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Huizilopoztli Luna-García, Hamurabi Gamboa-Rosales, José M. Celaya-Padilla, Carlos E. Galván-Tejada, F.E. López-Monteagudo, Ricardo Mendoza-González, Cesar A. Collazos, Alfredo Mendoza-González

# FRONT-END DESIGN GUIDELINES FOR INFOTAINMENT SYSTEMS

Huizilopoztli Luna-García[1], Hamurabi Gamboa-Rosales[2], José M. Celaya-Padilla[3], Carlos E. Galván-Tejada[4], F.E. López-Monteagudo[5], Ricardo Mendoza-González[6], Cesar A. Collazos[7], Alfredo Mendoza-González[8]

[1,2,4,5]Universidad Autónoma de Zacatecas, Centro de Investigación e Innovación Automotriz de México (CIIAM), Profesor Investigador, Jardín Juárez 147, Centro Histórico, Zacatecas, México, 98000, +52(492) 9222001, hlugar@uaz.edu.mx
[3]CONACyT-Universidad Autónoma de Zacatecas, Centro de Investigación e Innovación Automotriz de México (CIIAM), Profesor Investigador, Jardín Juárez 147, Centro Histórico, Zacatecas, México, 98000, +52(492) 9222001
[6]Instituto Tecnológico de Aguascalientes, Depto. de Sistemas y Computación, Profesor Investigador, Av. Adolfo López Mateos 1801, Ote. Fracc. Bonagens, 20256, Aguascalientes, Ags. México, +52(449) 9105002 ext. 157.
[7]Universidad del Cauca, Facultad de Ingeniería Electrónica y Telecomunicaciones, Calle 5 No. 4-70, Popayán, Cauca, Colombia, +57(2) 8209900.
[8]Instituto de Investigación, Desarrollo e Innovación en Tecnologías Interactivas, A.C. (IIDITI), Dirección de Investigación, Av. Moscatel 103, Aguascalientes, México, +52(449) 9724401

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**ABSTRACT:**
**This paper presents a set of front-end design guidelines intended to provide a starting point to designers of user interfaces for infotainment systems. The proposed approach suggests guidance on four dimensions inferred from state of the art such as crucial to achieve well designed automotive interfaces: a) Design; b) Interaction; c) Security; and d) Connectivity. Guidelines were thought by integrating conceptual-insights from Graphic Design; User Centered Design; Human-Machine Interfaces; Usability; and Human-Computer interaction. Additionally, were specified and structured to be used also as a comparing tool (Like Heuristic-Evaluation technique) to analyze front-end of existent infotainment systems. Said duality allowed to revise the pertinence of the proposal through a case study where 30 participants (25 regular users and 5 technical-experts) compared suggested guidelines' specification against interactions provided by the front–end of Mazda Connect© infotainment System. Obtained results suggested that setting of proposed guidelines was compatible with participants' perceptions facilitating to identify pain-points on current design; thus, proposed guidance could scaffold base-insights for new front-end designs.**

**Keywords: →Design guidelines, infotainment systems, automotive user interface, accessibility, usability.**

**RESUMEN:**
El artículo presenta un conjunto de guías de diseño para el front-end de sistemas infotainment con el fin de proveer un punto de partida para los diseñadores de interfaces de usuario de este tipo de sistemas. Las guías propuestas abarcan cuatro dimensiones inferidas del estado del arte como cruciales para lograr un buen diseño de interfaces automotrices: a)Diseño; b)Interacción; c)Seguridad; y d)Conectividad. Las guías se conformaron mediante la integración de ideas conceptuales provenientes de áreas como el Diseño Gráfico; Diseño Centrado en el Usuario; Interacción Humano-Máquina; Usabilidad; e Interacción Humano-Computadora. Asimismo, se estructuraron y especificaron de tal forma que pudieran ser utilizadas como herramienta de comparación (Similar a la técnica de Evaluación-Heurística) para analizar el front-end de sistemas infotainment existentes. Dicha dualidad permitió el análisis de la pertinencia de la propuesta mediante un caso de estudio en el que 30 participantes (25 usuarios regulares y 5 expertos técnicos) compararon las especificaciones sugeridas por las guías propuestas contra las interacciones del Mazda Connect© infotainment System. Los resultados obtenidos sugirieron que el contexto observado por las guías facilita la identificación de puntos de mejora en el front-end de sistemas infotainment existentes; y por ende, puede servir como estructura para ideas-base de nuevos diseños de interfaces de usuario para sistemas infotainment.

