UNIVERSIDAD POLITÉCNICA DE MADRID
ESCUELA TÉCNICA SUPERIOR DE INGENIEROS DE TELECOMUNICACIÓN

MÁSTER UNIVERSITARIO EN INGENIERÍA DE TELECOMUNICACIÓN

TRABAJO FIN DE MÁSTER

Design and development of an immersive training tool for people with intellectual disability

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Martina Merolli

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Título:	Design and development of an immersive training tool for people with intellectual disability
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Madrid, a de

Universidad Politécnica de Madrid

Escuela Técnica Superior de
Ingenieros de Telecomunicación

MASTER IN TELECOMMUNICATIONS ENGINEERING

Master Thesis

Design and development of an immersive training tool for people with intellectual disability

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SUMMARY

Intellectual disability is a complex condition characterized by deficits in both intellectual and adaptive functioning that affect a person's conceptual, social and practical abilities. These deficits may manifest themselves differently from one individual to another, as the environment in which a person lives plays a crucial role in determining his or her development. Although intellectual disabilities are usually permanent, levels of severity may vary over time. People with intellectual disabilities often have slower learning processes and need specific supports to develop new skills, such as working, understanding complex concepts and interacting socially. They also face social barriers, stigmatization and limited access to support services.

In this context, 2D tools are used to foster the development of memory and attention, but more and more is being invested in Virtual Reality (VR). This technology offers the opportunity to enhance not only cognitive abilities, but also the ability to move, making it particularly beneficial for people with intellectual disabilities. Cognitive therapy through VR offers an immersive experience in a simulated digital world, achieved through the use of specialized displays. This technology allows the user to be immersed in the environment, completely masking the perception of the surrounding physical world. Also crucial is the use of biomarkers such as eye tracking, head movements and heart rate, which are monitored to analyze emotions and anxiety levels, providing therapeutic information.

The objective of this Master's Thesis is to design and implement a cognitive training tool for people with intellectual disability using VR, aiming at supporting issues and difficulties of these individuals, with particular focus on the aspects of work and autonomy. The intention is to create virtual work environments in which users can improve and refine skills related to memory and attention, thus facilitating their integration into the labor market. Mainly two distinct immersive environments will be developed in Unity: a supermarket and a restaurant. For each of them, two specific activities will be designed, each characterized by different levels of difficulty. In addition, experimental tests will be conducted with users involving the collection and analysis of data at the Juan XXIII Foundation, in order to assess the effectiveness of the proposed therapy. The project will comprise the design and development of an immersive training tool, including the phases of creating the user experience, the design and implementation of the tests, and the statistical analysis of the data collected. Sensors on users and questionnaires will be used to monitor and assess cognitive performance, with a particular focus on memory and attention.

KEYWORDS

VR, XR, Task Design, Intellectual disability, Incluverso, Quality of Experience (QoE), Immer-

sive Learning, Accessibility.

RESUMEN

La discapacidad intelectual es una condición compleja caracterizada por déficits tanto en el funcionamiento intelectual como en el adaptativo, que afectan las habilidades conceptuales, sociales y prácticas de una persona. Estos déficits pueden manifestarse de manera diferente en cada individuo, ya que el entorno en el que vive una persona desempeña un papel crucial en la determinación de su desarrollo. Aunque las discapacidades intelectuales suelen ser permanentes, los niveles de gravedad pueden variar con el tiempo. Las personas con discapacidades intelectuales a menudo tienen procesos de aprendizaje más lentos y necesitan apoyos específicos para desarrollar nuevas habilidades, como trabajar, entender conceptos complejos e interactuar socialmente. También enfrentan barreras sociales, estigmatización y un acceso limitado a los servicios de apoyo.

En este contexto, se utilizan herramientas en 2D para fomentar el desarrollo de la memoria y la atención, pero cada vez se invierte más en la realidad virtual (VR, del inglés *Virtual Reality*). Esta tecnología ofrece la oportunidad de mejorar no solo las habilidades cognitivas, sino también la capacidad de movimiento, lo que la hace particularmente beneficiosa para las personas con discapacidades intelectuales. La terapia cognitiva a través de la VR ofrece una experiencia inmersiva en un mundo digital simulado, lograda mediante el uso de pantallas especializadas. Esta tecnología permite al usuario sumergirse en el entorno, enmascarando completamente la percepción del mundo físico circundante. También es crucial el uso de biomarcadores como el seguimiento ocular, los movimientos de la cabeza y la frecuencia cardíaca, que se monitorean para analizar las emociones y los niveles de ansiedad, proporcionando información terapéutica.

El objetivo de este Trabajo Fin de Máster es diseñar e implementar una herramienta de entrenamiento cognitivo para personas con discapacidad intelectual utilizando VR, con el fin de abordar los problemas y dificultades de estas personas, con un enfoque particular en los aspectos del trabajo y la autonomía. La intención es crear entornos laborales virtuales en los que los usuarios puedan mejorar y perfeccionar habilidades relacionadas con la memoria y la atención, facilitando así su integración en el mercado laboral. Principalmente se desarrollarán dos entornos inmersivos distintos en Unity: un supermercado y un restaurante. Para cada uno de ellos, se diseñarán dos actividades específicas, cada una caracterizada por diferentes niveles de dificultad. Además, se realizarán pruebas experimentales con usuarios que implicarán la recopilación y el análisis de datos en la Fundación Juan XXIII, con el fin de evaluar la efectividad de la terapia propuesta. El proyecto comprenderá el diseño y desarrollo de una herramienta de entrenamiento inmersiva, incluyendo las fases de creación de la experiencia del usuario, el diseño e implementación de las pruebas, y el análisis estadístico de los datos recopilados. Se utilizarán sensores en los usuarios y cuestionarios para monitorear y evaluar el rendimiento cognitivo, con un enfoque particular en la memoria y la atención.

PALABRAS CLAVE

VR, XR, Diseño de tareas, Discapacidad intelectual, Incluverso, Calidad de la experiencia (QoE), Aprendizaje inmersivo, Accesibilidad

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Acronyms

Acronym	Description
AR	Augmented Reality
CI	Confidence interval
DOF	Degree of Freedom
EDA	Electrodermal activity
EOG	Electro-oculography
FI	Factors of Influence
GTI	Grupo de tratamiento de imágenes
HMD	Head Mounted Display
HR	Heart rate
ICS	Immersive communication systems
LOD	Level of Details
MOS	Mean Opinion Score
MR	Mixed Reality
QoE	Quality of Experience
VOG	Video-oculography
VR	Virtual Reality
XR	Extended Reality

1. Introduction

In a world designed predominantly for people without disabilities, more than one billion individuals live with some form of disability [2]. Among these, intellectual disabilities pose specific challenges, often related to the achievement of autonomy, as lack of independence is one of the main barriers to social and professional integration.

This thesis focuses precisely on these difficulties, delving into strategies and technologies that can foster inclusion and improve the quality of life of these people by promoting opportunities that enhance their abilities and potential.

With this in mind, the project represents a unique opportunity to apply advanced technologies, such as virtual reality (VR) and biomarkers, to develop innovative approaches in cognitive therapy. In particular, the use of VR enables the creation of simulated work environments that foster the development of cognitive skills, providing safe and controlled spaces for focused and progressive learning.

To this end, the project introduces two distinct virtual scenarios: the supermarket and the cafeteria. These environments, designed to represent realistic working contexts, include progressive levels and specific tasks. To implement them, Unity, a reference platform in the field of immersive technologies, was used, which enables the creation of detailed and interactive scenarios thanks to advanced graphic and dynamic functionalities.

These scenarios aim to improve the users' attentional processes and inhibitory control capacity, supporting them in the social and labour inclusion paths promoted by the COFOIL ("Centro Ocupacional de Formación, Oportunidades e Inserción Socio Laboral") of the Fundación Juan XXIII.

To further optimise the experience, user experience questionnaires are administered to users. These questionnaires allow qualitative feedback to be collected on users' perceptions, feelings and satisfaction during therapy sessions. The information obtained from the questionnaires integrates physiological and cognitive data, providing a more complete view of the effectiveness of the therapies.

Additionally, a graphical interface was used that allows the therapist to monitor and adapt therapeutic activities in real time, offering a flexible and dynamic approach that responds to the specific needs of each user, thus helping to improve the effectiveness of the interventions.

This combination of advanced technologies makes it possible to create an adaptable therapeutic environment, fostering a more effective and sustainable integration of users in social and work contexts.

2. Objectives

The motivation behind this research stems from the need to develop inclusive tools capable of not only enhancing personal autonomy but also ensuring fair and meaningful access to the job market. The aim is to promote active participation of users in real and less controlled environments, offering concrete learning opportunities tailored to their specific needs. The immersive experience is structured around two distinct scenarios, the supermarket and the cafeteria, designed with a well-defined level structure, progressively increasing task complexity, and a detailed monitoring system. Through this approach, the project seeks to validate the effectiveness of extended reality (XR) technologies in enhancing professional training, thereby contributing to a more inclusive and accessible society.
The block diagram shown in the figure (1) illustrates the methodology followed during the project, highlighting the sequential process undertaken to achieve the objectives, with iterations that allow to improve the previous phases

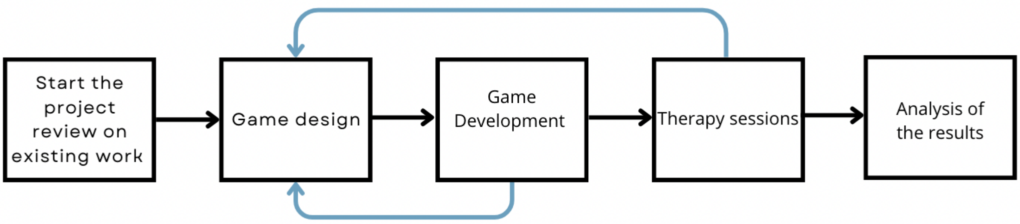


Figure 1: Project methodology

The project begins with a thorough review of existing research and technologies. Then, we move on to the design of the game, with the help of psychologists, with the definition of the structure, mechanics and progression, to create an immersive experience adapted to therapeutic and educational goals. In the development phase, these ideas are implemented, with the creation of immersive scenarios such as the supermarket and the cafeteria, enriched by interactive functionalities and monitoring systems. The game is then tested in controlled therapeutic sessions, where users interact with the system under the supervision of professionals, allowing to collect fundamental data. Finally, the analysis of results.

2.1. Document structure

After an introduction to the context and objectives, this Master thesis is divided into several sections. The second chapter examines the state-of-the-art of immersive technologies and the Incluverso project, with a particular focus on its use cases. The fourth chapter covers the application development, from scene and task design to level structure and activity monitoring. The experimental phase is described in detail in chapter 5, which describes the equipment used and the organization of the sessions. The results are presented in the sixth chapter, while the seventh focuses on conclusions and future prospects. The master thesis concludes with an analysis of the project's ethical, economic and social impacts.

3. State of the art

3.1. Immersive Technologies

In recent years, immersive communication systems (ICS) have gained increasing attention, becoming more and more part of our lives as a new mode of digital connection and interaction [3]. With the ability to create highly realistic and engaging experiences, these systems are redefining how we communicate, work and entertain.

Immersive technologies are a set of innovative tools and solutions designed to engage users in experiences that merge or enhance the real and digital worlds. Thanks to their ability to integrate visual and auditory stimuli, these technologies cross the boundaries between physical and virtual, offering simulated or enhanced environments with a high degree of realism and interactivity. Their main goal is to create a profound feeling of 'presence', i.e. the perception of being fully immersed in a digital or augmented environment, redefining the way people perceive and interact with reality [4].

To better understand these concepts, we can refer to both the immersion spectrum (See Figure 2) and the virtuality continuum, two models that classify immersive technologies. The immersion spectrum focuses on the level of engagement offered by the technologies: augmented reality (AR) is towards the extreme of low immersion, enriching the real environment with digital elements. On the other hand, virtual reality (VR) represents the extreme of high immersion, creating fully simulated environments that isolate the user from the real world. Mixed reality (MR) is positioned in the middle, combining physical and digital elements into a single integrated environment.

The continuum of virtuality provides a complementary perspective, describing a continuous scale from the fully real world to the fully virtual world. AR lies close to the physical side of the continuum, while VR lies towards the digital side. MR occupies an intermediate position, integrating both worlds.

Finally, extended reality embraces all these technologies, emphasizing the fluidity and connection between physical and digital experiences. These two models help to better understand both the level of immersion and the degree of integration between real and virtual offered by each technology [1].

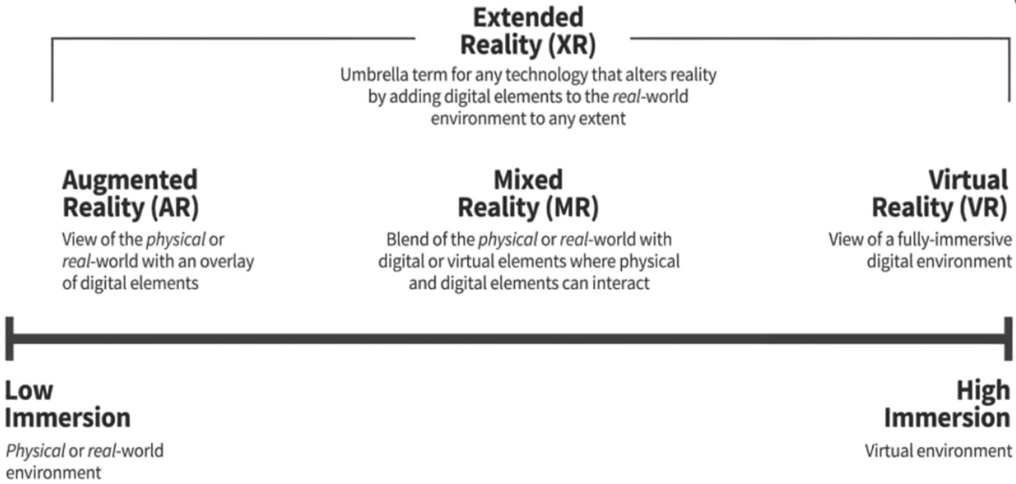


Figure 2: Classification of current XR technologies according to degree of immersion. [1]

In this chapter, we will look at each of these technologies and delving into their characteristics and applications.

3.1.1. Extended Reality (XR)

XR is an umbrella term that includes AR, VR and MR (See Figure 3). It also refers to technologies that support AR and VR capabilities. For this reason, the ”X” in XR is also considered as a conventional name for a variable rather than as an abbreviation of ”Extended” and can be replaced with ”A”,”V” or ”M” depending on the context [5]. Is a term that embraces all technologies capable of altering the perception of reality by adding digital elements to the physical world. In recent years, XR has attracted great interest, among other things, for its potential to convey non-verbal communication and offer solutions to current distancing problems. The goal of XR is to cross the boundaries between the real and the virtual, creating experiences that seamlessly integrate these two worlds. These technologies find application in various sectors, including entertainment, education, healthcare and marketing, offering new ways for users to interact and engage.

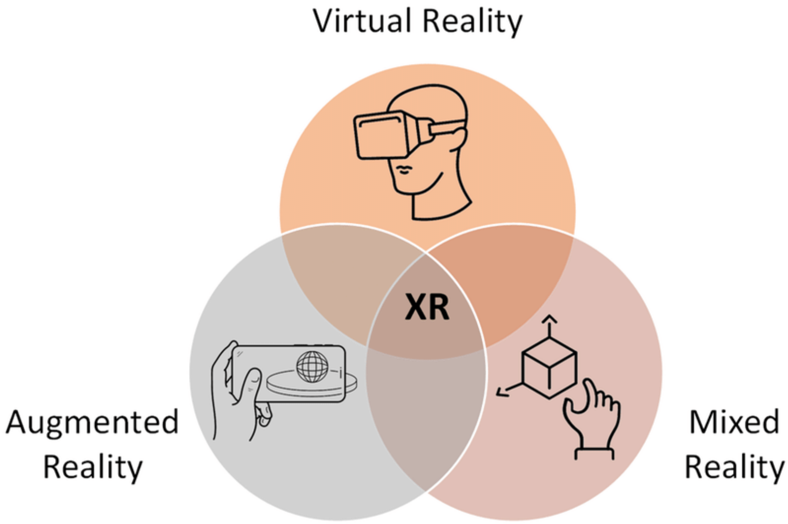


Figure 3: XR as the Intersection of Virtual, Augmented, and Mixed Realities.

3.1.2. Augmented reality (AR)

The most widely cited definition of AR comes from Ronald T. Azuma's in "A Survey of Augmented Reality" [6]. *AR can be seen as a variation of Virtual Reality. In VR, the user is completely immersed in a virtual world. However, with AR, virtual elements are superimposed upon or composited with the real world.* In other words, AR "augments" reality, overlaying digital content onto the real world [5]. This is achieved through devices equipped with cameras and sensors, such as smartphones, tablets or dedicated displays, which analyse the surrounding environment and integrate relevant virtual elements. Augmented reality is being applied in a number of areas, demonstrating significant potential. AR is useful for medicine, robotics in entertainment and retail, where it improves user experience in gaming, education and shopping [7].

Although AR has demonstrated enormous potential in these areas, the technology is still in its early stages of development and implementation, with many challenges yet to be faced.

3.1.3. Mixed reality (MR)

MR is a technology that merges the physical and digital worlds, creating a continuum that spans from reality to virtuality. It combines elements of VR and AR to develop interactive environments where real and virtual objects coexist [8].

A significant technological advancement in the context of MR is real-time egocentric segmentation, which allows users to visualize their own body in a virtual environment. This technology relies on an optimized neural network architecture and the use of diverse datasets.

The segmentation process ensures high-quality results, with precise definition of the user's body even in realistic configurations. Integrating segmentation into a complete MR system enables users to see their body interact seamlessly with the virtual environment, enhancing the sense of presence and immersion.

The development of real-time egocentric segmentation addresses critical challenges in MR, such as reducing latency and improving accuracy. However, ongoing research continues to focus on issues like the high cost of data labeling and the need for consistent performance in complex real-world scenarios [9].

3.1.4. Virtual Reality (VR)

First introduced to the general public in 1989 by companies such as VPL Research and Autodesk, which featured head-mounted displays and devices for interacting with virtual environments [10].
Whereas augmented reality, as explained in 3.1.2, superimposes digital information on the real world, virtual reality is a digital environment in which the user can interact and perceive sensations similar to those of a physical context, thanks to the use of sensory stimuli such as sight, hearing and touch, supported by devices for tracking movement and tactile feedback. In an ideal VR system, the experience would be indistinguishable from reality, even if current technologies do not yet reach this level of perfection [11]. One of the main characteristics of virtual reality, as we will explore in this thesis, is its ability to involve users' cognitive and motor skills. This immersive approach promotes the development of practical skills, making VR an effective tool for training and simulation. Virtual reality applications span across a range of sectors thanks to significant advances in the quality of virtual experiences over the past few years, especially with devices like Oculus Rift and HTC Vive, which have improved key aspects such as resolution, convenience and interactivity. Despite this, there are still issues related to high device costs, the creation of appropriate content and the quality of user experience.

3.1.5. Eye tracking in XR

Eye tracking represents an emerging technology that enables the detection and analysis of user eye movements, fostering a more natural connection between human interaction and digital systems. Its integration into virtual reality HMDs transforms human-machine interaction, offering more immersive and personalized experiences. It allows real-time monitoring of gaze focus points, enabling the adoption of techniques such as gaze-based rendering, a method that dynamically adjusts visual quality based on the user's point of view, optimizing computational resources while simultaneously enhancing the visual experience [12] .

