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Design of a Web Application Prototype to Determine if a Person Has the Necessary Cognitive Skills for Driving

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Abstract. Mild Cognitive Impairment is characterized by a slight cognitive decline that minimally affects daily activities, potentially impacting the ability to drive, as driving involves cognitive skills. KSCAr+Drive, a specific tool, rapidly evaluates individuals with suspected neurocognitive impairment. Comprising various tests, it covers a wide range of cognitive abilities. This article prioritizes User-Centered Design as an essential element for the design, implementing the phases outlined in ISO 9241-210:2019 to develop a web application prototype aimed at determining a person's cognitive suitability for driving.

Keywords: Web Application Prototype, User-Centered Design, Cognitive Skills, Mild Cognitive Impairment.

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1. Introduction

Cognitive skills encompass the essential mental faculties for interpreting, processing, and responding to stimuli, enabling adaptation to various situations (*Las capacidades cognitivas*, 2022). In driving, these abilities are vital, involving perception, attention, motor control, memory, and decision-making (Leis et al., 2015). To assess these abilities in individuals, especially in older adults, the Kingston Scales Institute has developed a tool called the

"Kingston Standardized Cognitive Assessment - Revised - Plus Driving Scale (KSCAr+Drive)". This tool examines aspects such as memory, language, and visuomotor functions, generating percentile scores and providing a comprehensive evaluation that includes orientation, comprehension, and abstract thinking (*Cognitive Assessment*, n.d.).

This study aims to innovate the application of KSCAr+Drive for detecting mild cognitive impairment and driving incapacity. Such impairment affects cognitive abilities without significantly altering daily activities; if it impacts independence, it is considered a major neurocognitive disorder (*Mild Neurocognitive Disorder / Mild Cognitive Impairment (MCI)*, 2021). Mild cognitive impairment is classified as a minor disorder, distinguishing it from major impairments based on its impact on daily life (González Palau et al., 2015).

The 2018 WHO Report highlights 1.35 million annual deaths due to traffic accidents, with road traffic injuries being the leading cause of mortality among individuals aged 5 to 29 years (*Global Status Report on Road Safety 2018*, n.d.). Assessing cognitive fitness for driving is essential for road safety, identifying individuals with cognitive impairment early to prevent accidents by avoiding driving.

2. Materials and Methods

A user is capable of interacting with an application or system through an interface. The discipline of Human-Machine Interface (HMI) serves as an intermediary interface between the individual and the technology they are using (*HMI*, n.d.). This discipline has undergone an evolutionary period in which it has incorporated various fields, allowing for an expanded area of study while simultaneously improving interaction styles.

The importance of an interface lies in achieving the user's intended goal. To achieve this, ease of interaction must be considered, leading to the discipline of User Experience (UX) design. UX encompasses both functional and aesthetic experiences, focusing on the overall experience of the end user. This is the result of successful execution of user actions when interacting with the interface (*Entretejidos La Importancia de Una Interfaz Usable En Un Sistema de Administración*, n.d.).

2.1. User-Centered Design

User-Centered Design (UCD) involves engaging end users in the product development process to meet their needs (14:00-17:00, n.d.; Strömberg et al., 2005). It is a multidisciplinary process that brings together different stakeholders. The ISO 9241-210:2019 standard guides the User-Centered Design (UCD) process throughout the life cycle of interactive systems. UCD aims to understand user needs and guide design to meet those needs. Its goal is to ensure product acceptance by users. The process is visualized in Figure 1.

- **Understanding and specifying the context of use:** The context of use encompasses users, tasks, and environments in order to support design. The gathered information is used to identify an initial statement of requirements. To understand and comprehend the necessary information for context analysis, the project is described as a problem that requires a solution.
- **Specifying user requirements:** Obtaining and analyzing requirements is the most crucial part of software development. In addition to technical and functional requirements, usability requirements are essential. A statement of user-centered requirements is formulated based on the context and using IEEE 830.
- **Produce designs and prototypes:** With relevant contextual information and user requirements, design solutions and prototypes are created. A low-fidelity prototype allows for screen layout, followed by a high-fidelity prototype for interaction.
- **Evaluation:** A prototype enables user-based evaluation to refine the design. It verifies whether user needs are met. If not, the DCU process restarts from the initial stage.