**Palabras Clave**: Guías de diseño, sistemas de información y entretenimiento, interfaces de usuario automotrices, accesibilidad, usabilidad.



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## 1.- INTRODUCTION

In recent years we have witnessed advances in the use of new technologies in the automotive industry. In 2007, for example, a new age in the development of automotive user interfaces started when the Ford Company announced the first *infotainment system* [1]. Since then, user interfaces for vehicles have been transformed into interfaces with increasing processing, storage, communication and interaction capabilities. As a result, a wide variety of both hardware and software technologies have been developed in the last decades. These technological advances have created a new communication environment and user experience between cars, drivers and passengers, allowing the development of applications with a wide range of interaction possibilities; consequently, new challenges in fields such as design, interaction, security, reliability, connectivity, quality and usability requirements have emerged. According to [2,3], graphical user interfaces must provide adequate information and interaction to drivers and passengers. Furthermore, users with different abilities, capabilities or special needs must be supported.

Today, intelligent vehicles or connected vehicles incorporate *applications* with dynamic features according to the context of use, offering advanced information and entertainment features for drivers and passengers. These applications are called *infotainment systems* [4] and their purpose is to allow the necessary functionality and communication–interaction between system, drivers and passengers. However, these systems increase the complexity in driver´s conduction has a main task. Drivers have now access to multiple functions (or gadgets) inside the car that inevitably increase the drivers' interaction with the user interface and decrease their focus on driving, which still is the primary task and should be the highest priority. It is important to consider aspects such as work load level «visual, auditory, physical and mental» while designing an infotainment system to prevent drivers from distracting [5]. In this way, infotainment systems play a very important role in the integration of the functionalities and services provided by the vehicle, as it is through its interface where drivers visualize, communicate and interact with the drivers and passengers. Sophisticated infotainment systems are common in new vehicles and the research community and the automotive industry have developed principles and best practices [6,7]; guidelines[8-15]; frameworks and standards [16] for the design/development of IVI Systems «In-Vehicle-Infotainment» considering proven aspects of achieved experience from academy [5], automotive industry [2] and companies such as Apple [17], Microsoft [18], Android [19] or the open source community [20]; likewise, new architectures [21], methods, techniques and processes [22,23] have been developed for the design and evaluation of this type of systems [24]. In the last decades several recommendations have been proposed for the development of infotainment systems; however, there are key aspects that still need to be standardized by the scientific community before commercializing the smart vehicle. That is, infotainment systems must be intuitive, useful and easy to use and must consider aspects such as Human Factors and Human-Machine Interface [3].

According to [1,25-27], smart vehicles will become an extremely important platform for Human-Computer Interaction. The current challenge for researchers and developers is to design easy to use interfaces with functional digital features and Quality of Services (QoS), while minimizing the potential risks associated with unfocused driving as well as ensuring user privacy and safety.

This paper proposes 17 design guidelines to provide a basic but reliable starting point for designers and developers on the interactions required to achieve well-designed interfaces for infotainment systems.

## 2. RELATED WORKS

Literature report several related works with the purpose to minimize the efforts in the development of user interfaces for vehicles, considering aspects as communication, interaction, feedback, visual data, among others. Several recommendations have been proposed including general guidelines [28] that include principles on safe and efficient IVI systems and best practices to incorporate mobile devices features into vehicles [6,7]; safety guidelines to alert designers of IVIs no legal, ergonomic or navigation issues [10,12-15]; ISO standards for safety vehicles [16]; recommendations for designing interfaces taking into account physical ergonomics information [29]; task rules that specifies maximum allowable task time for interaction-navigation system tasks performed while driving when using visual displays and manual controls or objects [13], or more specific aspects related with the design of infotainment systems, e.g., [30] have