The most common methods for eye tracking in HMDs include video-oculography (VOG), which uses cameras to capture eye movements, and electro-oculography (EOG), which measures the electrical signals around the eyes. VOG is preferred for its accuracy and ease of integration into devices.
The HTC Vive Elite (hmd used in this project) utilizes advanced eye-tracking technology: two sensors equipped with infrared illuminators capture gaze direction, pupil size and position, and eye openness [13].

Although current systems offer good levels of performance, there is still room for improvement in all these areas. Another significant challenge is the calibration process, which is necessary to obtain accurate data. However, this process can be lengthy and complex, and it is not always effective for all users, particularly those with attention deficits or motor difficulties [12].

3.2. Learning games for individuals with intellectual disabilities

The use of serious games as educational tools for individuals with intellectual disabilities is gaining increasing attention within academic and educational communities. Designed with specific educational objectives, these games provide innovative opportunities to engage and motivate users, fostering the development of their cognitive, social, and practical skills [14]. Recent studies on adults with Down syndrome, mild cognitive disorders and autism spectrum disorders have shown that personalised games can respond to the specific needs of different cognitive profiles. A significant example is an educational application designed [14] to teach the use of public transport, which has integrated game learning analytics to monitor user engagement and learning progress. However, some key challenges remain, including the need for further studies to validate the effectiveness of these tools in diverse educational settings and the development of standardised guidelines for the design and implementation of such applications.

3.2.1. NeuronUP

NeuronUP [15] is a web-based platform developed to assist healthcare professionals in neurorehabilitation and cognitive stimulation. It is specifically designed to support the treatment of patients with a wide range of neurological conditions, leveraging 2D technology to deliver targeted interventions. NeuronUP offers hundreds of structured exercises, divided into different areas of intervention, such as basic cognitive functions, everyday activities and social skills. The platform allows you to create personalized profiles for each patient, record the results obtained and monitor over time the evolution of their skills. The games offered by this platform have inspired the development of this project, which is distinguished by the use of cutting-edge technologies compared to simple 2D.

3.2.2. Evolution of NeuronUP, XR for people with intellectual disabilities

In recent years, XR has seen increasing adoption as a tool to enhance accessibility, inclusivity, and educational and therapeutic opportunities, surpassing the limitations of traditional technologies. Guided by the principle of "Accessibility by Design", XR experiences are tailored to personalize interactions and content, effectively addressing the diverse cognitive and physical limitations of users. Numerous research projects are currently underway to develop and validate XR solutions, placing the user at the center of the design process and adapting technologies to meet their specific needs. Furthermore, the immersive nature of XR has proven particularly effective in treating mental health disorders, such as anxiety and depression, which are often comorbid with intellectual disabilities [16].

3.3. Incluverso

The research presented in this thesis is part of Incluverso, a collaborative project involving UPM, Nokia, and Fundación Juan XXIII. The INCLUVERSO 5G [17] project aims to develop advanced XR technologies and 5G telecommunications to create immersive experiences applicable to therapy, telepresence, and teletraining contexts. The goal is to promote the inclusion of people in situations of psychosocial vulnerability, fostering a fully inclusive metaverse. The project focuses on two main areas: the design of 5G infrastructure and edge systems for enabling XR services, and the development of inclusive XR platforms.

3.3.1. Use Cases

The INCLUVERSO 5G project [17] collaborates with the Juan XXIII Foundation to develop and validate specific use cases, aimed at people in conditions of psychosocial vulnerability, as a fundamental step towards the development of a fully inclusive ecosystem, including:

- Cognitive and behavioural therapy: Targeted at people with a high level of addiction and specific therapeutic needs. Through highly controlled and systematic XR content, targeted stimuli are developed to facilitate research into technologies such as interaction and emotional regulation. An example is the use of immersive systematic desensitization to treat the phobia of stairs [18].
- Telepresence for supervised apartments: Designed for more autonomous individuals who still require external supervision, this solution leverages XR technologies to enhance communication between users and operators by integrating advanced tools such as telepresence. Through the Nokia Owl telepresence prototype, based on 360-degree video communication captured in real-time by a dedicated camera, the system enables the remote user to participate in the conversation using VR headsets. These headsets allow the user to view a portion of the scene based on head movements, providing a highly immersive and realistic experience. All of this is carried out with the continuous support of an educator who supervises and guides the evaluations [16].
- Teletraining for work inclusion: Designed for people with intellectual disabilities, but adaptable to a wider audience. This use case involves the creation of immersive learning environments in vocational training centres and job placement programmes, enabling the validation of technologies developed in less controlled environments and promoting skills development and access to the world of work. Teletraining for work inclusion.

The use case for bathmophobia was successfully completed last year, demonstrating the effectiveness of immersive systematic desensitisation to treat scale phobia, while the other cases are currently ongoing.

This thesis focuses in particular on the use of teletraining for work inclusion.

3.4. Quality of Experience

Quality of Experience (QoE) is a multidimensional concept that reflects users' subjective perception, specifically their level of satisfaction or dissatisfaction during interactions with multimedia services. This concept develops through a complex cognitive process that integrates audiovisual perceptions, physical reactions, and contextual information, making a linear categorization challenging. The very subjectivity of QoE adds further complexity to its definition, as it emphasizes the importance of measuring quality from the user's perspective. This can be achieved by explicitly requesting feedback through questionnaires or by using biosignal measurements, such as EEG or ECG, to analyze emotional engagement in real-time.
In the study of QoE, the Factors of Influence (IF), which include any characteristic of the user, the system, the service, or the context that may affect the quality of experience, can play an important role alongside the level of technological competence of users. These factors are divided into three main categories [11]:

- **Human factors**, which include demographic and socioeconomic background, physical and mental constitution, and the emotional state of the user.
- **System factors**, related to the technical quality of applications and services, such as acquisition, encoding, transmission, storage, representation, and display of media.
- **Contextual factors**, which encompass physical aspects (location and movement), temporal aspects (time-related factors), social and economic aspects (costs and subscriptions), task-related factors (focused or multitasking experiences), and technical aspects (interactions with other systems and devices).

With the evolution of advanced technologies such as VR and XR, optimizing QoE has become essential to deliver increasingly engaging and satisfying experiences. Immersive experiences, in particular, are built on three key concepts: immersion, immediacy, and presence [19].

Immersion measures the degree of sensory engagement of the user in the digital environment but can be negatively impacted by perceptual discrepancies or delays, leading to phenomena such as "cybersickness". This condition, characterized by symptoms such as nausea and disorientation, varies among users depending on the duration of exposure, familiarity with virtual environments, and technical or contextual factors.

Presence, on the other hand, refers to the subjective feeling of being in a place different from the physical one. It can manifest in three main forms: physical presence, related to the perception of truly being in another location; social presence, referring to the sense of interacting with virtual or remote interlocutors; and self-presence, concerning the awareness of one's identity in a virtual environment [19].

Questionnaires based on different scales are commonly used to assess QoE. The most common are scales from 1 to 5 or from 1 to 7, where the response options generally vary from "strongly disagreed" to "strongly agree" [20]. These questionnaires are used to collect subjective data from users in order to understand and measure their overall experience.

In this master thesis, a scale of 1 to 3 will be adopted to simplify the evaluation process and facilitate the response by users.

3.5. Statistical measurements

To evaluate the QoE, data collected through questionnaires are analyzed and processed with the aim of optimizing the systems and improving the overall user experience. Specifically, the opinion score reflects observers' perceptions of system performance and is determined based on a different criteria [21].

3.5.1. Mean Opinion Score (MOS)

Mean Opinion Score (MOS) is a numerical indicator that measures the overall quality of an event or experience based on the perception and subjective evaluation of human beings. It is calculated as given in the formula (1) :

$$\bar{u}_{jk} = \frac{1}{N}\sum_{i=1}^{N} u_{ijk} \tag{1}$$

Where u_{ijk} is the score selected by observer i under test conditions j, and stimulus k with a number of observers N.

3.5.2. Confidence Interval (CI)

To assess the variability of the score from the mean, the Confidence Interval (CI) is calculated, which is the range within which the estimated value is expected to fall in most cases.

The calculation process is done in two steps: initially the Standard Deviation is determined after which the 95% Confidence Interval is calculated with a margin of error of 5%. It is essential that the MOS is accompanied by the relevant confidence intervals, which are presented in the results analysis section. The calculation of CI is represented by the formula (2).

$$\delta_{jk} = 1.96\frac{S_{jk}}{\sqrt{N}} \iff S_{jk} = \sqrt{\sum_{i=1}^{N}\frac{(\bar{u}_{jk} - u_{ijk})^2}{N-1}} \tag{2}$$

3.5.3. Parametric and non-parametric tests

In statistical analysis, the choice of hypothesis testing method depends on the nature of the data and assumptions about their distribution. Statistical tests are divided mainly into parametric tests, which assume a known distribution of the data (normal), and nonparametric tests, which do not require any assumptions about the underlying distribution [22].

Parametric tests rely on a fixed set of parameters to construct a probabilistic model and are applied when the data follow a normal distribution or can be approximated to it. These tests make it possible to compare the averages of one or more groups provided that normality of the data and homogeneity of variances are met. One of the most widely used tests is Student's t-test, which tests whether there is a significant difference between the averages of two groups.

Non-Parametric tests do not rely on fixed parameters and do not require assumptions about the distribution of the data. This makes them particularly suitable for analyzing data with unknown or undefined distributions. Unlike parametric tests, which rely on means and variances, nonparametric tests use rank comparisons to assess whether significant differences exist between groups. Among the most widely used nonparametric tests are the Kruskal-Wallis test and the Mann-Whitney U test, both of which are used to compare the distribution of data between independent groups. The Kruskal-Wallis test is suitable for comparing three or more independent groups, while the Mann-Whitney U test is used to compare two groups. Both methods test hypotheses:

- Null hypothesis (H0): the distributions of the groups are equal, so there are no significant differences between them.
- Alternative hypothesis (H1): at least one group has a different distribution from the others.

4. Development the user's application

The development of the user application consisted of several stages, all of which were closely followed by the psychologists. First, the game environments were created. Next, the different tasks and levels were planned. Finally, once the game was started, modifications and optimizations were made based on the feedback received (See Figure 4).

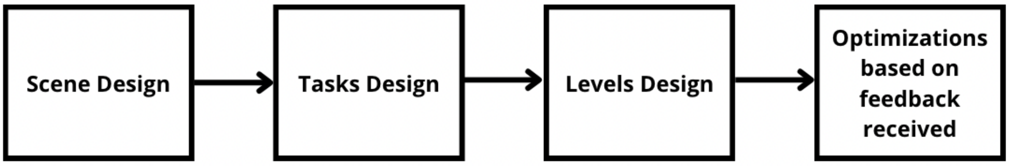


Figure 4: Phases of User Application Development

4.1. Unity Framework

The main part of this Master thesis focuses on application development using Unity.

Unity is a versatile and powerful platform for game design and 3D application development. Thanks to which it is possible to develop applications for augmented reality AR and VR platforms, such as Oculus, HTC Vive (as in the case of this project), and many others.

One of the key elements of Unity is the use of the C# programming language, which is essential for creating game functionality and dynamics. Its strength lies in managing the hierarchy of objects, consisting of visual, interactive, audio, and physical elements in both 2D and 3D. This hierarchy can be defined and managed in an intuitive development environment that combines a drag-and-drop approach with advanced development tools. The following is a brief explanation of the main components needed to create a game in Unity as shown in the Figure 5.

- **Scene (1)**: This window is the main place where the game is constructed, adding models, cameras, lights, and other elements.
- **Game (2)**: This window allows you to test the game during the development and editing phase.
- **Hierarchy (3)**: This window displays all elements (GameObjects) in the current scene.

- **Project (4)**: This window contains all the resources available in the project. These include models, prefabs, textures, sounds, scripts, and more.
- **Inspector (5)**: This window allows the GameObjects to be configured. Parameters such as position, rotation, scale (Transform), gravity and other attributes are defined and customized for each object, ensuring proper functioning within the game.

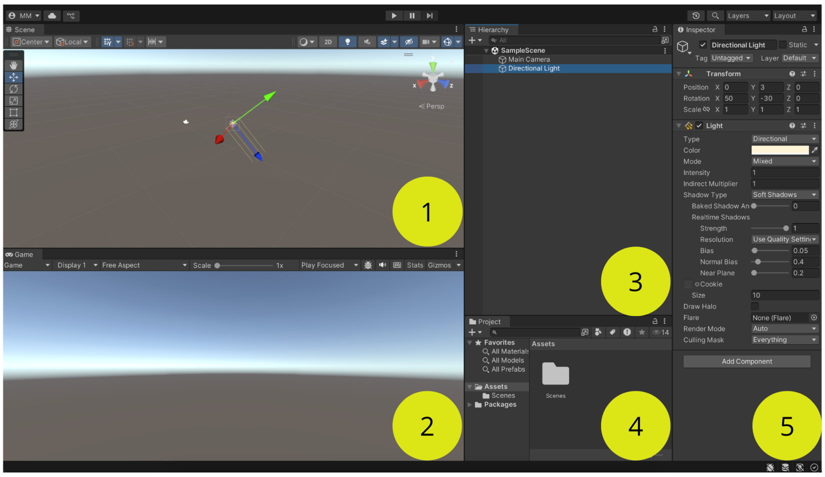


Figure 5: Unity Editor Overview: Scene, Hierarchy, Inspector, Project and Game

GameObjects, mentioned earlier, represent the core elements of the Unity framework, which are the essential building blocks for creating games. These GameObjects can be customized and extended by adding components and materials, making them interactive and visually interesting. All objects used in the creation of the supermarket and cafeteria are GameObjects, designed to allow the user to interact with them as if they were tangible objects. The figure 5 shows an example of a GameObject.

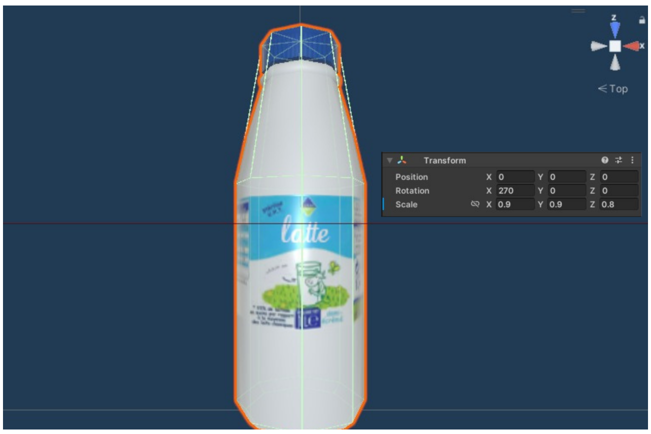


Figure 6: Example of Game object used in the supermarket scene with its transform

4.2. Scene Design

Two distinct VR game environments were created for scene design: a supermarket and a coffee shop. In both scenarios, the user can walk freely within the virtual environment and benefit from 6-degrees-of-freedom (6DoF) control, which allows both rotational (yaw, pitch, roll) and translational (forward/backward, up/down, left/right) movements. Both were created using prefabs available in Unity's Asset Store [23][24], which provided a base of preconfigured elements, facilitating scenario construction.

The 3D models included in the packages not only offer a wide range of characteristic objects for each scenario—shelves, groceries, checkouts, and refrigerators for the supermarket, and furniture such as tables, chairs, counters, appliances, and specific products for the cafeteria—but also integrate the management of Levels of Detail (LOD), a feature that will be explored in greater detail in the following section. In our case, we used LOD 0 for the products utilized in the game to ensure maximum visual quality for interactive elements.

The scene structure (See Figure 8), for both scenarios and for each task, remains the same through all levels of play. It was designed specifically to fit the environment of the computer classroom at Fundación Juan XXIII (See Figure 7).

Both original scenarios were too large to be used entirely as a play area. Therefore, significant changes were made to adapt them to the needs of the project.

In the case of the supermarket, the space was reduced by eliminating unnecessary aisles and retaining a single main aisle with three shelves and a table, which are the key elements of the game. Instead, a refrigerator, a cash register and surrounding areas, such as the parking lot and the continuation of the aisle beyond shelf 3, were retained to recreate an environment as realistic and similar to a real supermarket as possible. However, these additional parts are not part of the actual play area and serve only to enhance user immersion.

In terms of the cafeteria, the playing area was also reorganized by redistributing the tables; in addition, the areas accessible to players were clearly marked with security tape to prevent participants from moving outside the designated gameplay areas. Tables were shrunk and numbered; in addition, unnecessary items were removed, leaving only those essential for the gameplay activities. Again, some areas were kept as part of the scenery, but without being included in the actual gameplay area, in order to recreate as realistic an atmosphere as possible.

An additional aspect addressed during the creation of the scene was the method of grabbing objects. Previous studies [18] revealed that users tended to hold the controller in a way that made the use of the grip button instead of the trigger more intuitive to perform this action.

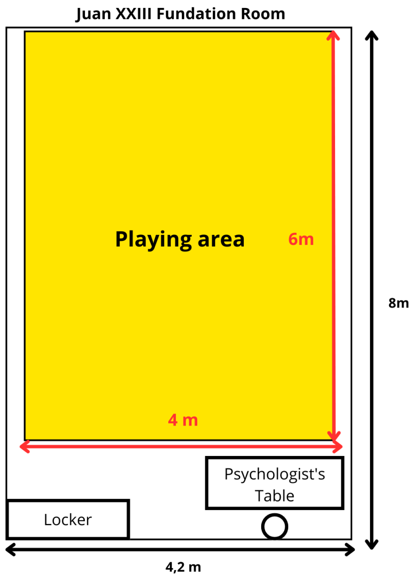


Figure 7: Floor plans of the Fundación Juan XXIII

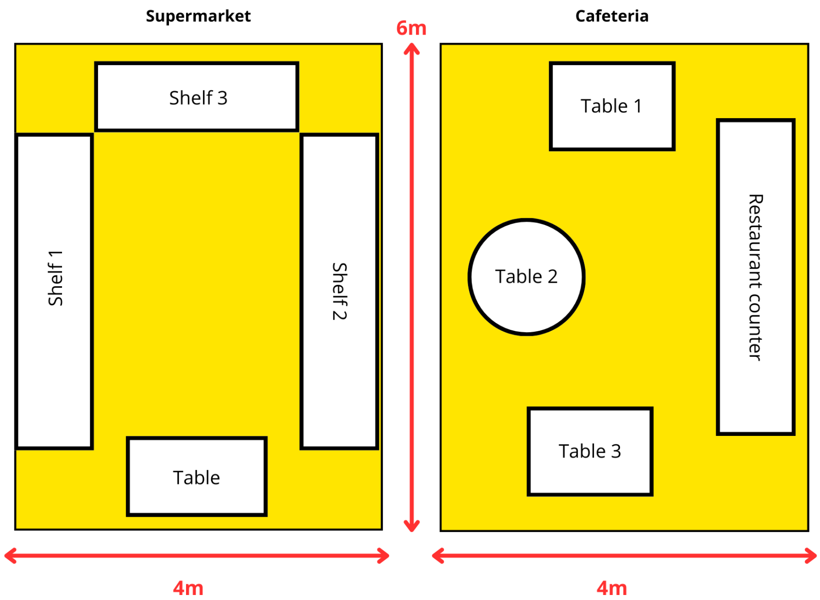


Figure 8: Floor plans of the supermarket and cafeteria

4.2.1. LOD

This technique is designed to improve graphics performance optimization by reducing the load on the GPU during rendering. LOD works by dynamically adjusting the level of detail of a model based on the distance from the camera. To implement this technique, each 3D model has multiple versions of its geometry, each characterized by decreasing polygonal complexity. When an object is close to the camera, Unity uses the highest level of detail, ensuring the highest visual quality. Conversely, when the object is at a greater distance, Unity automatically switches to simplified versions of the model, with fewer triangles, thus reducing computational load. LODs are configured as child GameObjects, each with a Mesh Renderer component that determines what level of detail to show based on the model's distance from the camera. The image below (See Figure 9)[24] shows a GameObject example of the supermarket package, represented by a shopping cart. Specifically:

- **LOD 00**: 7070 triangles, the maximum detail level, used for close-up viewing.
- **LOD 01**: 3774 triangles, a simplified version for intermediate distances.
- **LOD 02**: 1996 triangles, a significant reduction for longer distances.
- **LOD 03**: 746 triangles, the minimum level of detail, used for very distant objects.

