or other negative mental effects. A vehicle can help in reducing the possibility of these accidents through the implementation of a fatigue detection system, which, UI-wise, should consider the way warnings related to driver fatigue are presented to the driver, [15]. The UI adaptive capabilities can also serve to minimize fatigue [14], as a UI could be designed to detect the user's current mental state and emotions and to adapt itself accordingly and automatically [16] in an attempt to counterbalance possible negative mental effects the user may be experiencing. Another approach to minimizing driver fatigue is that of allowing the UI to aid the driver in deciding when to take a break, making recommendations based on the driver's perceived current state, and possibly also considering the driver's previous behavior to suggest a break location that would be of value to them, enhancing UX. [17], found success in implementing such a system, with prototype users providing mainly positive feedback.

Audio cues can be used to complement the physical aspects of a UI by allowing information to be communicated to the user without requiring them to avert their gaze from their current task. Ideally, the user should not be able to clearly identify the source of these cues (a speaker, for example) as this implementation of audio cues is not recommended for situations where users must react swiftly to incoming stimuli, [18].

When designing a UI for a machine, designers must consider that not all the information gathered by said machine holds the same relevance to the user, and consequently, information must be filtered according to its relevance to the current task and ordered, taking into account its relevance in relation to the amount of effort and time it takes to access it [19], as exposing the user to too much information at once can lead to a clouding of their decision making [20], which can have catastrophic consequences in the context of driving, as not providing the user with access to sufficient information at once can lead to them spending more time searching the UI for said information, also causing safety risks and creating a worse UX. Of course, different drivers will have different opinions regarding which elements of a UI are relevant and should be displayed, however, certain UI elements tend to be favored over others [21], which could imply they should be given special attention.

The concept of visual cues is another important aspect of UI design, as designing UI visual components, such as icons, to invoke a certain feeling, can lead to the reduction of driver stress and help designers lead the driver gaze to the areas of the UI considered to be more important. One way to achieve this is to embed relevant regional cues in the UI, [22]. When using icons it is also important to remember that they should always be accompanied by text stating what they represent, as just using the icon can potentially lead to confusion, [23].

A demographic that was often the subject of study was people with Autistic Spectrum Disorders (ASD), as their disorder leads to a very different way of perceiving the world around them, which should be considered when designing accessible UIs, [6]. To this end, various rules should be followed when designing UIs, such as adding static and simple supporting images to text and ensuring the UI design is consistent and follows clear patterns, [24].

While it is important to try to make a UI as accessible as possible, many times it is easier to develop different versions of the same UI that can be selected by the user depending on their needs, [6]. This customizability should not be limited to selecting a UI that is more accessible to a user with a preexisting condition, but also consider elements

such as the current brightness to ensure a good UX, [25].

A useful tool in the development of UIs is a pattern language that ensures the desired qualities of the UI, as it can serve as a guide when making design decisions and lead to better coordination during development, [26]. When developing a UI, user feedback is of utmost importance, as it allows the UI to continuously adapt to the expectations and needs of its future users, which allows us to not only develop a good UI but also to simultaneously develop a pattern that can be applied to future versions of the same interface or to interfaces of similar applications, [27].

Reference [28] provides an in-depth look at the distinct characteristics of UI and UX design, and how important UX design is when designing a UI, despite UX's rather abstract definition. It also provides a detailed analysis of three key aspects of a UI, those being color, typeface, and animation, highlighting how a user's reaction to a specific color doesn't vary much between users, how different typefaces can lead to more or less deviation in how different users respond to them and how animation can mimic real-life movements or gestures in order to achieve desired user reactions.

Diving deeper into the importance of color, it plays a key role in UI design and is a very versatile tool. Color can be used to group information [29], for example, which can be applied to a UI to facilitate navigation. The brightness of the used colors should also be considered, as brighter colors tend to attract more attention [30] and as such can be used to emphasize the most important parts of the UI.

The text composition used in a UI requires careful consideration as well, not only regarding font size but also the complexity of the phrases used, as many people have difficulties processing large amounts of information. When selecting the words to use in a UI, it is essential to remember the vital role culture plays in UI design [28], which extends to the selection of words used, [14]. The simplification of phrases can be done retroactively using external tools [31] but adapting these phrases to different cultures requires a more complex approach. The concepts of culture and language are closely related, as such, designing a UI around multiple languages can help bridge the gap between people from different cultures. However, determining how these multiple languages coexist in the UI requires some consideration, [32]. It should also be remembered that concepts that may seem trivial to the designer could be completely foreign to members of their target demographic, due to a variety of factors, including a disparity of relevant knowledge, [14], [33].