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analyzed and compared the three most popular types of interaction used in a new vehicle (steering wheel gestures, on-board touches and voice recognition), with the purpose of recognizing usability, subjectivity, workload and emotional response; [21] built up a Human Machine Interface (HMI) system architecture to lower and medium class vehicles to give all cars drivers access to these features (infotainment systems) to increase the safety of all passengers and drivers, likewise, they identify the main challenge sections for a HMI «visibility, design, components and connectivity»; [25] present a design proposal using Head-Mounted Displays (HMD) as an alternative for visual improvement on Head-Down Displays (HDD) and Head-Up Displays (HUD) for the purpose of superimpose the digital content directly into the driving scenario and avoid as much distraction as possible; [23] conducted a study to identify user needs and technical preferences toward HMI of personal vehicles for possible technologies that can be applied to satisfy user needs for cockpits in 2020, they present two cockpits conceptual designs; [31] introduce the aspect of design space for automotive user interfaces that "provides an overview of input and output devices in cars with respect to their placement, which part of the body they interact with, which kind of feedback they provide and to which task-class they are assigned", among others.

According to the above, we can discern that the scientific community and automotive industry are eager to improve the performance of the elements that make a smart car. These contributions contemplate different aspects such as design, interaction, communication, security, among others. Nevertheless, there are still several aspects that the scientific community and automotive industry need to address. As such, it is necessary to reinforce and update the requirements, principles, best practices, guidelines and propose structured design guidelines according with the existing and future technological user interfaces for vehicles. According to key researchers: [22] user experience design for autonomous cars needs a more elaborated understanding of user interactions in order to address well-designed user interfaces; [31] there are few guidelines for designers during the design process; [23] there are still reliability issues, which lay in the function hierarchy; [3] it is necessary to consider older people's capabilities since they often have difficulty learning new technologies, particularly new displays, digital dashboards and instruments, and new interactions types. The 17 design guidelines proposed contribute in the design and development of useful and easy-to-use infotainment systems since they describe solutions with a formal structure for real problems identified by the research community and automotive industry.

## 3. PROPOSED DESIGN GUIDELINES

This study started with a literature review of over 100+ academic papers and automotive industry experiences. A total of 11 proposals directly related with the objective of this research were selected by considering the principles, criteria and verification procedures on driver interaction with HMI interfaces and, on safe and efficient in-vehicle information and communication systems [6,7]; guidelines to avoid driver´s distraction [9], guidelines for designing HMI systems considering: safety [10], in-vehicle display systems [12], accessibility [13] and, human factors design [14,8,15,29], and finally, were considered design patterns for development HMI interfaces [2] to provide adequate features according to usability, accessibility and user experience.

This non-exhaustive set of guidelines (see Figure 1) is intended to reduce common gaps and flaws in user interfaces design for infotainment systems by (implicitly) suggesting a coherent and effective User Centered Design Process [32,33]. The guidelines were classified into four base sections taking into account key concerns addressed in the literature [2,3,5] for interactive infotainment systems design. Then, said sections were segmented into subsections to cover, as widely as possible, each related context as follows.

A) DESIGN: This level focuses on providing general aspects on the analysis, planning, and concept design of infotainment systems to achieve a coherent user-centered approach. It fosters to start the project setting the **User Requirements** by understanding the integration of a) The users' needs derived from those activities (and associated tasks) to accomplish through the infotainment systems without neglecting human factors such as automotive users´ cultural values and their individual preferences for human machine interfaces [40]; b) The environment where activities would be carried on; and c) The goals that infotainment system should to achieve to support identified users' needs [33,34]. On the other hand, suggest to **Structure** design alternatives considering a) To take advantage of available space


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in vehicle's cockpit; b) Organize interactive elements so all parts fit together to make an integrated whole that promote intuitive access to content; and c) To visualize suitable distribution/location of interactive elements [35]. Finally, includes aspects linked to the interactive-elements' **Appearance** focusing on a) Selecting the proper typography/fonts and colour-palette to convey the content and information clearly allowing legibility to facilitate understanding [35,36].