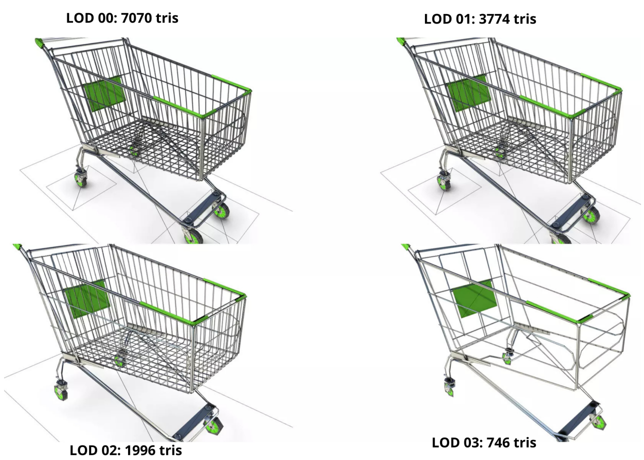


Figure 9: Example of LOD implementation on a Shopping Cart Model

4.3. Task design

In this project, several tasks were developed specifically designed for cafeteria and supermarket settings, with the goal of providing realistic and immersive virtual experiences. Each task is designed to stimulate natural interaction with the virtual environment, offering challenges that gradually evolve according to the player's abilities. This approach allows participants to progressively acquire new cognitive and motor skills, while also enhancing soft skills such as observation, attention to detail, and problem-solving ability.

Activities focus on everyday tasks such as serving tables, picking up dirty dishes, filling shelves or preparing orders, recreating scenarios that combine the realism of simulation with the engaging structure of gamification. Through the progression of difficulty levels and the introduction of dynamic elements, the tasks not only provide a challenging and immersive experience, but also contribute to the development of practical skills in a safe and controlled environment.

4.3.1. Supermarket tasks

- **Task 1: Filling the Shelves.**

The "Filling the Shelves" task is an activity designed to simulate reordering and organizing products in a virtual supermarket. It consists of taking products placed on an initial table and placing them in the empty shelf spaces distributed throughout the environment. Each empty space on the shelves is specifically assigned to a product type, requiring users to correctly identify items and place them in the right place.

The main objective of the task is to ensure that products are correctly arranged on the shelves, taking care not to place wrong or unnecessary items. The difficulty gradually increases with the introduction of distractors, such as products that do not have an assigned space or are already on the shelves, requiring users to carefully observe and evaluate before acting. In addition, the arrangement of products on the shelves changes randomly at each level, eliminating the possibility of mechanical memorization.
The following two images illustrate the scenario of the task (See Figure 10 and Figure 11).

Skills coached with the task:

1. **Attention**

   Users must carefully analyze the shelves to identify empty spaces and distinguish correct products from incorrect or already present ones. The introduction of distractors, such as unnecessary or misplaced items, demands constant attention and accurate evaluation of every action.

2. **Visuomotor coordination**

   The task requires users to pick up a product from the table and place it in the correct spot on the shelves, thereby improving synchronization between visual perception and physical movements.

3. **Memory**

   Even though the products on the shelves change frequently, users need to temporarily remember which items are needed and where the empty spaces are, training their short-term memory.

4. **Concentration:**

   Increasing complexity in advanced levels, with a greater number of products to handle and a more dynamic environment, helps improve the ability to remain calm and maintain focus under pressure.

These skills are closely related to future employment in a supermarket and provide a real opportunity to train practical, soft skills required in the world of work.

Figure 10: Virtual reality scene of Task 1 and Task 2 in a supermarket with a view on the shelves.

Figure 11: Virtual reality scene of Task 1 in supermarket with table view.

For task 1, a script was developed that represents the logical heart of the system. The main objective of this script is to dynamically manage the removal and repositioning of products on the shelves, add distractor products to increase the complexity of the task, and constantly monitor the player's performance, recording both errors and successes, managing the screw system and the whole logic of the game.

Each shelf consists of boxes containing specific products. At the beginning of a level, the script randomly selects a box from the shelves, deactivates it and leaves an empty hole in its place. Knowing the name of the deactivated product, the script searches for its counterpart in a GameObject containing individual products and activates it (or clones it in the case of repetitions), repositioning it following a predefined list of available positions. Each product placed on the table has a collider and a control script which, upon contact with the deactivated box collider, reactivates it, creating the illusion that the object has been put back in place.

- **Task 2: Complete orders**

«Complete orders» task is based on a similar mechanism as Task 1, with added complexity related to the handling of specific orders. The user is faced with a virtual environment that includes shelves containing various supermarket products and up to three «order bubbles» representing orders to be completed. Each «order bubble» specifies a list of products to be taken from the shelves and placed in the corresponding checkouts. When an order bubble fills up with products, the user must identify the indicated products; next, they must explore the environment to locate the required products, select them accurately, and place them in the designated crate associated with the corresponding order. As the levels advance, the complexity increases: the shelves to be checked become more numerous, the products more similar to each other, and the orders include more items to be handled. The goal is to complete each order accurately, avoiding mistakes. Below image shows the scene part with order bubbles (See Figure 12), while the shelves part is like the one in task 1 (See Figure 11).

Skills coached with the task:

- **Attention:** Users learn to distinguish between similar products and select the correct ones for each order, improving accuracy in item recognition.
- **Memory:** The task requires temporarily memorizing the products listed in the bubbles while exploring the shelves, strengthening short-term information retention.
- **Visual-Motor Coordination:** The task stimulates synchronization between visual perception of the products and their correct placement in the associated crates.
- **Concentration:** The dynamic environment, with multiple bubbles and products to manage, demands sustained attention to avoid errors.

Figure 12: Virtual reality scene of Task 2 in supermarket with orders view.

Through the implementation of this project, we believe that the skills developed and practiced in a simulated environment can be effectively transferred to the workplace, with applications not only in supermarkets but also in warehouses and similar sectors.

A dedicated script was also developed for Task 2, which manages the entire simulation system for order picking and completion. This script is the main engine of the task, coordinating the configuration of orders, dynamic shelf management and the precise positioning of products. The orders, dynamically generated for each level, specify both the number and type of products required. These are not simply static lists: the script adapts the content of the orders to the current level and the conditions of the game. After selecting the required products, the script places them in the order bubbles following a well-defined logic. Each product occupies a unique position within the container, preventing overlaps and ensuring a clear and orderly organisation. For some items, such as fruit or irregularly shaped objects, the script handles specific orientations and placements, respecting the characteristics of the products.Furthermore, as in Task 1, the script constantly monitors the player's performance, recording both errors and successes.

4.3.2. Cafeteria tasks

- **Task 1: Collect Dirty Dishes.**

Task 1 is designed to simulate the collection and disposal of dirty dishes in a virtual cafeteria. The user interacts with a scene featuring three numbered tables and a high bar designated for collecting dirty dishes. The primary objective is to collect dirty dishes that randomly appear on the tables and transport them to the designated bar for proper disposal. Initially, dirty dishes are placed on one table, while clean dishes are placed on another. As the levels progress, new elements such as dishes with clean food and dirty dishes of different types are introduced, creating more complexity. In addition, dirty and clean dishes begin to mix on the same table, requiring more attention from the user. This is explained in more detail in the section on levels. The image below illustrates the scene for Task 1 in the cafeteria(See Figure 14). Skills Coached with the task:

1. **Attention**

   Users must precisely distinguish between dirty and clean dishes, focusing on details to avoid errors.

2. **Visuomotor Coordination**

The activity requires users to pick up the dishes and transport them to the bar, enhancing the synchronization between visual perception and physical movements.

3. **Memory**

   As the variety of dishes increases, users must temporarily remember which items to collect and which to avoid.

4. **Concentration**

   The increasing complexity demands a high level of focus throughout the task.

Figure 13: Virtual reality scene of Task 1 in cafeteria.

- **Task 2: Serving Orders**

In this task, the user is in a scene with three numbered tables, similar to Task 1, but with one key difference: some tables have order bubbles, which represent an order to be completed. The orders contain a list of food or drinks that the user must pick up from the bar and place in the corresponding circles on the tables. The order bubbles and circles are activated only when the user needs to complete an order, guiding the user in the execution of the task in a clear and direct way. Below image shows the scene part with order bubbles. (See Figure 14) Skills Coached with the task:

1. **Attention**

Users must distinguish between similar foods and drinks, selecting the correct ones for each order.

2. **Memory**

   The activity requires temporarily remembering order details while interacting with the environment.

3. **Visuomotor Coordination**

   The need to pick up and place items improves synchronization between vision and movements.

4. **Concentration**

   Managing multiple orders and items requires a strong ability to maintain focus and avoid errors.

Figure 14: Virtual reality scene of Task 2 in cafeteria.

Both cafeteria tasks are designed to provide an immersive and educational experience, enhancing the practical skills needed for a real-world work setting.

4.3.3. Errors and successes

During the task definition phase, special attention was paid to handling errors and successes. We focused on clearly identifying what constitutes an error, asking fundamental questions such as, “What can be considered an error?” and “What actions determine success?” This analysis allowed us to define precise criteria for evaluating user performance, ensuring that each interaction was properly monitored and interpreted within the virtual environment.

We felt it was appropriate to define that, in the supermarket context, an error occurs when the user places a product in the wrong place on the shelves or in the checkouts, or selects and places an unsolicited item, such as a distractor present on the table. In contrast, success is the ability to accurately identify the required products and place them correctly in their respective spaces or checkouts, completing orders or repositions accurately and following the instructions given. We also felt it was right not to consider dropping a product to the floor as an error, since that was not the main “goal” to be achieved with these tasks, focusing instead on the accuracy of selection and placement.

In the case of the cafeteria, picking up clean dishes instead of dirty ones, or placing a dirty dish in an undesignated spot, such as a location other than the default bar, has been defined as an error. Similarly, picking up the wrong product or placing it in the wrong circle is an action considered wrong, as is not completing the required task or confusing similar orders by serving products not designated. Success, on the other hand, is measured in the ability to correctly pick up the dirty dishes and bring them to the bar, as well as accurately serve the required products in the orders in their respective circles.

Errors and successes are fundamental aspects of the gameplay and play a critical role in shaping the user’s experience. These concepts will be explored in greater detail in the section dedicated to level design. In both scenes, errors and successes are represented visually, via Unity’s canvas, as shown in the Figure 15. This immediate feedback system allows users to quickly understand whether their actions are correct or incorrect.

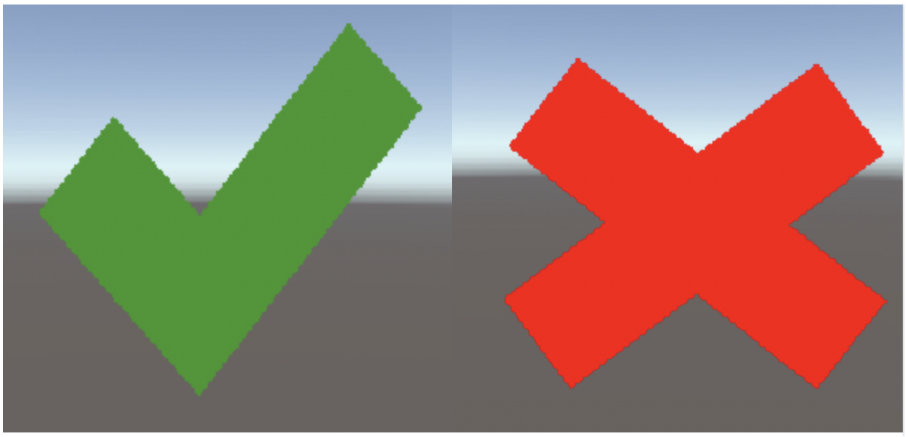


Figure 15: Canvas successes and errors.

4.3.4. Instructions

During the design of the tasks, the issue of instructions to be given during the game was also addressed. Some of these were integrated directly into the game through the use of Unity's Canvas (See Figure 16), offering immediate and visible instructions to the user during the course of the task. Other instructions, on the other hand, will be dealt with in more detail in the section dedicated to the introduction of the application used by the psychologist, which will provide a broader and more detailed context on the user experience.

Figure 16: Canvas instructions.

4.4. Levels Design

Once the contents and objectives of the tasks in the two scenarios had been defined, we proceeded with the level design phase. This phase allowed tasks to be structured in a progressive manner, gradually introducing elements of complexity. In agreement with the psychologists, it was decided to structure the game into 6 levels, each consisting of 3 repetitions. Each level begins with a total of 3 lives available to the user. For every 3 errors made, the user loses one life and must restart the current repetition. If all three lives are lost, the user will need to restart the entire level from the beginning, ensuring a gradual and engaging challenge that encourages focus and accuracy. All of this is visually explained in Figure 15.
In the image we can see that the graphic on the left illustrates the sequential structure of the game, designed to gradually guide the user through the virtual reality experience and introduce them to its dynamics. This progression is divided into a series of phases that accompany the user from initial familiarization to the completion of more complex levels.

The first phase, called familiarization with VR, aims to introduce the user to the virtual environment. It consists of the total immersion of the user in two distinct scenarios, the sea and the mountain.

Next, we move on to the Training - Level 0 phase, entirely dedicated to training. In this phase, simplified tasks are introduced, designed to teach the basics of gameplay, such as picking up and placing objects or following instructions.

Once the training level is completed, the user proceeds to the six main levels, each characterized by a progressive difficulty. In these levels, the tasks become increasingly challenging due to the introduction of distractors, more complex interactions and an increase in the amount of items to manage.

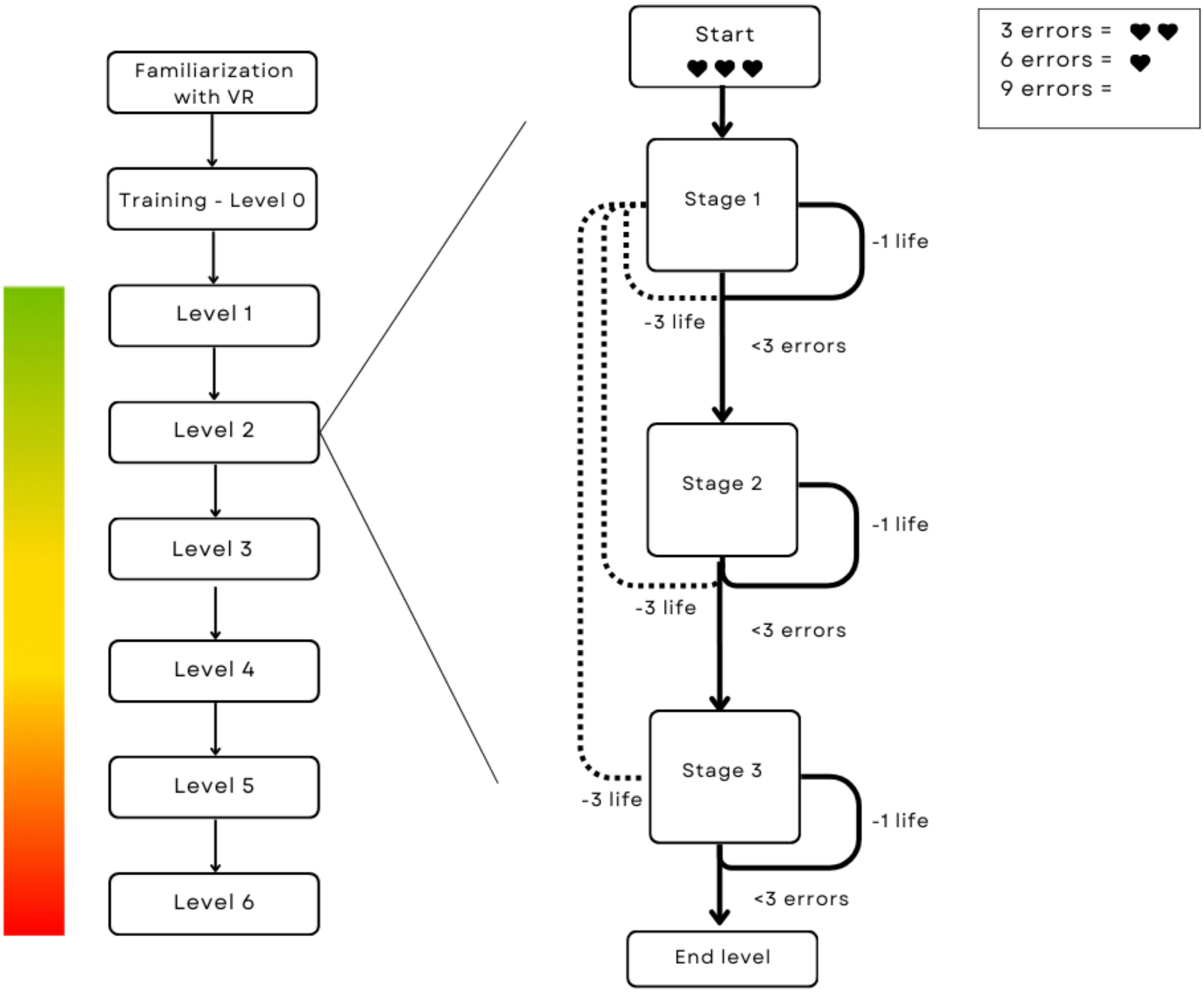


Figure 17: The left-hand side of the picture shows the sequence of steps, starting with the virtual reality familiarization session and continuing until the completion of level six. On the right hand side, the specific operation of each level is illustrated, showing the screw mechanism, permissible errors and the retry system in case of failure.

As described in section 4.3.3, errors and successes are communicated to the user through a canvas and sounds, as well as being recorded within the application through a script that manages the transition between stages and levels. However, in addition to errors, any significant event such as the completion of a repetition, the end of a level, the loss of a life or the total loss of lives (Game Over) is also communicated to the user via a canvas and sounds.

Figure 18: Canvas that warns the user that it is necessary to restart the repetition in progress because the allowed error limit has been reached. The user has lost a life.

Figure 19: Canvas indicating that the user has failed the level by losing all three available lives.