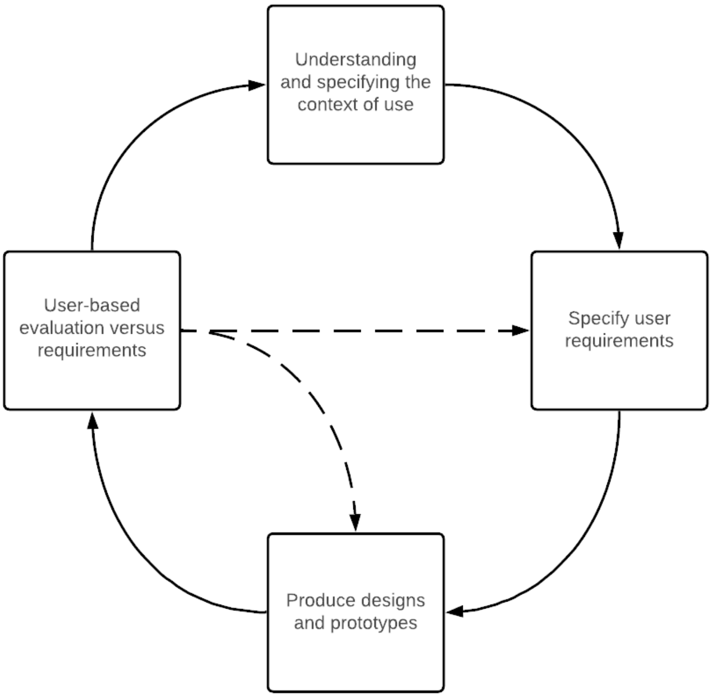

Figure 1. User-Centered Design Process

3. Results

During the execution of the User-Centered Design (UCD) process, user-focused requirements were identified. Consequently, progress was made in developing a web application prototype aimed at assessing the cognitive aptitude required for driving. The results achieved in the context of this phase of UCD are presented in the following sequence.

3.1. Understanding and specifying the context of use

In this initial phase, the lack of assessment of skills required to obtain driver's licenses in Mexico is highlighted. This gap can lead to drivers with cognitive impairment and an increased risk of accidents. The proposed solution involves identifying these skills through rigorous assessments during the licensing process. The approach is applicable to applicants of all ages, utilizing the standardized KSCAr+Drive tool developed by the Kingston Scales Institute. Originally designed to detect cognitive decline in older individuals, this tool now serves a broader purpose in assessing driving aptitude (Kilik et al., 2018).

While cognitive skills are essential for safe driving, the current process of obtaining licenses in Mexico does not take them into account. The integration of these assessments into regulations is proposed to enhance road safety by reducing accidents.

Existing tools were examined, and KSCAr+Drive was identified as a viable option for detecting cognitive impairment. Accident statistics in Mexico were investigated to assess the problem and the need for stricter measures in the driver's license application process.

Focus group technique was employed with users aged 20 to 35 years to understand their concerns regarding cognitive assessment in the driver's license acquisition process. Additionally, the personas creation technique, based on research and assumptions, was applied to keep the user at the heart of the design (*Personas*, 2023; *What Are UX Personas and What Are They Used For?*, 2022).

3.2. Specifying user requirements

In this stage, the essential elements that will shape the architecture and functionality of the web application are structured. It begins with an immersion in the IEEE 830 standard to create a Software Requirements Specification (SRS). This section not only addresses technical aspects but also considers the relationship with end users and how their needs influence the requirements. The collaborative process encompasses both functional and non-functional requirements.