B) INTERACTION: This level integrates guidance on determining specific widgets and interactive elements necessary to support functionality requirements from conceptual design (ideally generated by following guidance of the DESIGN level); and encourage better user experience. Suggests to consider interactive elements that offer diverse interaction **Modes & Flexibility** options by providing a) Support for combination of different input/output modalities; b) Adaptable interfaces without compromise interface architecture neither security standards; c) "Tweaking" possibilities to add the personal-touch to the interface appearance [37]. Additionally, provides guidance on inclusion of widgets that promote **Learnability** by suggesting familiar and comfortable workflows through the user interface of the infotainment system [38].

C) SECURITY: This level encompasses advices focused on providing understandable and usable information to drivers into a secure environment oriented to preserve drivers' focus on driving situations by designing user interfaces that enable interplay among infotainment systems, a) driving assistance and/or b) context awareness alternatives available in the vehicle in a safety manner. Moreover, proposes that infotainment systems' user interfaces take information from In-Car systems by c) complementing vehicle feedback in a fluid and comprehensible manner to facilitate information understanding [6].

D) CONNECTIVITY: This level encourages some insights addressed to integrate widgets that enable connectivity among infotainment systems **With Ambient** a) allowing fluid interplay with elements from technologies such as smart-cities and intelligent-roads; or even other vehicles around; and b) incorporating interactive elements to facilitate linkage among infotainment systems and diverse mobile devices. It also suggests to consider connectivity with cloud **Services** from public and private sources.