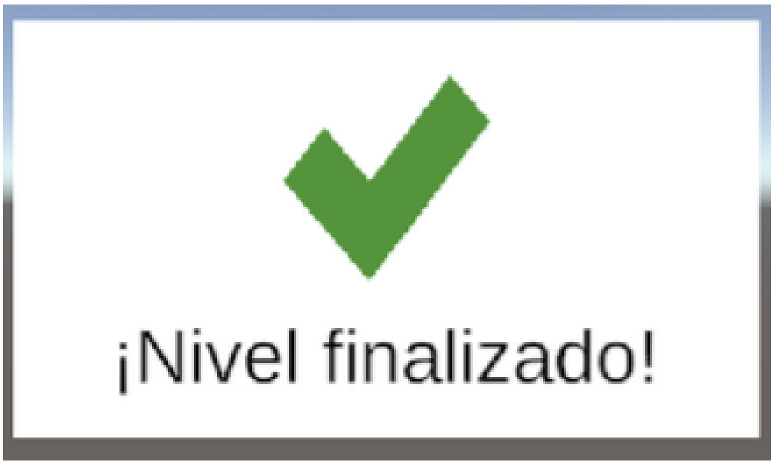


Figure 20: Canvas used to communicate the successful completion of a level or a phase to the user, signaling that they can proceed to the next stage of the game.

The same game logic and level structure is applied to both tasks, for both the supermarket and the cafeteria. However, with one difference: for Task 2, users will start directly from Level 1, as they will have already familiarized themselves with virtual reality during the previous phases.

4.4.1. Level monitoring

In both tasks in both areas, a game monitoring system was developed, designed to allow us to observe and analyse the flow of the game and, if necessary, identify any anomalies.

To analyse player behaviour and programme flow, log entries were implemented in the codes to monitor significant events during programme execution. These events include:

- `logSaver.SetLogEvent('Lanza_Acierto');`

  Logs an event to indicate that a success has been achieved

- `logSaver.SetLogEvent("Lanza_Error");`

  Logs an event to indicate that an error has occurred.

- `logSaver.SetLogEvent('3Errores_Nivel'+totalRepeatCount+ '_ReiniciaNivel');`

  Logs an event when three errors are made in a level.

- `logSaver.SetLogEvent('Pierde3Vidas_Nivel'+ totalRepeatCount + '_VuelveNivelAnterior');`

  Registers an event when the player loses three lives in the current level.

- `logSaver.SetLogEvent('Nivel_finalizado_' + SceneManager.GetActiveScene().name + '_' + currentLevel + '_Repeticion_' + totalRepeatCount);`

  Registers an event when a level is completed.

- `logSaver.SetLogEvent('Fin_Niveles');`

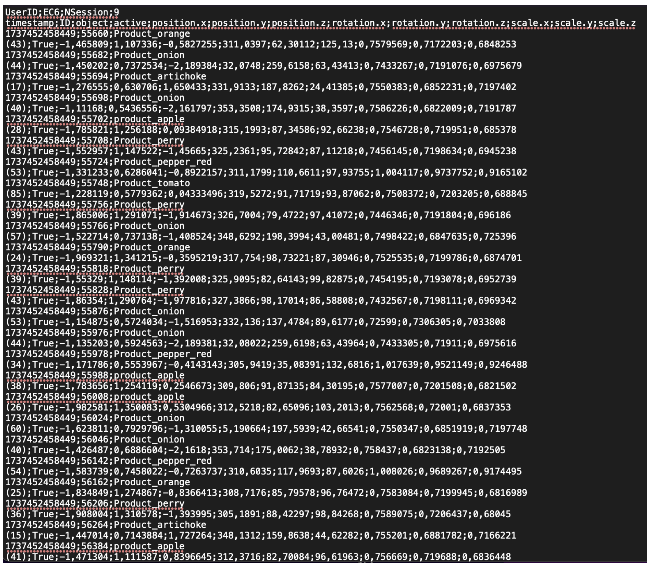
  Logs an event indicating the end of the game

At the end of each session, all data relating to each player is collected, as shown in the example in Figure 21. This data provides a detailed overview of the player's behaviour by showing information such as successes, errors, level restarts and completions.

```
UserID,EC6,NSession,9,ManoE4,mano_izquierda
TimeStamp,EVENT
1737452399674,Escena_EyeTrackingTest
1737452399820,StartCalibrationTest
1737452405423,False_separadores_estanterías
1737452456534,Escena_Supermercado_Tarea_1;Nivel3
1737452570246,Lanza_Acierto
1737452587812,Lanza_Acierto
1737452654188,Lanza_Acierto
1737452734853,Lanza_Acierto
1737452758048,Lanza_Acierto
1737452758649,Nivel_finalizado_Supermercado_Tarea_1_3_Repeticion_1
1737452783004,Lanza_Error
1737452783446,Lanza_Error
1737452784886,Lanza_Error
1737452784887,3Errores_Nivel_1_ReiniciaNivel
1737452806522,Lanza_Acierto
1737452826015,Lanza_Acierto
1737452843301,Lanza_Acierto
1737452865812,Lanza_Acierto
1737452881685,Lanza_Acierto
1737452882105,Nivel_finalizado_Supermercado_Tarea_1_3_Repeticion_3
1737452903012,Lanza_Acierto
1737452924571,Lanza_Acierto
1737452943698,Lanza_Acierto
1737452956906,Lanza_Acierto
1737452972127,Lanza_Error
1737452972392,Lanza_Error
1737452992059,Lanza_Acierto
1737452992157,Nivel_finalizado_Supermercado_Tarea_1_3_Repeticion_4
1737452992157,Fin_Niveles
1737453040126,Escena_EyeTrackingTest
1737453040329,StartCalibrationTest
```

Figure 21: Example of the generation of session logs. Including player and session data, initiation of calibration tests, completion of levels, error detection and correct execution of tasks.

In addition to significant events, the collection of data such as the position, rotation and state of objects provides detailed insight into the dynamics of user interaction within the game. Unity provides native tools, such as the Transform component, to monitor the position, rotation and scale of each object. The registration system relies on access to this data via a script that monitors the objects and performs near real-time scans collecting position, rotation and scale information. Each GameObject is assigned a tag: DynamicObject , each time an object with this tag is moved, the system automatically records the new coordinates along with the associated timestamp, creating a precise track of each change (See Figure 22).



```
UserID;EC6;NSession;9
timestamp;ID;object;active;position.x;position.y;position.z;rotation.x;rotation.y;rotation.z;scale.x;scale.y;scale.z
1737452458449;55660;Product_orange
(43);True;-1,465809;1,107336;-0,5827255;311,0397;62,30112;125,13;0,7579569;0,7172203;0,6848253
1737452458449;55682;Product_onion
(44);True;-1,450202;0,7372534;-2,189384;32,0748;259,6158;63,43413;0,7433267;0,7191076;0,6975679
1737452458449;55694;Product_artichoke
(17);True;-1,276555;0,630706;1,650433;331,9133;187,8262;24,41385;0,7550383;0,6852231;0,7197402
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(25);True;-1,834849;1,274867;-0,8366413;308,7176;85,79578;96,76472;0,7583084;0,7199945;0,6816989
1737452458449;56206;Product_perry
(36);True;-1,908004;1,310578;-1,393995;305,1891;88,42297;98,84268;0,7589075;0,7206437;0,68045
1737452458449;56264;Product_artichoke
(15);True;-1,447014;0,7143884;1,727264;348,1312;159,8638;44,62282;0,755201;0,6881782;0,7166221
1737452458449;56384;product_apple
(41);True;-1,471304;1,111587;0,8396645;312,3716;82,70084;96,61963;0,756669;0,719688;0,6836448
```


Figure 22: Example of session monitoring data in Unity. The dataset records detailed information about each object in the scene, including its unique ID, name, activity status, position, rotation, and scale in 3D space.

Thanks to all this information, it is possible to observe the game's progression and analyze the user's behavior during the session, allowing us to identify and diagnose any anomalies or issues that occurred during execution.

4.4.2. Supermarket

Whenever a level is selected through the application (Subject discussed in the paragraph 5.1.1), a variable containing the level number is transmitted. This variable is used by the script to determine and configure all the specific characteristics of the level, ensuring that the gaming experience is customized based on the difficulty and the elements expected for that level.

```
public int GetShelvesByLevel(int level)
{
    Debug.LogWarning("!!!! Entrto in GetShelvesByLevel");


    currentLevel = level;
    // SHELVES

    shelvesByLevel.Add(new List<GameObject> { shelveComida, shelveLibros }); // Livello 1
    shelvesByLevel.Add(new List<GameObject> { shelveComida, shelveLibros }); // Livello 2
    shelvesByLevel.Add(new List<GameObject> { shelveComida, shelveLibros }); // Livello 3
    shelvesByLevel.Add(new List<GameObject> { shelveComida, shelveLibros }); // Livello 4
    shelvesByLevel.Add(new List<GameObject> { shelveComida, shelveLibros, shelveFruta }); // Livello 5
    shelvesByLevel.Add(new List<GameObject> { shelveComida, shelveLibros, shelveFruta }); // Livello 6


    Debug.Log("!!!! shelvesByLevel popolato con Count = " + shelvesByLevel.Count);

    // Non e selezionato nessun livello

    if (level < 1 || level > shelvesByLevel.Count)
    {
        Debug.LogWarning("Livello non valido: " + level);
        game_shelves = new List<GameObject>();
        return -1;
    }

    // Aggiorna shelves con livello selezionato

    game_shelves = shelvesByLevel[level - 1];
    Debug.LogWarning("Livello Selezionato con: " + game_shelves);

    foreach (GameObject shelf in game_shelves)
    {
        Debug.LogWarning("Quale scaffale: " + shelf.name);
    }

    // PRODOTTI DA RIMETTERE IN ORDINE

    productsByLevel = new List<int> { 1, 1, 2, 2, 3, 2 };
    NumberProducts = productsByLevel[level - 1];
    Debug.Log("!!!! Numero di prodotti da scegliere per il livello " + level + ": " + NumberProducts);

    // PRODOTTI RANDOM

    RandomProducts = new List<int> { 0, 0, 1, 2, 3, 4 };
    NumberProductsRandom = RandomProducts[level - 1];

    // PRODOTTI RANDOM NON PRESENTI NEL SUPERMERCATO

    RandomProductsDiff = new List<int> { 0, 1, 1, 1, 1, 2 };
    NumberProductsRandomDiff = RandomProductsDiff[level - 1];

    return level;
}
```

Figure 23: A code example of Task 1 shows how the levels, shelves, products to be put back in order and distractor products are selected.

The code for Task 2 follows a similar logic to that of Task 1, but with one fundamental difference: no distracting products are inserted into the game. In this case, the focus is exclusively on the selection and placement of products that the participant must put back in order.

- **Task 1: Filling the Shelves.**

As detailed in Table 1, the various levels of Task 1 show a gradual increase in difficulty. This

increase is brought about by the gradual addition of products, shelves and distractor products. At each successive level, the cognitive load increases, requiring greater attention and distinguishing ability on the part of the participant.
Distractors, are items that appear on the table without having a specific space allocated for storage. They can include both objects already present on the shelves, as well as elements that are completely unrelated to the scene (See Figure 24) , thus contributing to increasing the complexity of the task.

Figure 24: Examples of distractors completely unrelated to the scene.

Objects play a fundamental role in the context of the game. Once the level has been selected, with all its characteristics (See Table 1), the shelves are filled. An exception is the fruit shelf, whose products remain unchanged.
The placement of products on the shelves is managed by dedicated scripts, which arrange the objects randomly, but following a logic that places products of the same type close together. The selection of objects to be placed on the shelves is done via Unity's inspector (See Figure 25).

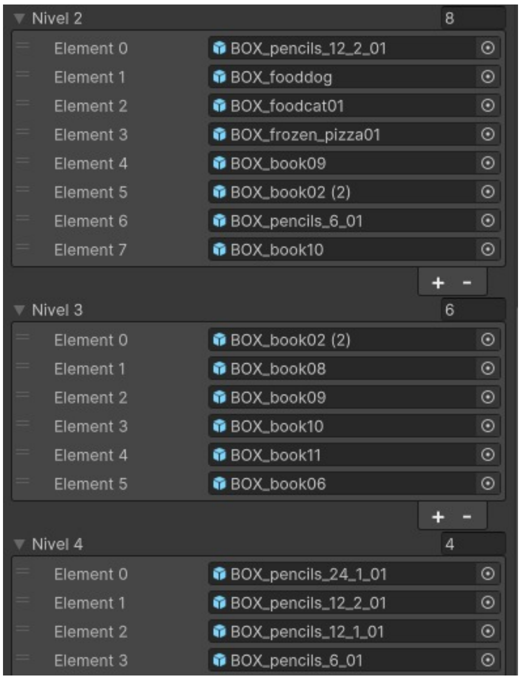


Figure 25: Example of product selection directly from the Unity inspector for shelf 3 levels 2,3,4

As the levels increase, not only the number of objects to be placed in order increases, but also their similarity.
In addition, a function was implemented for Task 1 to restore objects if they fall or end up misplaced. The script saves in advance a list containing the objects and their positions. Objects on the shelves, or which may have fallen to the ground, are deactivated, while all objects in the list are cloned and activated in the correct positions. Subsequently, a check is made on the objects to be put back in order, so that the previously deactivated case where the product is to be placed is deactivated.

The activation of this function automatically restores all objects to their original positions on the shelves, ensuring the correct progression of the game and preventing any interruptions caused by unforeseen events.

DIFFICULTY	LEVEL	DESCRIPTION	OBJECTS TO RESTORE
Easy	N1	One object appears on the table at a time and must be placed on one of the two shelves. There are no distractors.	5 obj x 3 rep = 15 obj
	N2	On the table there are objects that must be placed on two shelves. There is a distractor, which is an object that is not on any of the shelves.	5 obj x 3 rep = 15 obj
Medium	N3	One object appears on the table at a time that must be placed on one of the two shelves. In addition, there are two distractors: one is an object that is not on either of the shelves, and the other is an object that is present on the shelves, but does not need to be replaced. The products within the shelves are more similar.	5 obj x 3 rep = 15 obj
	N4	Two objects appear on the table at the same time that need to be placed on two shelves. There are three distractors on the table: one is an object that is not on any of the shelves, and two are objects that are present on the shelves, but do not need to be replaced.	5 obj x 3 rep = 15 obj
Difficult	N5	Three objects appear on the table at the same time and must be placed on three shelves. There are four distractors on the table: one is an object that is not on any of the shelves, and three are objects that are present on the shelves, but do not need to be replaced.	5 obj x 3 rep = 15 obj
	N6	Two objects appear on the table at a time that need to be placed on the three shelves. There are six distractors on the table: two are objects that are not on any of the shelves, and four are objects that are present on the shelves, but do not need to be replaced.	5 obj x 3 rep = 15 obj

Table 1: Levels of Task 1 in the supermarket game.

- **Task 2: Complete orders**

As far as Task 2 is concerned, the management of levels follows a logic similar to that of Task 1, but without the introduction of distracting products. At each level progression, the number of orders to be completed and the amount of objects contained in each order are determined in addition to the products. All characteristics of the levels are shown in Table 2.

The main difficulty in this mode lies not only in the increasing number of shelves, but also in the increasing similarity of products (The Figure 26 and Figure 27 show examples of similar products). Each level is designed to increase both the number of objects to be arranged and the degree of similarity between them, making the task progressively more challenging for the user.

Figure 26: Example of similar products used for shelve 2

Figure 27: Example of similar products used for shelve 3

Once the products have been selected according to level, number of orders and number of objects for each order, a dedicated script automatically generates the agreed quantity of objects for each order. At this point, the user can start selecting the objects and placing them in the appropriate boxes.

DIFFICULTY	LEVEL	DESCRIPTION	OBJECTS TO RE-STORE
Easy	N1	Products appear in a bubble, and they must be selected and taken to the boxes to complete the orders. The products belong to one shelf.	Order 1: 5 obj 5 obj x 3 rep = 15 obj
	N2	Products appear in a bubble, and they must be selected and taken to the boxes to complete the orders. Now, the products are more similar. The products belong to one shelf.	Order 1: 5 obj 5 obj x 3 rep = 15 obj
Medium	N3	Products appear in two bubbles, and they must be selected and taken to their respective boxes to complete the orders. The products belong to two shelves.	Order 1: 2 obj Order 2: 4 obj 6 obj x 3 rep = 18 obj
	N4	Products appear in two bubbles, and they must be selected and taken to their respective boxes to complete the orders. The products belong to two shelves.	Order 1: 3 obj Order 2: 3 obj 6 obj x 3 rep = 18 obj
Difficult	N5	Products appear in three bubbles, and they must be selected and taken to their respective boxes to complete the orders. The products belong to three shelves.	Order 1: 2 obj Order 2: 3 obj Order 3: 3 obj 8 obj x 3 rep = 24 obj
	N6	Products appear in three bubbles, and they must be selected and taken to their respective boxes to complete the orders. The products belong to three shelves and are now more similar.	Order 1: 1 obj Order 2: 4 obj Order 3: 3 obj 8 obj x 3 rep = 24 obj

Table 2: Levels of Task 2 in the supermarket game.

4.4.3. Cafeteria Tasks

Also in the cafeteria, the six levels are designed to progress from the simplest to the most complex, gradually increasing in difficulty through the handling of objects. Each level introduces new combinations and a greater variety of elements, requiring the player to pay increasing attention.

- **Task 1: Collect Dirty Dishes.**

In the first task, which consists of collecting dirty dishes, only dirty dishes and food residues were included. To simplify and not overload the initial environment, the implementation started with only one type of food on the plates. As levels progress, the variety of food increases, up to six different types of food and four different types of dirty dishes. This increase in variety makes the levels progressively more complex. Selected foods include dishes with toast, hamburgers, pies, pizza, cheese and chicken, while dirty dishes include pizza remains, chicken wings, eggs and fruit. Below is the table with information on all levels (See Table 3)

- **Task 2: Serving orders**

In the second activity, the focus shifts to the serving of orders, which includes both food and drinks. For this activity, various beverages were chosen that, in the initial levels, have an easily distinguishable appearance. As the player progresses through the levels, more similar-looking drinks (such as different types of juices or similarly colored drinks) are introduced, with the intention of increasing the difficulty in recognition and selection. The foods selected are the same as in the first activity, presented in pairs or groups of four with similar characteristics, while the drinks include bottles of water, wine, beer, juices, coffee and fizzy drinks. As levels progress, the number of drinks with similar appearance increases, making the task increasingly challenging. The table below contains information on all levels (See Table 4) and a graphic example of the objects chosen for level 4 (See Figure 28).

Figure 28: Example of products used for level 4

DIFFICULTY	LEVEL	DESCRIPTION	OBJECTS TO COLLECT
Easy	N1	Dirty plates appear on one table and clean plates on another table. All clean plates are of the same food type. All dirty plates are identical. When collected, more plates appear on another table.	2 obj x 3 rounds = 6 obj 6 obj x 3 rep = 18 obj
	N2	Dirty plates appear on one table and clean plates on other tables. The clean plates contain different foods (3 types). All dirty plates are identical. When collected, more plates appear.	3 obj x 2 rounds = 6 obj 6 obj x 3 rep = 18 obj
Medium	N3	Dirty plates appear on two tables and clean plates on another. The clean plates contain different foods (6 types).	6 obj x 1 round = 6 obj 6 obj x 3 rep = 18 obj
	N4	Dirty and clean plates appear on three tables. When collected, more plates appear. This time, the dirty and clean plates are mixed.	6 obj x 1 round = 6 obj 6 obj x 3 rep = 18 obj
Difficult	N5	Dirty and clean plates appear on three tables. Now there are 2 different types of dirty plates. The dirty and clean plates are mixed.	6 obj x 1 round = 6 obj 6 obj x 3 rep = 18 obj
	N6	Dirty and clean plates appear on three tables. Now there are 4 different types of dirty plates. When collected, more plates appear. The dirty and clean plates are mixed.	6 obj x 1 round = 6 obj 6 obj x 3 rep = 18 obj

Table 3: Levels of Task 1 in the cafeteria game.