Another aspect UI has an impact on is that of user trust. With the evolution of technology and the development of new complex tools that help drivers perform necessary tasks more efficiently and safely, ensuring the drivers trust these tools they likely don't fully understand is important, and a UI can help in achieving this by providing the user with insight as to what the vehicle is doing automatically and why. This raises the question of how this insight should be passed onto the driver to ensure higher trust in the vehicle, with [34] showing that, at least regarding certain information (related to partial maneuver automation and the vehicle's surroundings), keeping the driver informed through a mixture of audio and visual cues is an effective approach. Personalization and adaptation also play a role in a user's connection to and consequent trust in a system, as suggested by [35].

Reference [36] delved into the possibility of using UI to encourage eco-friendly driving, drawing attention to a UI's role in helping the driver monitor their performance regarding this aspect. This article found that many drivers desire their vehicle to assist them in monitoring their driving, mainly to help them save fuel/energy and reduce maintenance costs, but also to enhance safety. The article also highlights that, for such a monitoring system to work, drivers must trust it, so that they may also trust its feedback and use it to adjust their driving. As to how this kind of monitoring system could pass its information onto the driver, [37] presents a variety of display methods that could be adapted and applied to a vehicle's UI, focusing on displaying information related to eco-friendly driving.

4 Discussion

In this section, the previously presented research questions (RQ) are answered using the results obtained from the analysis of the selected papers.

4.1 Research Question 1 (RQ1): What are Some of the Important Aspects to Consider when Designing a Vehicle UI/UX?

The overview of the studies led to the following conclusions:

• The colors used in the UI can evoke powerful user reactions, guide a user's gaze, and organize information. As such, they should be carefully considered.

• The text/words used in a UI need to be accessible to people of different backgrounds and cultures.

• User trust is an important metric for UIs, and should be treated as such.

• A UIs adaptive capability and a customer's capability of customizing said UI can be used in tandem to solve many problems relating to accessibility and appealing design, but a designer should not rely exclusively on these factors when designing a UX/UI

• Driver fatigue and distraction can lead to dangerous situations when driving, but a UI can help in reducing these conditions.

• Different input methods have varying advantages and disadvantages.

4.2 Research Question 2 (RQ2): What can be done to ensure the quality of a UI/UX relative to these aspects?

The overview of the studies led to the following conclusions:

• The main input methods of a vehicle are touchscreen, physical buttons (ideally located on or close to the vehicle's main control interface, be it a steering wheel or handlebars), and voice commands. These input methods should be selected (in tandem or by themselves) depending on the task being performed in order to maximize performance.

• UIs should make use of visual and auditory queues to provide feedback, both to alert the driver when they are distracted or tired and to ensure fluid navigation of the UI.

•UIs should provide a level of transparency to the user regarding the automated decisions the vehicle is making, as this increases a user's trust in the vehicle.

• Embedding regional cues in parts of the UI (icons, for example) helps to better direct the user's attention and consequently smoothen navigation.

• Neural network technology can be used to help ensure a UIs adaptability.

5 Conclusion

Designing a UI/UX is a highly complex and difficult process, that considers a variety of aspects of the target demographic. A good UI ensures a good UX not only by presenting a pleasant and concise design but also by making use of a multitude of subconscious associations users tend to possess to allow them to navigate the UI effectively and by providing adequate and efficient adaptation and customization possibilities. To make effective use of these tools, a UI designer needs to map out a variety of possible user journeys and ensure that during each step of those journeys, the UI provides sufficient information and a good UX and is accessible to a variety of users, some of which differ from physical or cognitive abilities.

While there exist an immense number of contexts in which a UI is used, the previously mentioned core principles of UI design remain relevant across all of them, including motorcycles.

Many of the articles selected for this study weren't directly related to motorcycles and had to be adapted to suit this context. Effort was put into ensuring this adaptation was done efficiently, however, it is possible that relevant information was lost during this process or that emphasis was put on topics that did not warrant it.

Having gathered this information, a possible next step in regard to future research would be to apply it to a motorcycle's UI, present said UI to a select target group, and gather feedback from said group, which could then be used to further deepen knowledge of UIs and UX.

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- Miguel Lehmann conducted the investigation for this paper, wrote its original draft and subsequent revisions and was responsible for visualization.
- Tânia Rocha, João Barroso was responsible for the conceptualization of this paper and selection of the methodology used in its creation.
- Tânia Rocha, Ricardo Nunes were responsible for the supervision of this papers development.

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