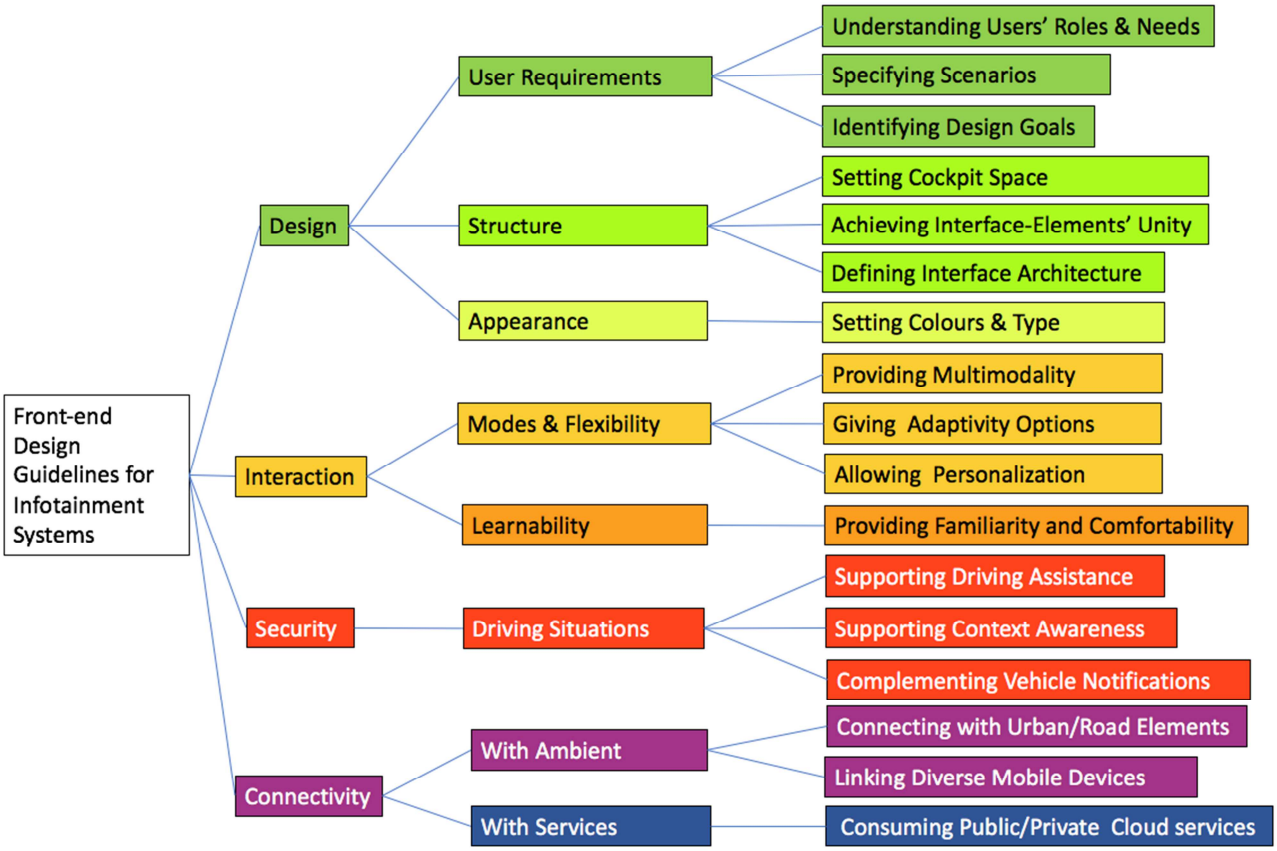




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*Fig. 1: Set of Front-End Design Guidelines for Infotainment Systems.*

The specification of the proposed guidelines was structured as follows: (The complete description of the guidelines is available at https://goo.gl/WTzfcN).

| Name | Understanding Users' Role & Needs |
|---|---|
| Context | When designing for people, it is crucial to pay attention to those things that they care about to stablish good designs. Said things are closely related to tasks (associated to a set of needs) derived from specific activities. |
| Purpose | Getting as much information as possible about the users' activity to accomplish, to identify their related tasks and clearly understand those needs that infotainment systems should be able to cover. |
| Benefits | When the activity to accomplish is well understood, solid basis and a railroad to good designs are stablished too. |
| Guide to Action | There are several alternatives to do this, but a good start could be the following sequence: Observing People; Being-Apprentice; Interviews; Focus Groups; Debriefing; and Personas. |

*Table 1. Example of the guidelines´ structural specification.*

## 4.- CASE STUDY

Structural specification of proposed guidelines allows to use them as a comparing reference; this aspect naturally match with Heuristic Evaluation (HE) technique which represents an inspection method commonly used in usability engineering to find usability problems in hardware and/or software user interfaces, in this case an infotainment system. HE could be performed even by a small group (3-5 evaluators/users), and analyzes the level of accomplishment of specific usability/good-design principles which are called «Heuristics» [35,38]. About 75% of usability problems can be detected by this number of evaluators [38]. Inspired by mentioned context, the pertinence of proposed guidelines (to serve as an initial common ground for designers of user interfaces of infotainment systems) could be inferred from their capacity to detect pain-points in existent designs. In this way, study case was performed as follow:

A) DESCRIPTION: This proposal was evaluated from two perspectives «technical experts» and «user experience of drivers» in order to validate the relevance of the proposed design guidelines in the identification of usability problems in infotainment systems. «Mazda Connect© (property of Mazda Motor Corporation)» was selected as infotainment application due to it is one of the best-selling brands in Mexico, according to (https://goo.gl/B7L8ea). Finally, the 17 design guidelines were used as heuristics for the evaluation.

B) PARTICPANTS: A total of 30 individuals participated in the validation of the proposed heuristics, including 5 research professors or technical experts in the disciplines of Human-Computer Interaction (HCI), usability, User-Centered Design (UCD) and User eXperience (UX) and 25 drivers (7 Mexican women and 18 men, between the ages of 25 and 45) from the cities of Zacatecas and Aguascalientes, Mexico. It is important to mention that some participants had already used some type of infotainment system, therefore, a pre-training was not necessary for them.

C) APPARATUS: Throughout the evaluation heuristic, participants were seated in the driver´s seat of a stationary Mazda 3 vehicle equipped with the Mazda Connect© Infotainment system (see Figure 2), whish allowed users to operate context such as applications, media, phone calls, navigation and setting up.



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*Fig. 2. Mazda Connect© Infotainment System (property of Mazda Motor Corporation).*

D) PROCEDURE: First, technical experts were provided with an overview of the study purpose and they were given a set of proposed guidelines expressed in Heuristic fashion. The experts then individually evaluated the Mazda Connect© Infotainment system. The obtained feedback helped determinate the technical pertinence of the proposed technique. Second, 8 task and 24 sub-tasks were defined for the drivers to complete. The results helped determine the level of experience and usability of each user that used the infotainment system.