DIFFICULTY	LEVEL	DESCRIPTION	OBJECTS TO SERVE
Easy	N1	An order appears on one of three different tables. Only drinks are present (6 different types).	1 obj x 5 rounds = 5 obj 5 obj x 3 rep = 15 obj
	N2	Two orders appear on two of three different tables. Food and drinks are mixed (6 types of each).	2 obj x 3 rounds = 6 obj 6 obj x 3 rep = 18 obj
Medium	N3	Three orders appear on three different tables. Food and drinks are mixed (6 types of each).	3 obj x 2 rounds = 6 obj 6 obj x 3 rep = 18 obj
	N4	Three orders appear on three different tables. Drinks and food are more complex. There are pairs of similar drinks and food.	3 obj x 2 rounds = 6 obj 6 obj x 3 rep = 18 obj
Difficult	N5	Six orders appear on three different tables (two per table).	6 obj x 1 round = 6 obj 6 obj x 3 rep = 18 obj
	N6	Six orders appear on three different tables (two per table). Drinks and food are more complex. There are groups of four similar drinks and food.	6 obj x 1 round = 6 obj 6 obj x 3 rep = 18 obj

Table 4: Levels of Task 2 in the cafeteria game.

4.5. Optimization based on feedback received

As a final optimization of the app, once the trials started, we started receiving feedback from the psychologists, which led to further final modifications.
For the supermarket scene:

- During gaming sessions, users were found to prone to placing products in spaces between objects, causing confusion. To solve this problem, a button was added which, via a script, allows the gray barriers between products to be activated or deactivated. These barriers were embedded directly in the prefabs of the objects and are switched on and off as required.
- A function has also been implemented, again via script, which allows all products to be repositioned on the table. This option allows items to be quickly restored to their original position in the event of confusion or errors, facilitating reordering. To achieve this, a method has been added to the main script which checks all active products to be put back in order and distracting active products in the scene. Once identified, these are deactivated and then reactivated in the table positions.
- All types of fruit were removed from the distractor products in level 1. This decision was made because the presence of fruit made it easier to make mistakes, as players tended to place the fruit on top of other fruit already present, without waiting for the box to be emptied.

For both scenes, we observed that users tended to overstep the boundaries of the play area. For this reason, a prohibition signal was introduced via canvas, accompanied by the vibration of the remote control, which is activated every time the user crosses the boundaries.

5. Development of the experiment

Before starting the actual sessions, we went to the Fundación Juan XXIII to carry out some preliminary tests. These trials were conducted with two users not participating in the experiment. User 1, having previously used Head Mounted Display devices, completed the tests with relative speed. User 2, on the other hand, having never worn a Head Mounted Display before, approached the tests more slowly and with some more difficulty.

The official sessions started on 10/10/2024. The psychologists selected eight participants for the experiment, whom we will identify as EC1, EC2, ..., EC8.

In this chapter, I will provide a detailed explanation of how a session is conducted and the materials and tools required for it to run smoothly.

5.1. Equipment

For the realisation of the project, the technologies described in the following paragraphs were used. In addition to those mentioned, two computers were used: one for the psychologist and one for the development of the application in Unity, a router for the connection, a smartphone for the use of the Empatica device and, of course, the HTC Vive XR - Elite head mouted display.

5.1.1. Control App

A key part of the sessions is the application, which allows customised sessions to be created for each user.

The application used (See Figure 29) allows advanced and customized control of therapy sessions through the TCP communication protocol, ensuring reliable and efficient data exchange. TCP is a connection-oriented protocol for network communication that creates WebSockets to send control commands from the monitor to the Unity app running on the HMDs, and receive data from the virtual environment. The system configuration also integrates tools such as the Android Debug Bridge (ADB), which allows starting, stopping, or configuring the application on the HMDs. Additionally, ADB enables the user's view to be mirrored on the therapist's monitor [18]. The user's view is transmitted to the therapist's computer via a wireless access point using scrcpy, a free and open-source screen mirroring application. Scrcpy primarily uses ADB over a wireless connection to ensure a real-time representation of user interactions, providing tools for monitoring and managing sessions. Finally, the system counts with an .ini configuration file, which makes it possible to dynamically customize network and session parameters without recompiling the software running on the HMD.

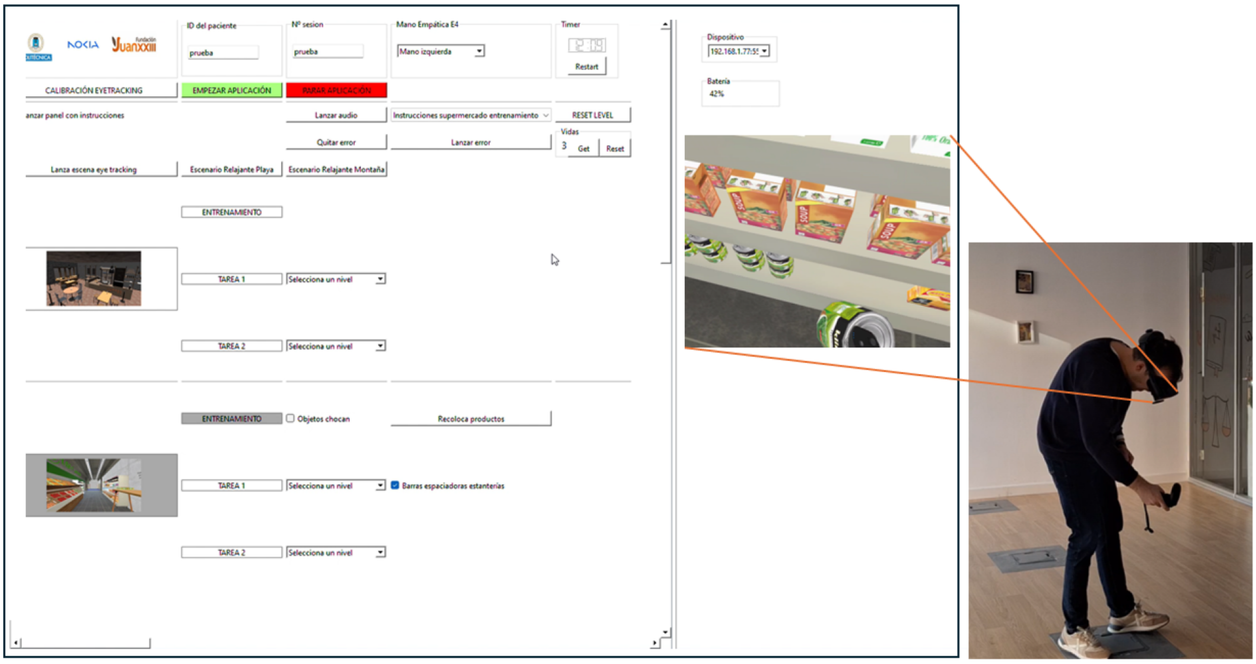


Figure 29: Application Screen: the left panel shows the control area and the right panel shows the user's viewport.

Through the interface, the psychologist can initiate game levels, launch calibration scenes, send customised audio instructions to the user, rearrange products or add bars to separate products in the virtual supermarket, reset the entire scene and launch errors and successes. As for the audio instructions, they were strategically implemented to offer direct and targeted support to the user during interaction with the virtual environment and are as follows:

- Instrucciones cafeteria entrenamiento
- Instrucciones supermercado entrenamiento
- Instrucciones cafeteria
- Instrucciones supermercado
- Anda hacia adelante
- Avanza

- Mira abajo
- Mira arriba
- Mira a la derecha
- Mira a la izquierda
- Mira detras

Before starting each session, the psychologist enters the patient's ID, the session number and the hand in which the patient has placed the Empatica EmbracePlus bracelet. Generally, to avoid interference or noise in the data, the device is placed on the hand opposite the one used by the patient to hold the remote control. At the end of each session, all data is automatically saved directly.

5.1.2. Empatica EmbracePlus bracelet

The Empatica, represented in the Figure 30, is an advanced wearable device designed for continuous, real-time physiological monitoring [25]. After being connected to the mobile phone and activated, it is worn by the patient during the session to detect various physiological parameters. These include electrodermal activity (EDA), which records skin conductance related to sympathetic nervous system activation, being particularly useful for detecting levels of stress, anxiety and arousal, monitors heart rate (HR), body movements and skin temperature.

The data collected is stored and subsequently synchronised with a cloud platform.

Figure 30: Empatica EmbracePlus bracelet

5.1.3. Cometa PicoBlue EMG sensors

We use wireless EMG sensors, represented in the Figure 31, to measure muscular tension, applied to the patient using adhesive electrodes. The sensors are placed in pairs: two on the arms and two on the shoulders [26]. These devices connect via Bluetooth to an application on the psychologist's computer.

Figure 31: Cometa PicoBlue EMG sensors

5.1.4. Eye tracker

Using the Eye Tracker, represented in the Figure 32, mounted on the HTC Vive XR Elite [13] and following calibration, allows us to have precise tracking of eye movements. It allows us to monitor and record the fixation point of the gaze, eye movements, and even the pupil diameter.

Figure 32: Eye tracker

5.2. Structure of a Session

The session begins with the application of HMDs and wearable devices, which begin to monitor the user. The user is made to sit on a chair placed in the centre of the room (See Figure 7), which is the starting point of the game. Subsequently, the chair is removed to allow the user total freedom of movement without obstacles.

Once the preparation is complete, an initial calibration is carried out via the eye tracker integrated in the HTC Vive XR Elite HMDs. Subsequently, the application starts a second calibration, specifically developed by us, characterised by a simpler, more intuitive and fun approach than the previous one. At the end of this phase, the game begins.

The user uses the HMDs for a time of approximately 30 minutes, the recommended limit to ensure safe and comfortable use. At the end of the session, the user proceeds to fill out the questionnaires.

The diagram below (See Figure 33) illustrates the sequence of steps just described.

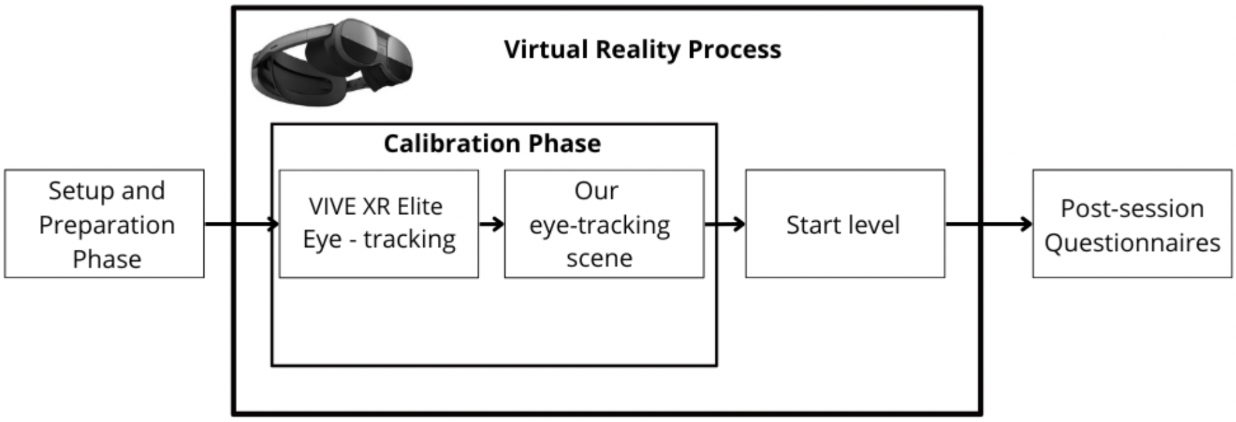


Figure 33: Flowchart of the Virtual Reality Process. The diagram outlines the sequence of phases in the virtual reality session, starting with the Setup and Preparation Phase, followed by the Calibration Phase. After calibration, users proceed to the level start, concluding with post-session questionnaires

5.2.1. Calibration Phase

The calibration phase is crucial for collecting data to analyze users' eye-tracking. As shown in the graph, this phase is divided into two distinct calibrations: one intrinsic to the HMDs, provided directly by the VIVE manufacturer, and another developed in the GTI lab. The second calibration scene was created in response to difficulties encountered by users during initial training sessions, as many struggled to complete the initial calibration process.

The main issue was that the calibration had to be launched directly from the HMD's main menu, requiring the user to use the controller to select the button and relaunch the calibration whenever it wasn't completed successfully. Despite attempts to contact the manufacturer, it was not possible to implement a feature to launch this scene directly from the therapist's application.

To address these limitations, a second calibration scene was developed, which can be launched directly from the therapist's computer. Additionally, this version was designed to be more intuitive and user-friendly, making the calibration process simpler and more accessible for users [27].

The scene was created using Unity. Upon launch, various icons, such as a flower or a teddy bear, will appear one at a time. The user will need to look at each icon until it disappears (See Figure 34).

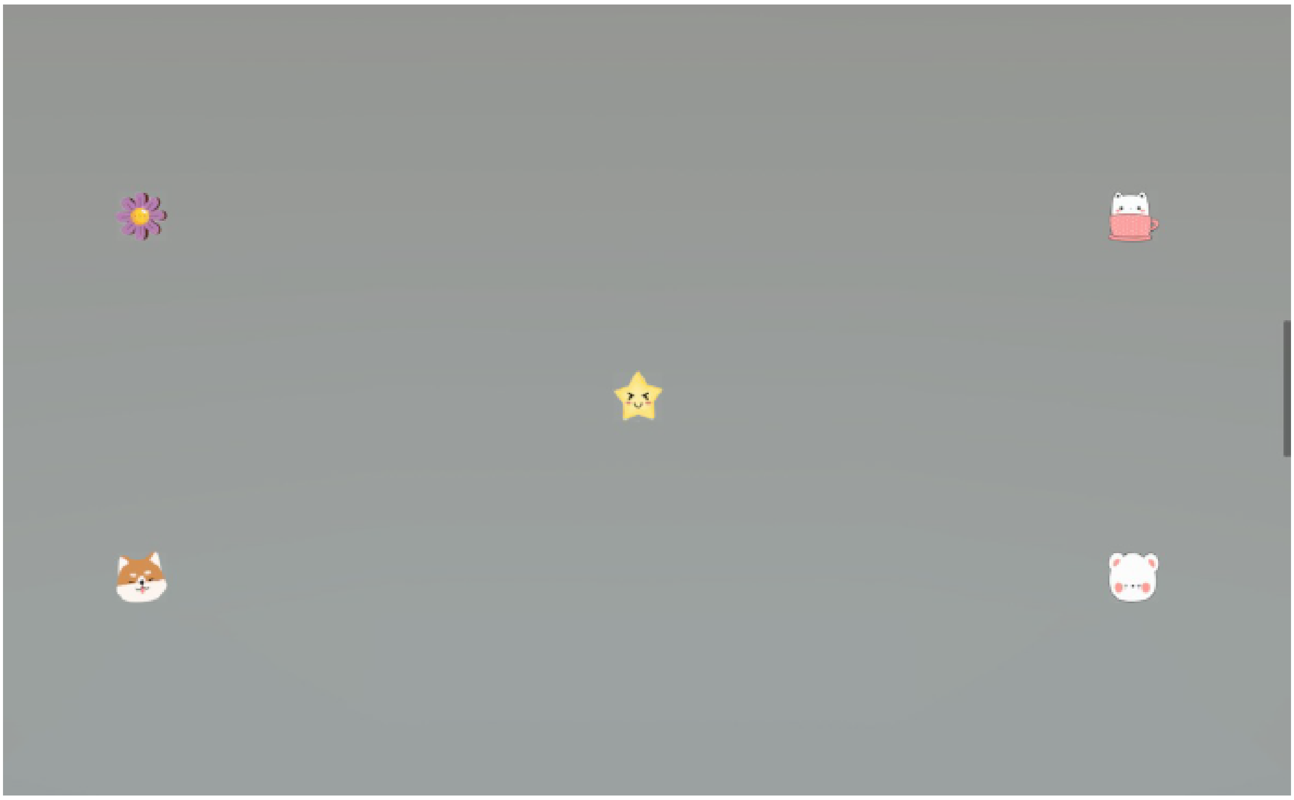


Figure 34: Example of the second calibration scene

5.2.2. Questionnaires

At the end of each session, the psychologist submits a questionnaire to the users to assess their subjective experience (overall, quality and performance), spatial presence, usability, sense of nausea, and mental load. This phase is crucial to gather concrete data and obtain measurable results on the effectiveness of the work carried out and QoE. Users can express their evaluations by choosing from the following options: Poorly, Regular, Very Good, Regular, Bad or Yes, Regular, No, depending on the question (See Figure 35).

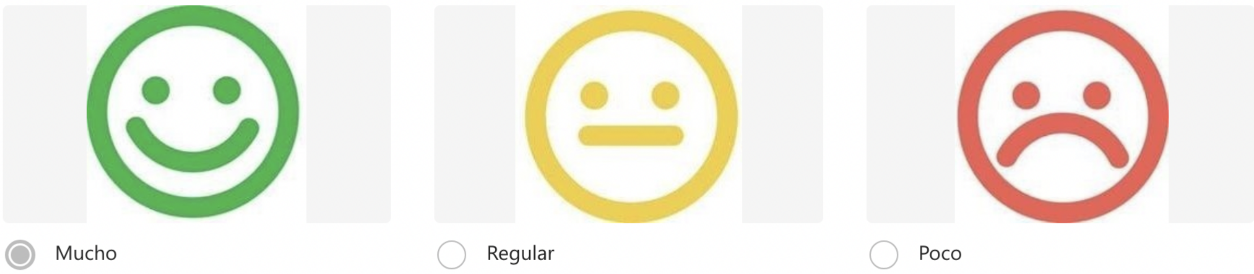


Figure 35: Example for the answer to a question in the questionnaire.

When designing questionnaires to assess the Quality of Experience (QoE) post-VR , it is essential to consider several psychological factors to ensure an accurate portrayal of the user experience and to minimize possible bias. For this reason, the questionnaires were carefully designed with the support of psychologists, taking into account the sense of presence in virtual reality [28].

Through targeted questions and the use of sensors during the session, the aim is to capture authentic emotional reactions, providing a more complete and detailed view of the entire user experience.

The use of Google Forms was chosen for its intuitive interface and excellent integration with Excel. This approach makes data collection efficient, accessible and user-friendly for both researchers and psychologists.

Below are the questions that were administered to the participants:

- **Spatial presence.**
  - ¿Has sentido que estabas realmente en una cafetería/supermercado?
  - ¿Has sentido que podías ver todo lo que estaba pasando en la cafetería/supermercado?

- ¿Has sentido que podías tocar las cosas que había en la cafetería/supermercado?