The application aims to assess cognitive abilities for safe driving. Users take standardized tests that provide instant results and support decisions regarding driver's licenses. The user-system interaction guides the scope based on testing and evaluations. Evaluated users (seeking licenses) and assessors (interpreting results) play central roles.

This stage not only establishes technical foundations but also the relationship between technology and users, ensuring that the application meets technical requirements and satisfies real needs.

3.3. Produce designs and prototypes

A low-fidelity prototype (Figure 2) is created based on the results obtained in the previous stages. This initial prototype includes a homepage and pages dedicated to KSCAr+Drive tests. Its purpose is to provide a preliminary visualization of interface elements and establish the navigation sequence between different screens.

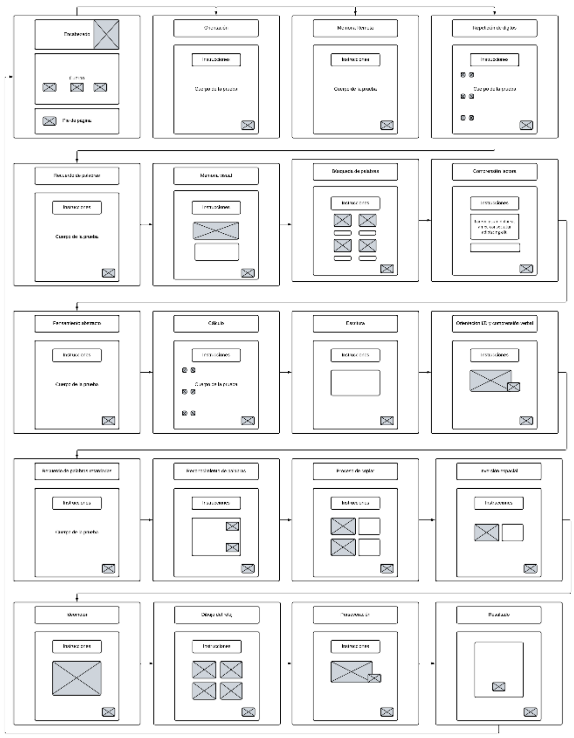

Figure 2. Low-Fidelity Prototype

Subsequently, a high-fidelity prototype (Figure 3) is developed, which allows for a more detailed and functional definition of user interaction with the interface. In the realm of software development, high-fidelity prototypes are valuable for undergoing testing and evaluations by users, aiming to gather feedback and refine the design before the final product launch (Babich, n.d.).

Simultaneously, the user interface is designed using Nielsen's 10 heuristics. Although these heuristics are typically used for usability evaluation, in this case, they have been incorporated from the prototyping process as a design guide, with the intention of enhancing the quality of the final product.