E) TASKS: The following is an example of the sequence to implement a task. The participant reads the task aloud, e.g., "Identify in the interface the button which allow to make a phone call". Then, "Please call Diego Luna by selecting the phone number in the directory". If participants did not understand any task, they could ask for any questions. The task was completed when the sound system started dialing the call. It is important to say that the tasks were developed to manipulate some functionalities regarding: applications, entertainment, communication, navigation and setting up from de infotainment. The following list shows the simplified set of tasks users were asked to perform, sub-tasks are not described.

1) Play track 5 from USB Flash-Memory.
2) Tune FM radio station to given frequency.
3) Make a phone call to a given contact from the contact list.
4) Make a phone call to a given contact using the voice command.
5) Set up a route in the map given a specific direction using the interface.
6) Set up a route in the map given a specific direction using the voice command.
7) Display specific information about the vehicle from given information.
8) Set up the interface language.

## 5. RESULTS

In the first stage, the technical experts were provided by the 17 set of design guidelines/heuristics and they evaluated the «Mazda Connect©» Infotainment system through the "expert analysis", this technique is used to identify potential usability and interaction issues in user interfaces. They found several design and interaction flaws related to the way the drivers interact with the interface elements and voice commands´ structure. Table 2 shows a fragment from the experts´ perception including a brief description of the detected faults and the dimension-category-guideline that could attend the problem.

| PROBLEM | DIMENSION | CATEGORY | GUIDELINE |
|---|---|---|---|
| 1. Some ***interfaces do not provide adequate feedback***, or do not show any feedback, e.g. section "Traffic Map Radio HD" does not display any feedback if the system do not detect HD radio stations in the local area. | Design<br><br>Interaction | User Requirements<br><br>Modes & Flexibility | Specifying Scenarios<br><br>Providing Multimodality |
| 2. In some user interfaces, ***icons are not intuitive and*** | Interaction | Modes & Flexibility | Providing Familiarity & |



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| | | | |
|---|---|---|---|
| ***do not illustrate the tasks they perform***, e.g. the button that allow to tune a specific radio station by manual or the icon to accept data configuration of a route on the map. | | | Comfortability |
| 3. ***Some interfaces restrict user input data***, this does not allow the completion of a specific task, e.g. when you are trying to introduce the data of an address manually. | Design | Structure | Defining Interface Architecture |
| 4. ***The voice command structure*** to set up a destination address ***does not correspond to the structure of the Mexican driver's mental model***, e.g. the command structure in the infotainment system is: *«state-city-street-number»*, and the local context structure in México is: *«street-number-locality-city-State»*. Also, the provided example by the wizard in the feedback does not correspond with the local address structure and it is in another language. | Design<br>Interaction | User Requirements<br>Modes & Flexibility | Specifying Scenarios<br>Giving Adaptivity Options |
| 5. Some prompts by voice ***commands are extensive and could distract the user while driving***. | Design | User Requirements | Specifying Scenarios |

*Table 2. Identified problems by technical experts.*

In second stage, drivers used the Mazda Connect© System, they found inconsistencies related with user interface elements and voice commands. Table 3 shows some comments made by the drivers while they performed the user experience and usability evaluation, using the thinking-aloud method and then corroborated with a final comment session.

| Problem detected | Driver data |
|---|---|
| 1. I had a ***visual problem*** with the main menu trying to understand if it was scrollable. | Mr. Aguirre, 42 years old |
| 2. I had some ***problems*** **trying to** ***identify the button*** that allow to tune a specific radio station. | Mr. Estrada, 38 years old |
| 3. I had ***problems trying*** **to** ***follow the voice assistant instructions***, they were very long instructions. | Mrs. Romo, 26 years old |
| 4. The ***instructions*** for setting up a route using the interface ***were very long.*** | Mr. Olmos, 45 years old |
| 5. I *was* ***unable*** **to setting up the address** ***with the voice command*** because the system did not recognize my input address data. | Mrs. Sandoval, 25 years old |
| 6. I was ***unable to complete the task*** of setting up a route because ***the interface did not allow entering a specific address*** and I cannot identify the button to finish the task, e.g. "the confirmation button" | Mr. Muñoz, 30 years old |
| 7. The way to access some options in the interface are not well-defined, ***icons do not define the tasks they perform***. | Mr. Ruiz, 27 years old |
| 8. When a did a mistake trying to input an address, the ***example given for the wizard did not correspond with the national structure for directions.*** | Mr. Medrano , 30 years old |
| 9. When I was trying to set up a route using the voice command, I made a mistake and the ***system directed me to another application***, it sent me to the radio station. | Mrs. Rodríguez, years old |