- **Experience (overall, quality and performance) subjective. Both cafeteria and supermarket.**
  - ¿Te ha gustado la experiencia?
  - ¿Veías bien la cafetería/supermercado y las cosas que había?
  - ¿Cómo has hecho la tarea?
  - Explicación (de cómo ha hecho la tarea).
  - ¿Te sentiste con confianza para hacer la tarea?
- **Usability**
  - ¿Te han molestado las gafas?
  - ¿Cuanto te han molestado las gafas?
  - ¿En qué te han molestado?
  - ¿Te ha parecido fácil coger los objetos?
  - ¿Te has sentido seguro/a haciendo la tarea?
  - ¿Has entendido bien lo que tenías que hacer?
- **Motion sickness and mental strain**
  - ¿Te has mareado?
  - ¿Cuánto te has mareado?
  - ¿Has sentido que podías hacer la tarea con calma?
  - ¿Te has cansado de pensar haciendo la tarea?
  - ¿Cuanto te has cansado de pensar haciendo la tarea?
  - ¿Te has cansado de moverte haciendo la tarea?
  - ¿Cuanto has cansado de moverte haciendo la tarea?
  - ¿Te has puesto nervioso/a haciendo la tarea?
  - ¿Cuanto te has puesto nervioso/a haciendo la tarea?

- Observaciones

All the answers to the questions were subsequently downloaded into an Excel file and analyzed in the dedicated chapter 6.

6. Results

This chapter presents the analysis of the data collected through the questionnaires. It is important to note that the data collection sessions are still ongoing, so the results reported here represent only a portion of the overall sample, which will continue to be expanded over time. The analysis will focus on levels 1, 2 and 3 of both scenarios, supermarket and cafeteria, as these are the levels completed by all users. As explained in Chapter 5.2.2, the questionnaires include questions based on subjective experience, spatial presence, usability, motion sickness and mental strain. I have analyzed the following characteristics for each type of question.

To better understand the analise of sessions and levels, the Table 6 was developed. This provides a summary of the number of sessions completed by each participant (EC1, EC2, EC3, EC4, EC5, EC6, EC7, EC8), distinguishing between the two environments, and the overall total number of sessions completed. In the first section of the table, the number of sessions completed for each user in the cafeteria and supermarket are observed next, the levels completed by each user in each context are reported.

User	Cafeteria sessions	Supermarket sessions	Total sessions
EC1	3	3	6
EC2	3	3	6
EC3	3	3	6
EC4	3	5	8
EC5	3	4	7
EC6	3	3	6
EC7	3	3	6
EC8	3	3	6
Total	24	27	51

Table 5: User sessions in Cafeteria and Supermarket

6.1. Spatial Presence

This section examines how the user feels physically in the virtual environment and the ability to interact with it. I decided to analyze all levels completed by all users in both scenarios. For each level, I calculated the MOS and the corresponding CI (see Figure 36).

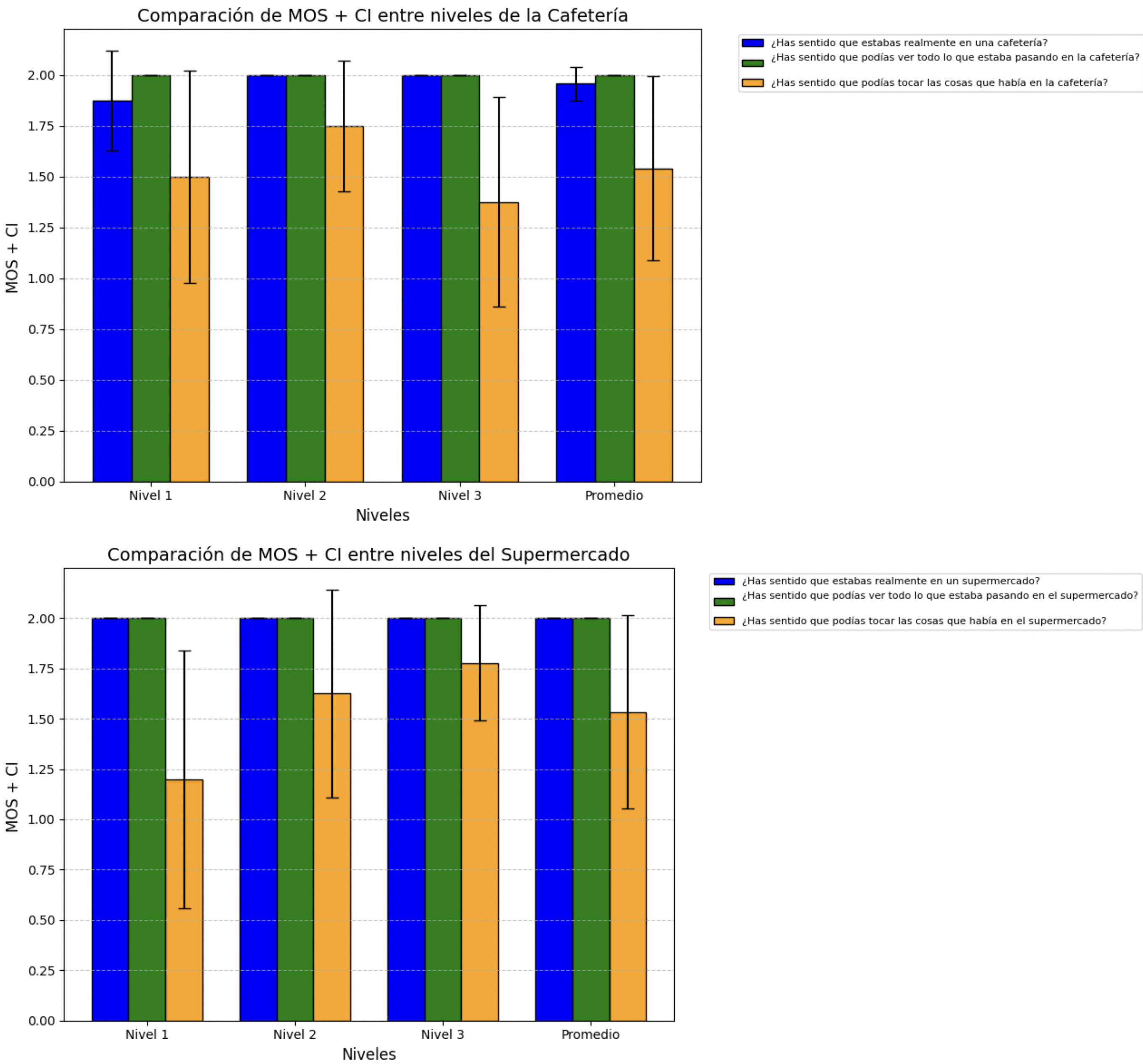


Figure 36: Comparison of levels for spatial presence (Cafeteria and Supermarket).

To understand the perception of spatial presence in the two scenarios, Figure 37 compares the mean values of the three questions analyzed for the cafeteria and the supermarket.

In the case of the cafeteria, the feeling of presence "¿Has sentido que estabas realmente en una cafetería/supermercado?" shows slightly lower values in the cafeteria than in the supermarket, suggesting a less pronounced perception of immersion in this environment.

The visibility "¿Has sentido que podías ver todo lo que estaba pasando en la cafetería/supermercado?" is highest in both cases, indicating that users perceive that they can clearly see their surroundings, with no significant differences between the two scenarios. However, the most striking difference is observed in "¿Has sentido que podías tocar las cosas que había en la cafetería/supermercado?" which represents the feeling of being able to touch the objects in the scene: in both scenarios the mean is lower than in the other two questions. This suggests that the tactile experience represents the aspect with greater differences between the two scenarios.

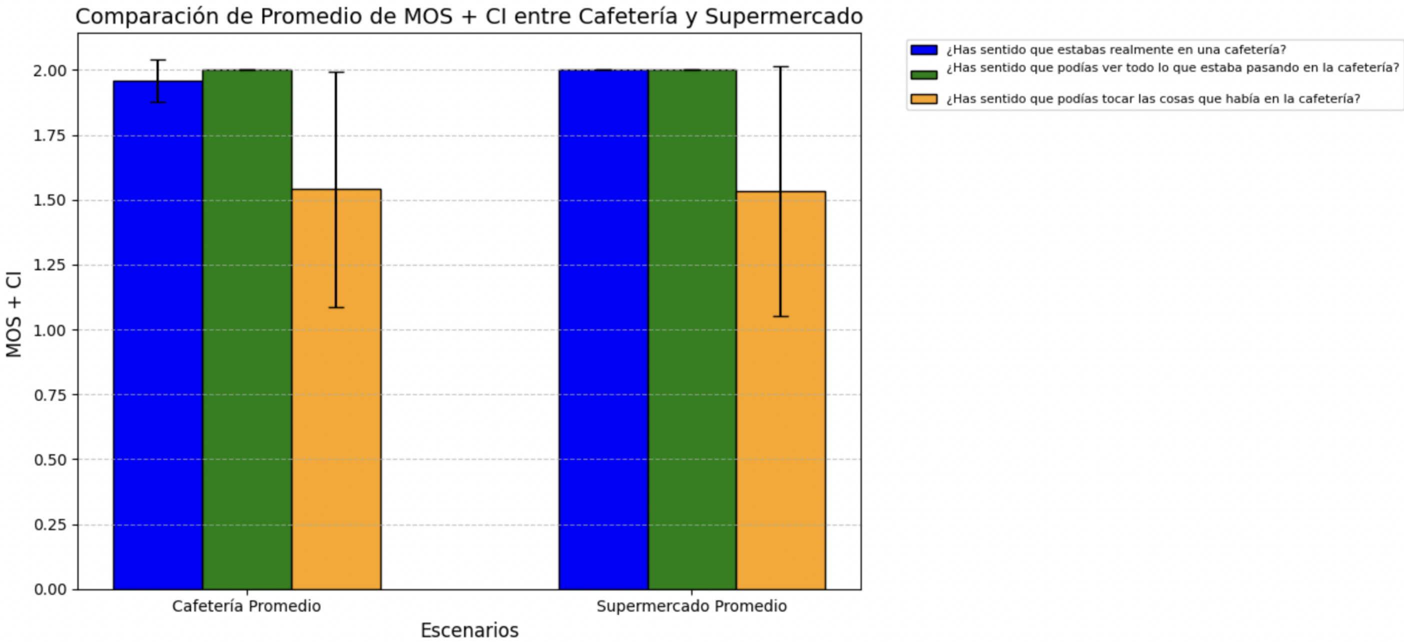


Figure 37: Comparison of Cafeteria and Supermarket for Spatial Presence

Precisely because of this difference, the responses to question "¿Has sentido que podías tocar las cosas que había en la cafetería/supermercado?" were analyzed in more detail, with the aim of better understanding the factors that influenced the perception of the possibility of touching objects in the two scenarios. Initially, I looked at the responses to the question from each individual user (See Figure 38), and because almost the majority of users fluctuated in their responses I examined the different levels (See Figure 39), including all users, trying to understand whether the difficulty of the task could influence the perception of the tactile experience. From the data collected, we see different behavior between the two scenarios. In the supermarket, the perception of tactile experience is lower in the first level and tends to increase with experience, suggesting a possible effect of learning or adaptation to the environment. In the cafeteria, on the other hand, perception fluctuates between levels, showing no clear trend, indicating that there may be other factors influencing this sensation.

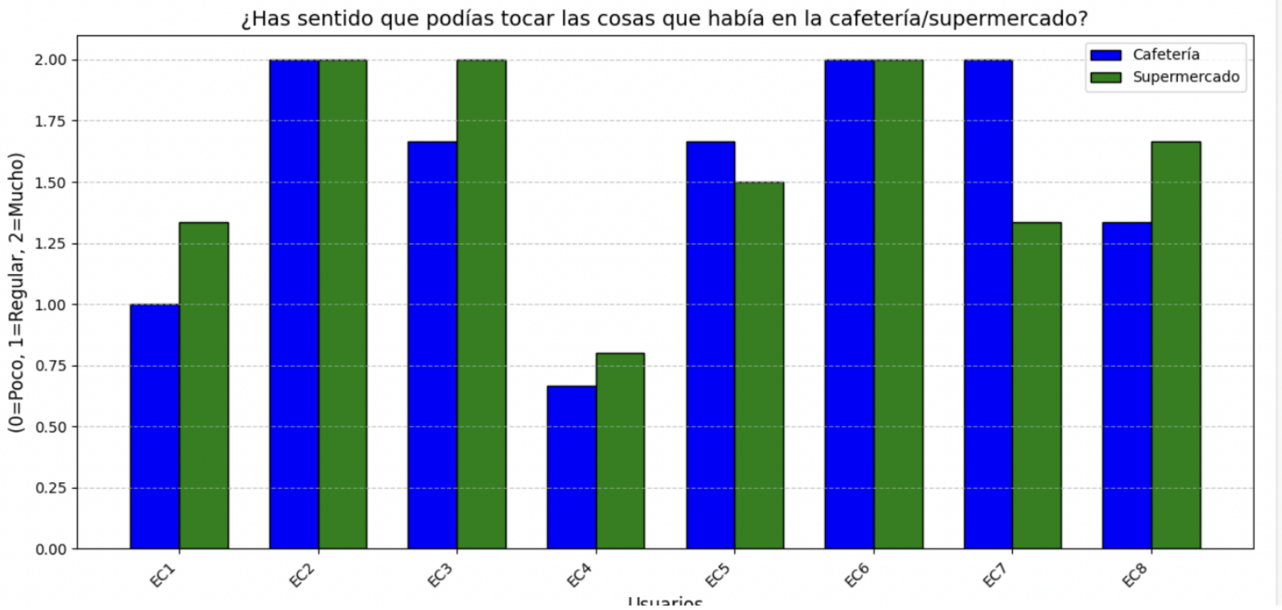


Figure 38: ¿Has sentido que podías tocar las cosas que había en la cafetería/supermercado?

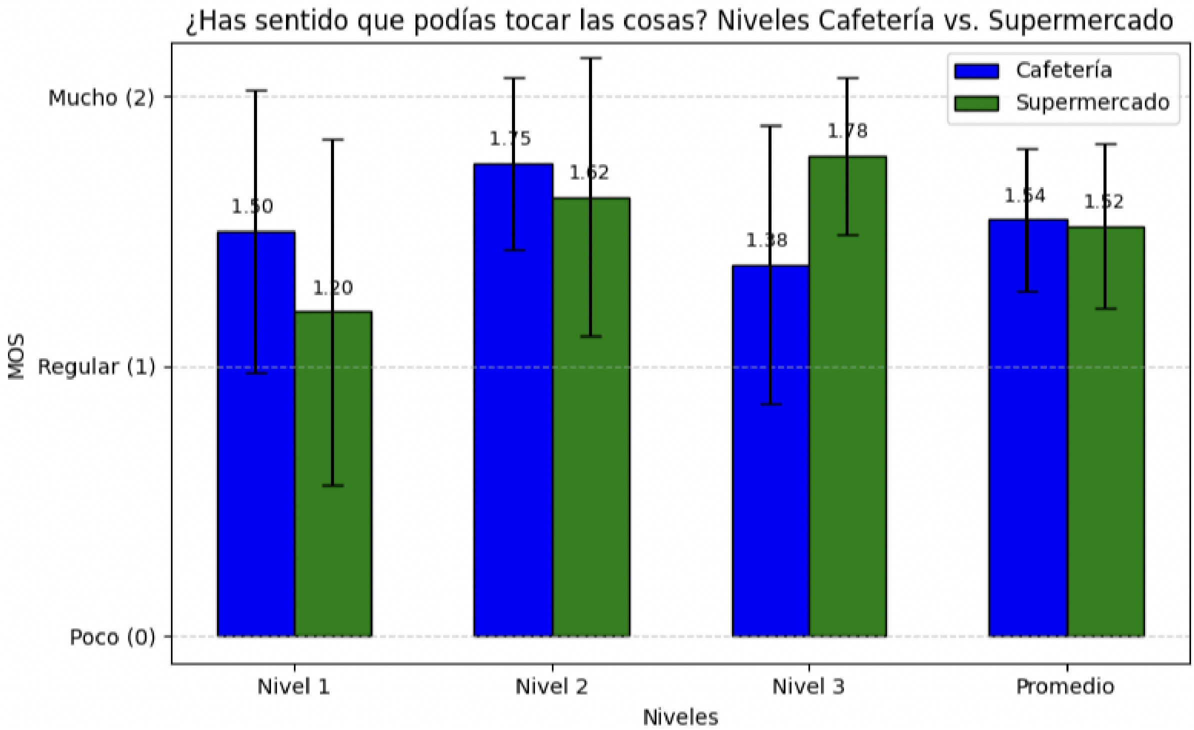


Figure 39: ¿Has sentido que podías tocar las cosas que había en la cafetería/supermercado? for Levels

From the preliminary analysis on spatial presence, it was found that the perception of objects is the most relevant aspect. For this reason, specific statistical tests were conducted: the first to assess the differences between the two scenarios and the second to analyze the variations between the different levels within each scenario.

First Test - Significant differences between Cafetería and Supermercado by perception of objects

After checking the distribution of the data with the Kolmogorov-Smirnov (KS) test and finding that the data did not follow a normal distribution for both scenarios ($p < 0.05$), the Mann-Whitney U test was applied. This choice is due to the fact that it is a non-parametric test, so it does not require the data to be normally distributed and accepts samples of different lengths, a necessary condition given that the number of sessions conducted in the Supermercado is greater than in the Cafetería. The test hypotheses are:

- H0 : The two distributions (Cafetería and Supermercado) are equal. There is no significant difference between the scores obtained in the two scenarios.
- H1 : The two distributions are different. There is a significant difference between Cafetería and Supermercado scores, with one group tending to have higher or lower values than the other.

The test statistic result is 313.0 with a $p = 0.81197$ Since the p-value is much greater than 0.05, we cannot reject the null hypothesis (H0). This means that we do not have enough evidence to conclude that there is a significant difference between the two distributions. Therefore, we can say that the experience of touch perception in the virtual environments of Cafetería and Supermercado is similar and there are no statistically significant differences between the two scenarios.

Second Test - Significant differences between the levels of Cafetera and the levels of Supermercado by perception of objects The Kruskal-Wallis test was performed separately for Cafetería and Supermercado, comparing the different levels. I chose this test because it is nonparametric and allows the medians of multiple independent groups to be compared without assuming a normal distribution of the data.

The Hypotheses of the test are:

- H0: the feeling of being able to touch things is the sames among the different levels of the scenario considered (Cafetería or Supermercado).

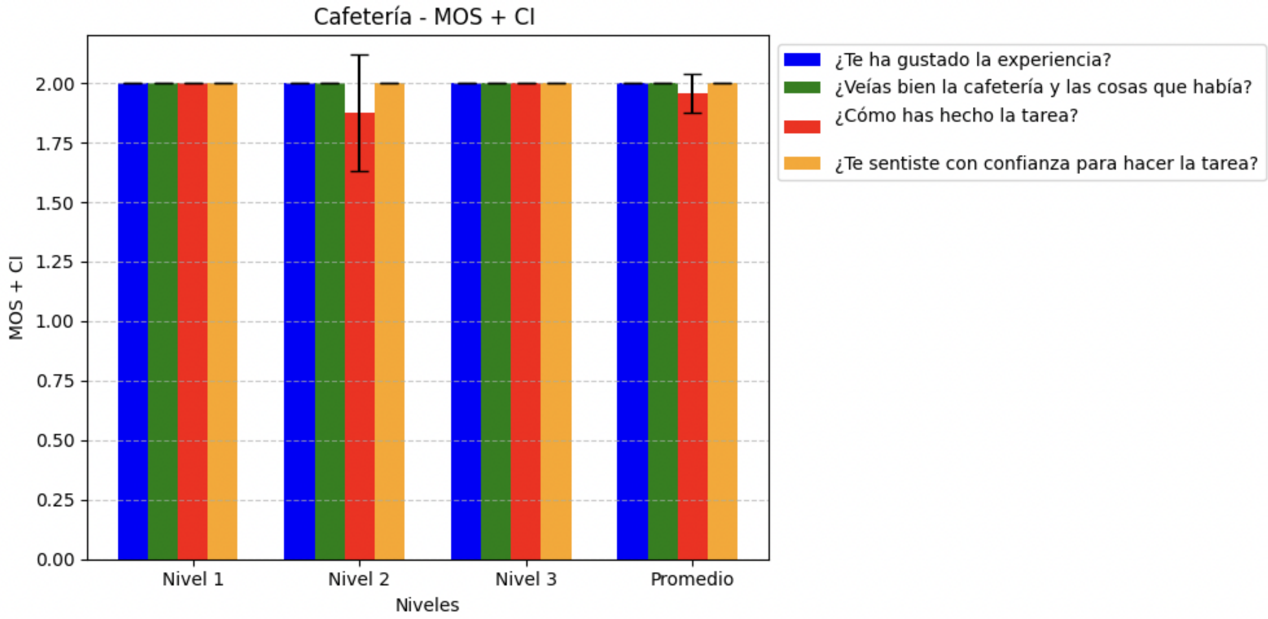
- H1: At least one level has a different distribution from the others.