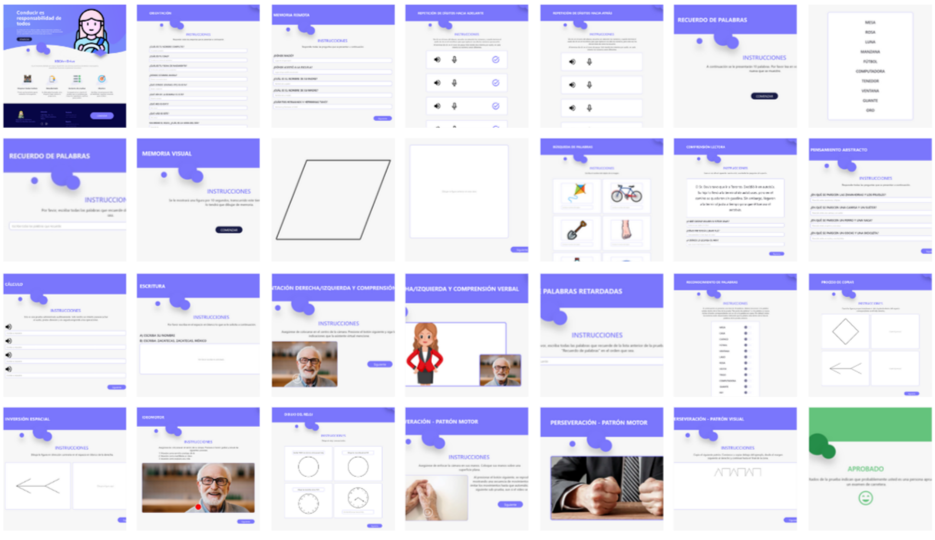

Figure 3. High-Fidelity Prototype

3.4. Evaluation

The usability of the prototype is evaluated, measuring the ease of use and effectiveness of the interface for users (14:00-17:00, n.d.). Usability testing aims to ensure that the product is intuitive and meets expectations, using methods such as architecture analysis, user testing, task analysis, and surveys. The architecture analysis indicates that the prototype aligns with KSCAr+Drive, and its structure and information are appropriate. The user test involved five participants aged 18 to 55 through the Ballpark platform (*Ballpark - Product Research so Simple, You'll Never Skip It Again.*, n.d.). They were assigned the task of navigating from the home screen to the last one, while their interaction was observed and their opinions were heard. (Figure 4).

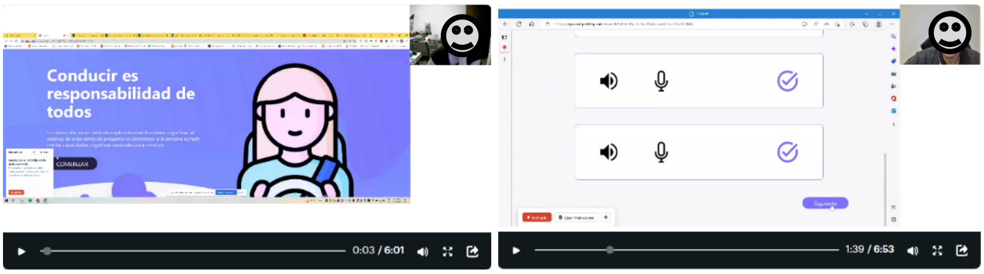

Figure 4. Observation of User Interaction with the Prototype

After interacting with the prototype, users completed the Computer System Usability Questionnaire (CSUQ), a questionnaire designed to assess usability. It consists of ten items that cover ease of use, error recovery, efficiency, satisfaction, and ease of learning. Responses are given on a scale from “completely disagree” to “completely agree.” The questionnaire results can be used to identify areas for improvement in the usability of a computer system and to compare usability across different systems. For Spanish-speaking users, an adapted version with sixteen items was used (Hedlefs et al., 2016).

The results of the evaluations (user tests, task analysis, and surveys) indicate the following:

- The heatmap for each screen of the prototype shows where users clicked, demonstrating the intuition and clarity of the interface.
- All users successfully completed the task of navigating from the initial screen to the last one, which displays the results of the KSCAr+Drive test.
- The ratings in the responses to the Computer System Usability Questionnaire (CSUQ) items, which measure usability, were high, with no rating below 5.8 (out of a maximum of 7), indicating that it is a good prototype.

4. Conclusions

At no point in the process of obtaining a driver’s license in Mexico is the evaluation of cognitive abilities considered, which is an important factor for enhancing road safety and consequently reducing automobile accidents.

Through the implementation of user-centered design, a web application prototype was designed to determine whether a person has the necessary cognitive skills for driving. In an initial approach with users, it was verified that the prototype is suitable in terms of design. However, some areas for improvement were identified based on the responses to the CSUQ items.

Regarding the final product, the ideal scenario would involve incorporating machine learning algorithms that enable the analysis of each of the responses from the tests that make up the KSCAr+Drive. This way, it would be possible to determine whether the person taking the test is capable of driving or not, and the result would not rely on human factors.

Similarly, this application could be complemented by using a virtual reality environment, in which the results of the KSCAr+Drive test are reinforced through a driving simulator.

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