*Table 3. Identified problems by drivers.*

As presented in Table 2 and Table 3, the results of the evaluation carried out by the technical experts are closely related to the problems that the drivers identified when using the infotainment system.

Study revealed that main difficulties occurred during tasks that required voice commands (tasks 4 and 6 in Table 4), even for those participants with certain experience using In-Vehicle Infotainment (IVI) systems. Particularly, the structure of voice commands for address its incompatible with the participants' mental model for addresses in Mexico. Similarly, several participants found that system icons' purposes do not match with standard icons appearance (tasks 2 and 5 in Table 4 ).

Finally, three tasks were completed 100%, which have a direct relationship with activities that users perform on other mobile devices (e.g. smartphone) such as: playing a song, searching for a contact in the directory and configuring aspects of the device.



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| TASKS | % OF PARTICIPANTS WHO COMPLETED TASKS | |
|---|---|---|
| | YES | NO |
| 1) Play track 5 from USB Flash-Memory. | 100% | 0% |
| 2) Tune FM radio station to given frequency. | 80% | 20% |
| 3) Make a phone call to a given contact from the contact list. | 100% | 0% |
| 4) Make a phone call to a given contact using the voice command. | 40% | 60% |
| 5) Set up a route in the map given a specific address using the interface. | 80% | 20% |
| 6) Set up a route in the map given a specific address using the voice command. | 40% | 60% |
| 7) Display specific information about the vehicle from given information. | 80% | 20% |
| 8) Set up the interface language. | 100% | 0% |

*Table 4. Tasks list completed by the participants.*

## 6. CONCLUSIONS

A non-exhaustive set of 17 guidelines was provided in this paper to complement previous efforts on providing designers structured alternatives that help in design of automotive user interfaces particularly infotainment systems. Considering perspective from seminal paper written by Frederick P. Brooks [40], these guidelines can be used as a starting-point by novel designers (or designers who have little time/interest for research) on front-end design for infotainment systems. From this vantage point, guidelines encourage designers to consider those essential design criteria addressed to conform well-designed interfaces in this field. Designers can follow these guidelines from concept to implementation stages into user-centered design process easily and sequentially. Therefore, following these guidelines in designing front-end for infotainment systems could derive in better user experiences for drivers. On the other hand, where guidance on design front-end for infotainment systems is the main topic here, the structure of these guidelines allows them to be used as a basic tool for empirical evaluation (like Heuristic Evaluation). Consequently, it could help designers in exploring insights (presented as Lo-Fi mocks or Hi-Fi mocks), or evaluate functional front-end infotainment systems. These guidelines highlighted said aspects as advantages, since previous alternatives appear to neglect them despite its importance.

A study case was performed as a proof of concept and as illustrative example; findings suggested that users' mental models should be previously well-understood by designers; this aspect directly impacts to user experience. This issue could be improved by considering the guidance of "User Requirements" level of this proposal (see Figure 1). Obtained results suggested pertinence of the proposal since participants found several improvement opportunities in the front-end of the evaluated system. Similarly, guidelines facilitate redesign process by encouraging new design ideas; better problem-solving; accurate decision-making; and inspiration to correct errors.

There are several avenues to transit as future work, such as expand the proposal to broader context reinforcing important human factors. Additionally, it is important to evaluate the proposal's behavior by reviewing more complex infotainment systems involving multicultural users.

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Tel +34 944 237 566 - www.dyna-newtech.com - email: info@dyna-newtech.com