Being the results for the cafeteria: Statistic = 1.21 and p-value = 0.546 and for the supermarket: $Statistic = 1.632$ and $p - value = 0.442$ Since the p-value in both cases is high ($p < 0.05$), we cannot reject the null hypothesis. This implies that there are no statistically significant differences between Cafetería or Supermercado levels in relation to perceived contact with objects.

Since this is the only question in which responses varied between scenarios, but statistical tests showed no significant differences between levels within each environment, we can infer that, as far as spatial presence is concerned, there are no significant differences between the two scenarios.

6.2. Subjective experience

To assess the subjective experience, I initially analysed for each participant the level of enjoyment of the experience of both scenarios (See Figure 40), the visual clarity of the environment, the individual's perception of their own performance in carrying out the task and the sense of security felt during the activity.



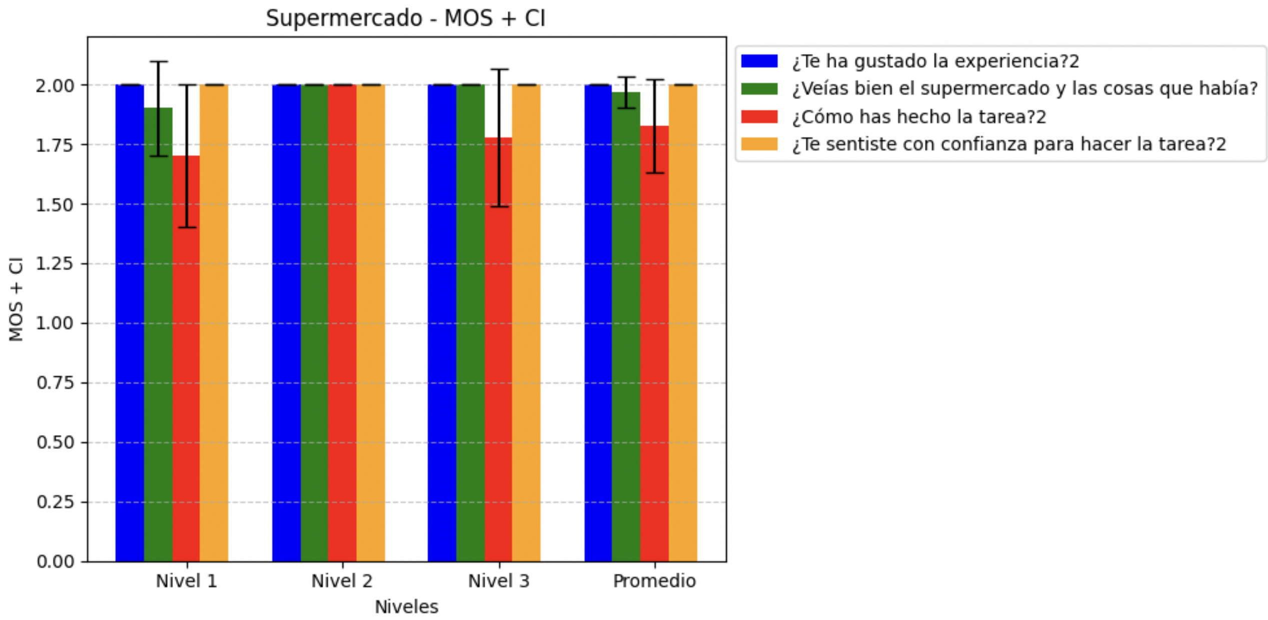


Figure 40: Subjective Experience Cafeteria and Supermarket

Analysis of the two graphs reveals a generally positive experience for all users. In fact, a certain consistency can be observed in the answers given by the participants. However, there is a slight variation in the case of the supermarket, where the confidence intervals are slightly wider than those of the cafeteria, particularly in the question '¿Cómo has hecho la tarea?'.

Despite this small difference, the overall variability of the answers remains very low. Therefore, in an initial analysis of the data, we can consider the subjective experience of the participants as satisfactory. It is important to emphasise that, as these are subjective experiences, external factors unrelated to the tests may also come into play. For example, one user had an accident inside the foundation on the same day he participated in one of the trials, which may have influenced his perception of the experience.

Finally, I grouped all the users' answers in order to get an overview of the subjective experience of the two scenarios (See Figure 41), confirming all the above observations, reinforcing the conclusion that the subjective experience of the participants was generally positive and consistent in both scenarios.

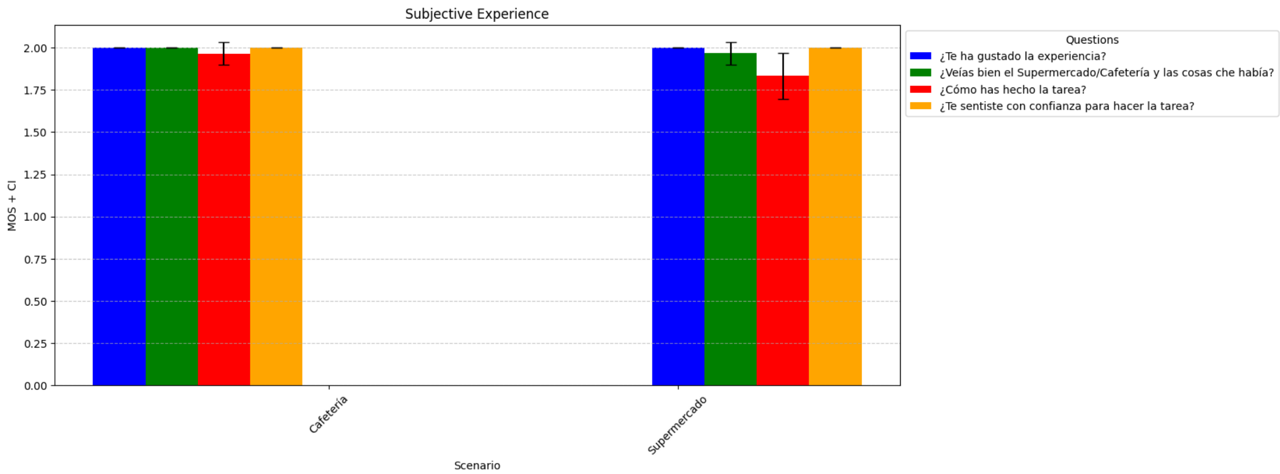


Figure 41: MOS + CI of Subjective Experience Questions in Two Scenarios

Next, I analyzed the individual users (See Figure 42) and observed that many of them had the perception that they did not perform the cafeteria tarea to the best of their ability. To further explore this dynamic, two separate graphs were made representing each user's personal situation. These graphs allow for a better visualization of progress between sessions.

Below, the table with the detailed analysis are shown.

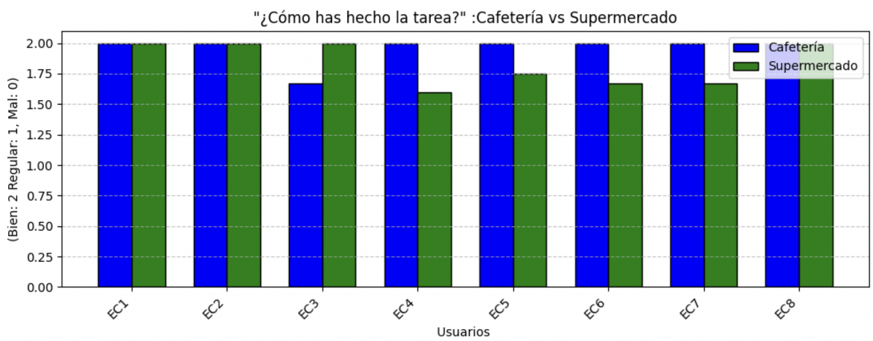


Figure 42: User experience for '¿Cómo has hecho la tarea?' - cafeteria and supermarket

The users taken into analysis were those who gave somewhat lower responses to the question, in the following figure (See Figure 43) the two scenes will be distinguished to get a clearer view.

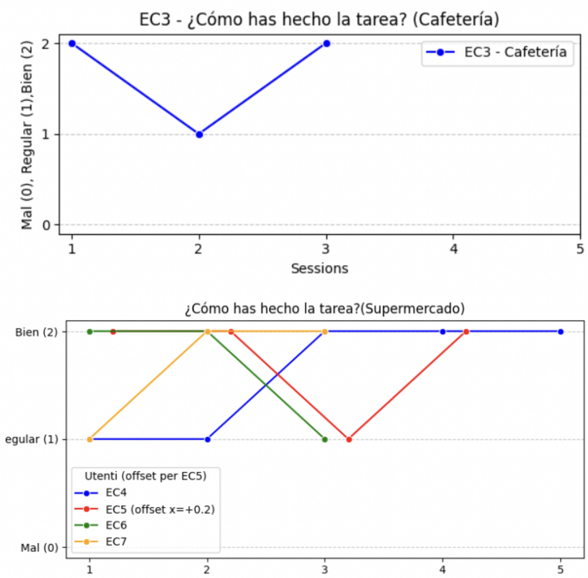


Figure 43: Evolution during the sessions of '¿Cómo has hecho la tarea?' - cafeteria and supermarket

The Figure 43 shows a single incident in which EC3 expressed difficulty because he could not correctly understand the buttons to use to grab the plates in the cafeteria.

As for the supermarket, users' responses are more diverse. EC7 shows improvement between the first and subsequent sessions, suggesting progressive adaptation to the task. EC4, on the other hand, has a perception in the second session that he did not perform the task to the best of his ability. In this session, there was a significant delay before the actual start, due to problems with the eye tracking system and the psychologist's difficulty in connecting the remote controls. EC4 also encountered difficulties in finding the correct spaces in which to relocate products, while, in the penultimate session, EC5 reported having no more products to place.

Preliminary analysis showed that only the question "¿Cómo has hecho la tarea?" showed differences within the two environments. The Figure44 shows the difference between the various levels of each scenario and between the various scenarios, through statistical tests we will go on to analyze both.

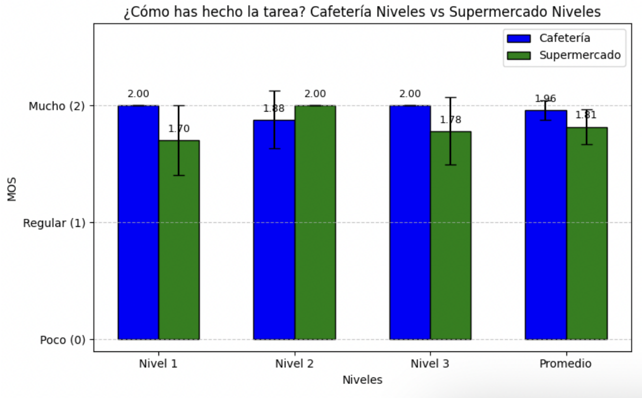


Figure 44: Difference between Scenarios and levels of "¿Cómo has hecho la tarea?"

To test whether the data follow a normal distribution, the Kolmogorov-Smirnov test was used, and since both $p-values$ are less than 0.05, we can conclude that they do not follow a normal distribution in either scenario.

First Test - Significant differences between Cafeteria and Supermarket in task execution.

Therefore, the Mann-Whitney U test with assumptions was applied to compare the scenarios:

- H0: There are no significant differences between the two scenarios.
- H1:There is a significant difference between the two scenarios.

Obtaining the results, $Statistic = 313.0$ with a $p = 0.812$, since p is much higher than the significance threshold we can say that no significant differences emerge between Cafeteria and Supermarket with respect to the way users perceive that they have done the task.

First Test - Significant differences between the levels of Cafeteria and the levels of Supermarket in task execution.

To analyze the differences between levels for both supermarket and cafeteria the Kruskal-Wallis test was applied with:

- H0: The distributions of the variable "¿Cómo has hecho la tarea?" are the same among the different levels of the scenario considered.
- H1:At least one level has a significantly different distribution from the others.

The results obtained for the cafeteria were : $Statistic = 1.211$ and $p = 0.546$, while for the supermarket: $Statistic = 1.632$ and $p = 0.442$. Again the p in both cases are greater than 0.05.

Thus, we can say that the perception on how the tarea was carried out remains similar within both the cafeteria and the supermarket.

Even for the subjective experience, we can then say that there were no major differences in users' perceptions between the two scenarios.

6.3. Usability

With regard to usability, I did not consider it necessary to analyze the differences between the two scenarios, Since both scenarios were created with the same characteristics in terms of usability. The focus was therefore on evaluating the overall user experience.

6.3.1. HMD

As a first step, I found it necessary to analyze user responses regarding HMD. In the Figure 45, the green section represents negative user responses, that is, those who did not experience any discomfort when using HMDs. In contrast, the red section indicates positive responses, i.e., users who reported discomfort during the experience.

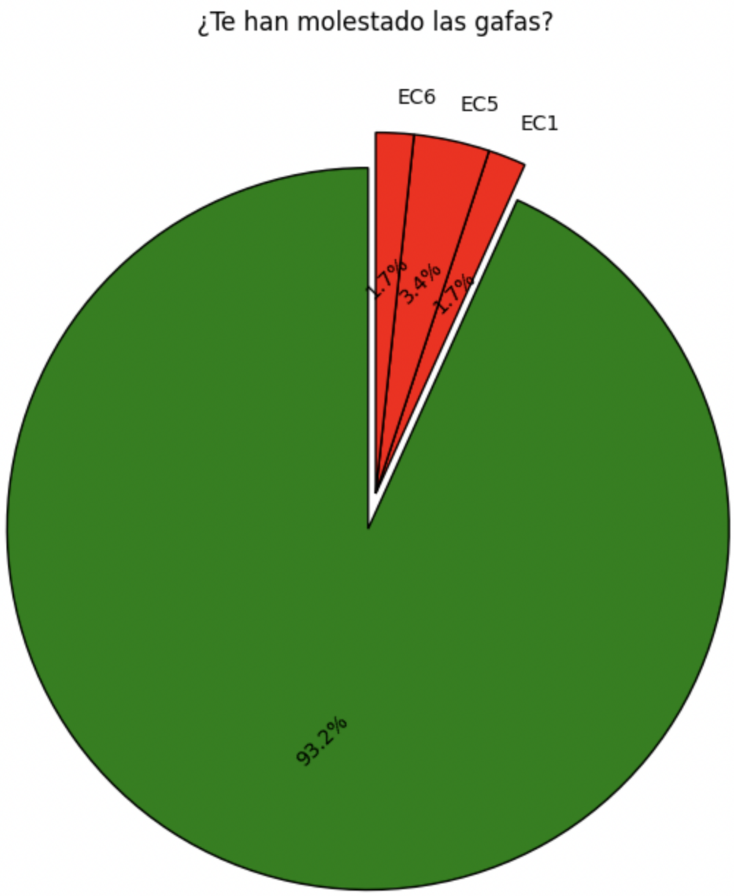


Figure 45: Pie chart of HMD responses

It can be seen by looking at the green part that none of the users experienced significant discomfort while wearing the HMD, which is a positive aspect, as it was not a major problem for usability. Five out of eight users did not experience any discomfort while wearing the HMD. As EC1, EC5 and EC6 reported some discomfort, I analysed their experiences individually (See Figure 46) in relation to time, observing how their perception of the HMD evolved over the course of the experience. The aim was to understand whether the discomfort could be related to the need to get used to the use of the visor.

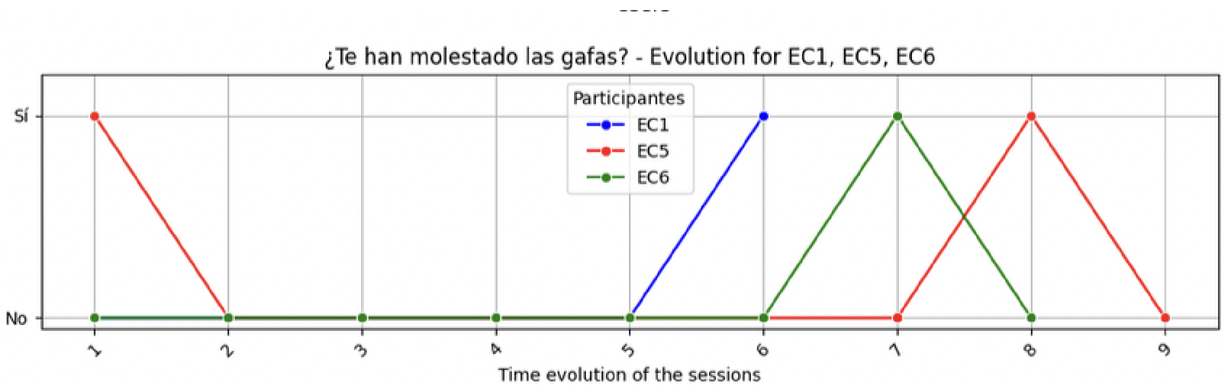


Figure 46: EC1, EC5, EC6 HMD Experience

Surprisingly, I observed that their experience did not depend on how long it took them to become familiar with the device. In fact, each of them reported episodes of discomfort randomly, with no clear progressive trend. This suggests that discomfort may have been influenced by individual factors.

For example, EC1 experienced problems with the fit of the device because he wore his glasses together with the HMD. For EC5 and EC1, on the other hand, discomfort seemed to stem from greater personal sensitivity: EC5 complained about the intensity of light, whereas EC6 perceived discomfort due to the proximity of objects in the HMDs.

6.3.2. Perception of Ease of Interaction, Safety and Clarity of Task

For the analysis of the clarity of the instructions, the ease of interaction with the objects and the perceived level of safety during the task, I followed a similar approach to that adopted for the HMDs (6.3.1). Specifically, I analysed the users' responses for each of these three distinct aspects, as can be seen in the Figure 47, Figure 49 and Figure 51).

In the first graph (See Figure 47), it can be seen that comprehension of the task was generally good. In fact, only two users (EC2 and EC5) (See Figure 48) experienced some minor difficulties, while for the majority of participants the instructions were clear. However, considering the low overall variability, it can be concluded that the instructions were well understood by the majority of users.

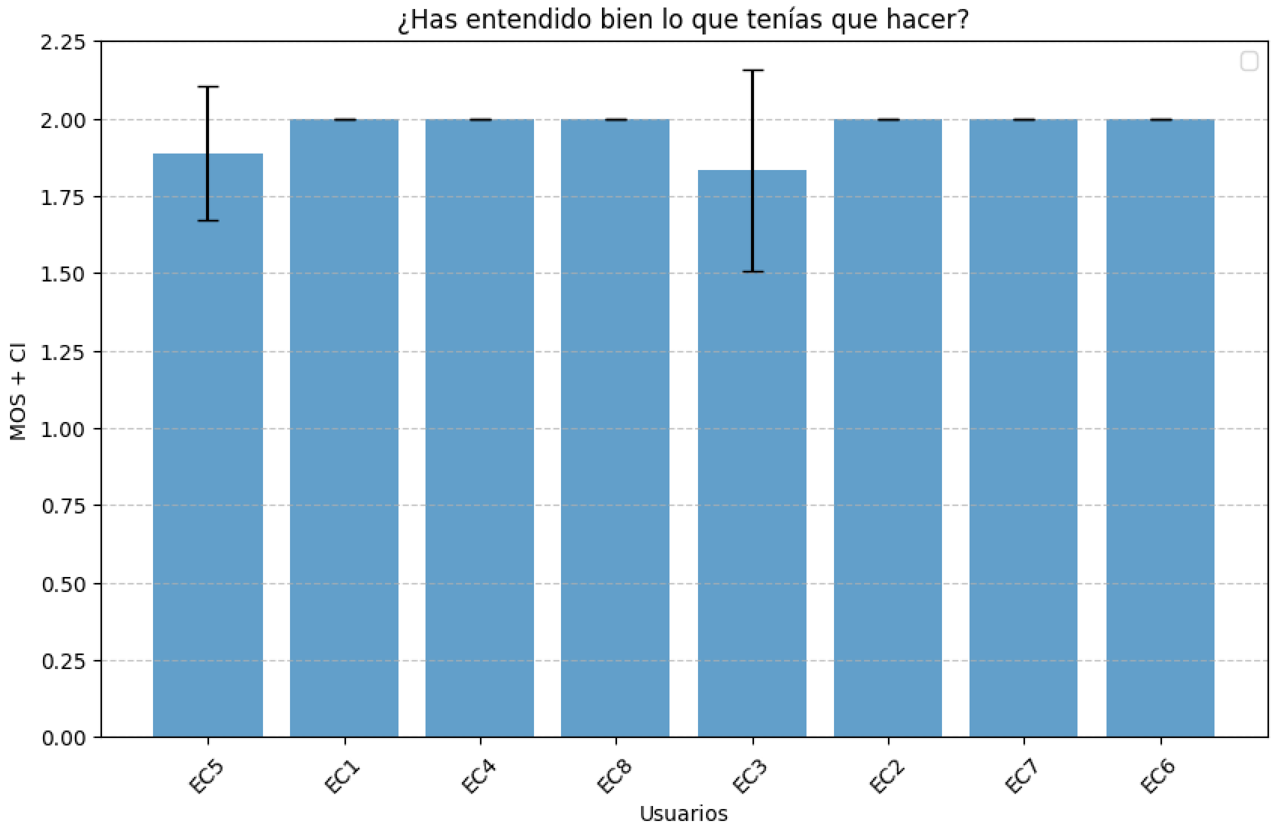


Figure 47: MOS + CI of clarity of tasks responses

In the Figure 48, I decided to analyze separately the sessions of users EC5 and EC3, the users who gave lower scores to the question, to better understand what aspects they did not understand. The graph shows that they both encountered difficulties in level 2 of the supermarket. In this level, as explained in the chapter 4.4, the first distractor is introduced, which leads me to assume that the two users were unaware that products not on the shelves would appear.

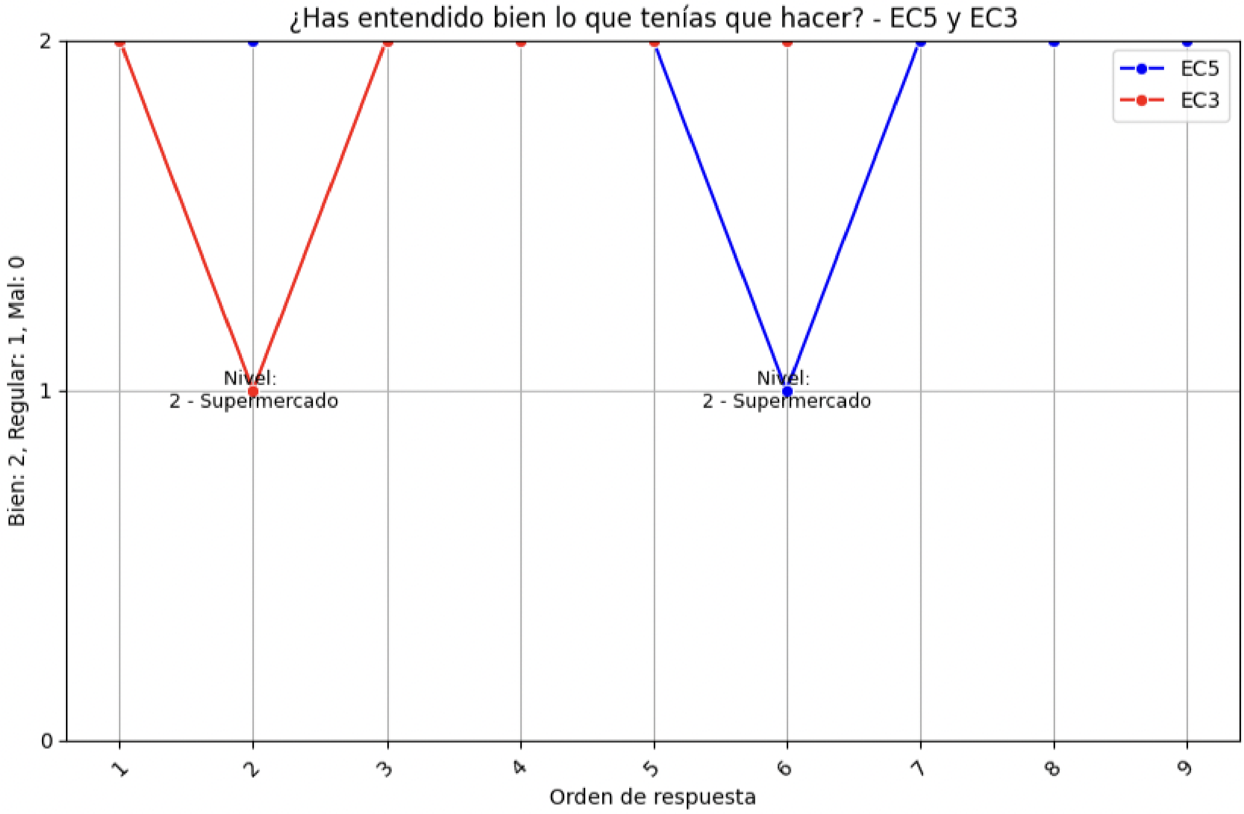


Figure 48: EC5 and EC3 user, view sessions where with lower rating

In the table below (See Table 49), the question «¿Te ha parecido fácil coger los obetos?» is analyzed where most users with the exception of EC2, EC4 and EC7, who never encountered difficulties, had at least one episode of slight difficulty in grasping objects during one of the sessions. Nevertheless, the overall values remain positive.

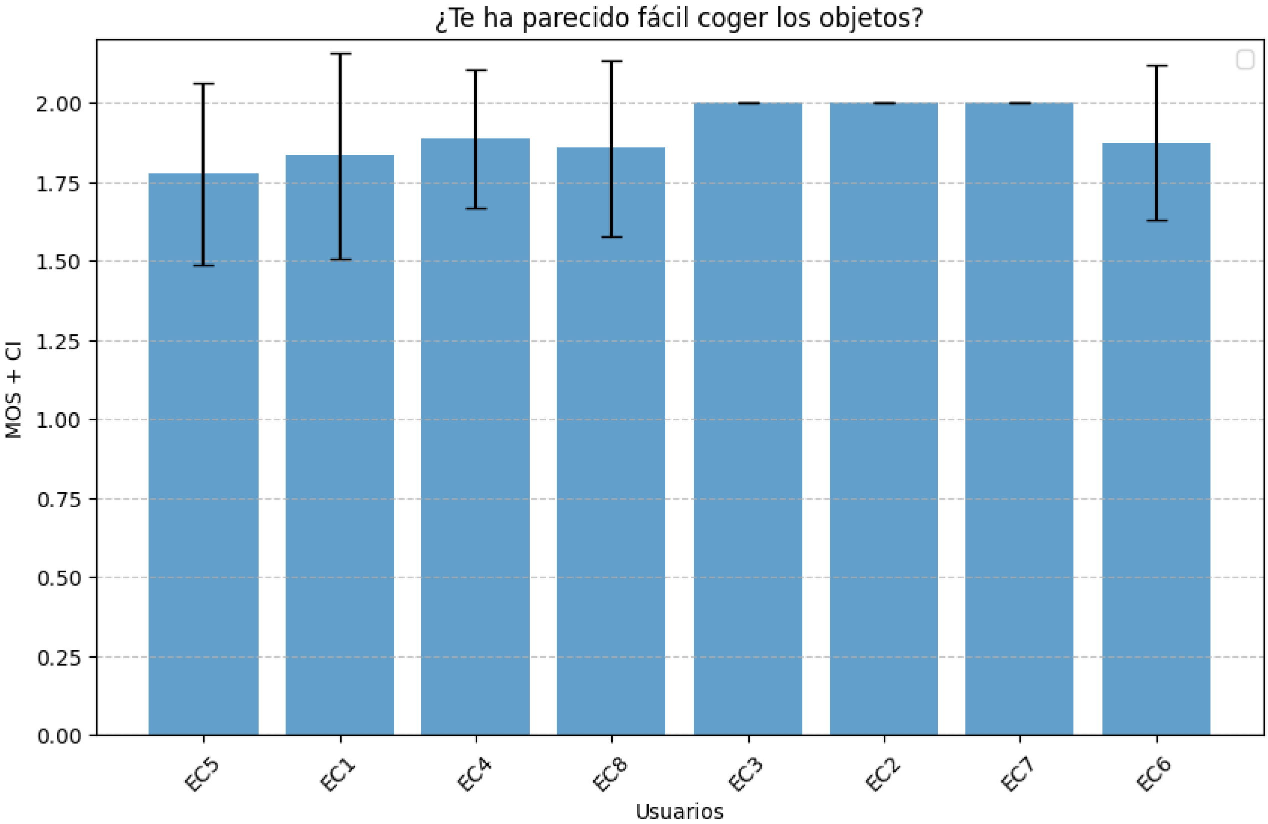


Figure 49: MOS + CI of security responses

Again, I analyzed each user's situation individually to see whether the difficulties occurred only at the beginning of the sessions, evolving over time, or whether they remained constant throughout the sessions. From the Figure 50, it is observed that users EC5, EC1, EC4, EC8 and EC6 experienced difficulties in both cafeteria level 1 and supermarket level 2.

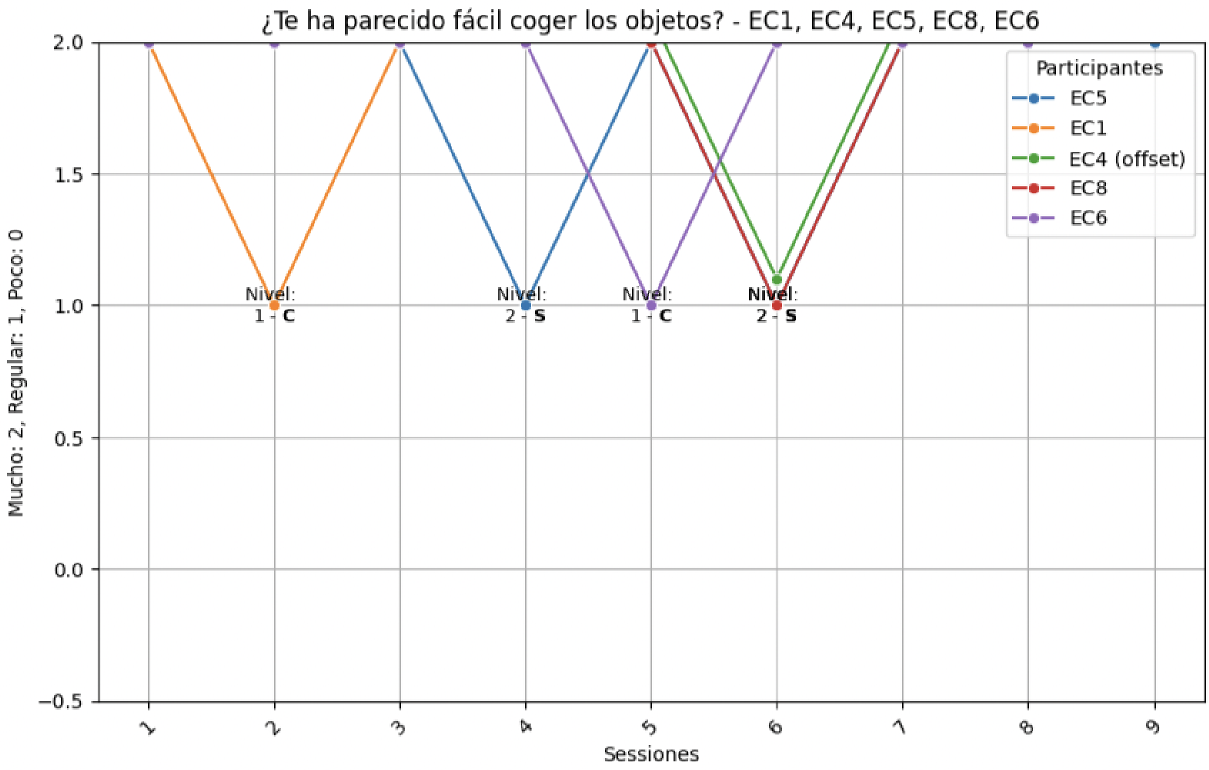


Figure 50: C5,EC3,EC4,EC8,EC6, display the sessions in which the rating is lowest.

The Figure 51 shows that almost all users felt safe during all sessions, contributing positively to the QoE.

The only exception is EC3 , who experienced a degree of insecurity during the second session, as he was afraid of bumping into objects. This explains its slightly lower value, even if the confidence interval is small, suggesting a perception of discomfort limited to a specific episode (See Figure 52).

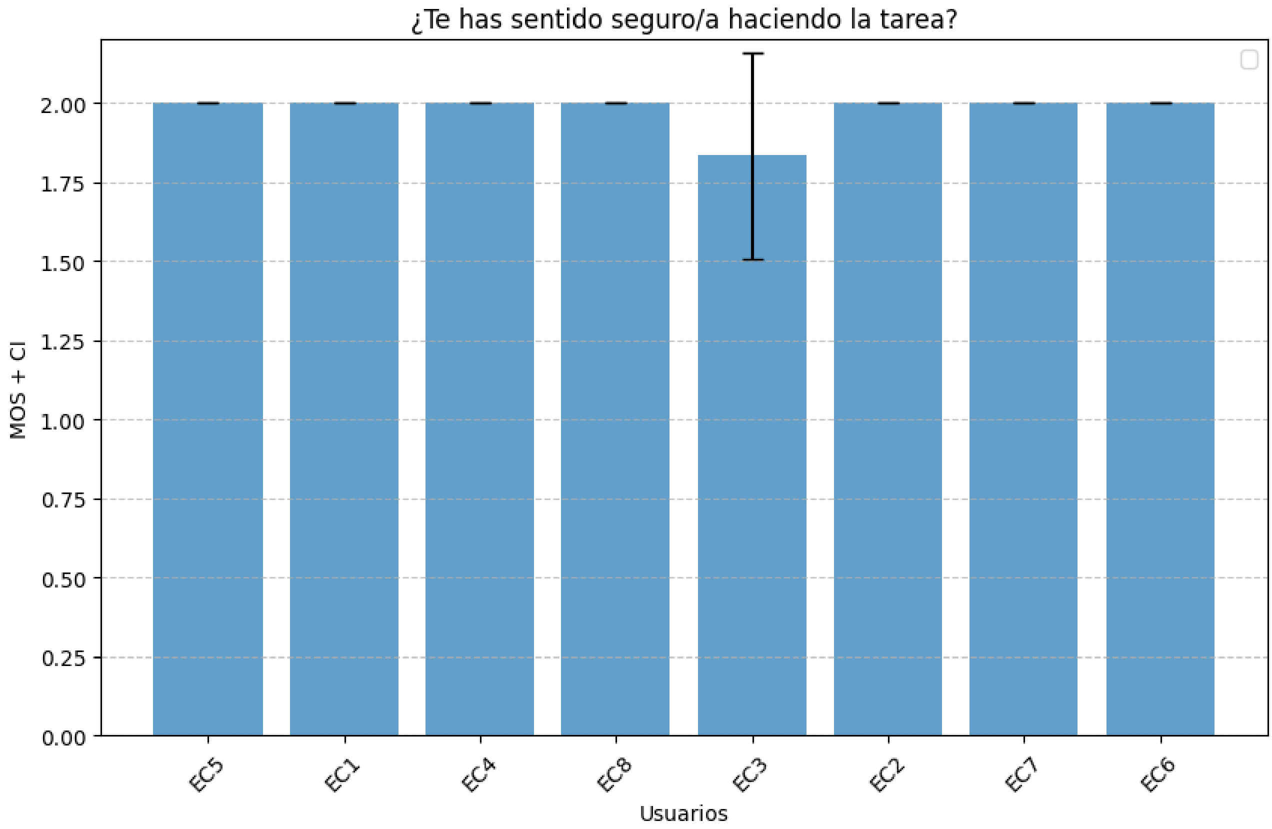


Figure 51: MOS + CI of interaction with objects responses

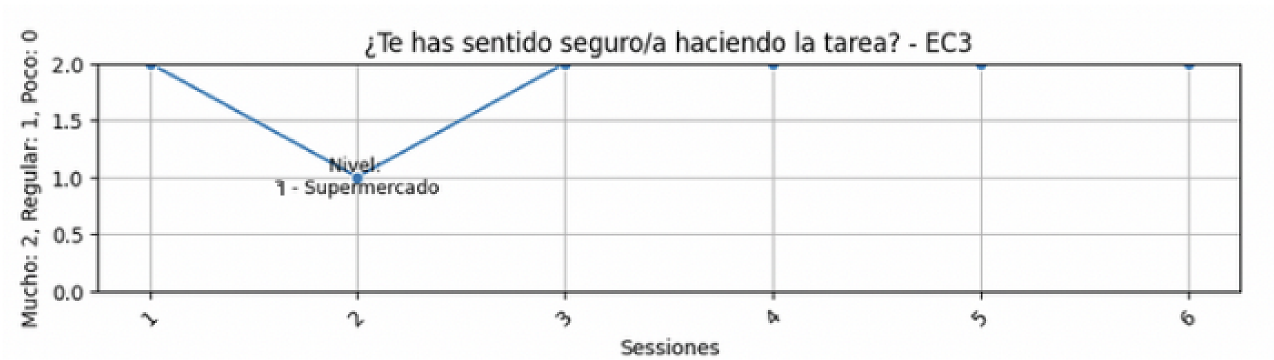


Figure 52: Single Episode where EC3 felt insecure

Finally, the following Figure 53 highlights the comparison between the three questions, clearly showing that, as far as Usability is concerned, the feedback received is predominantly positive.

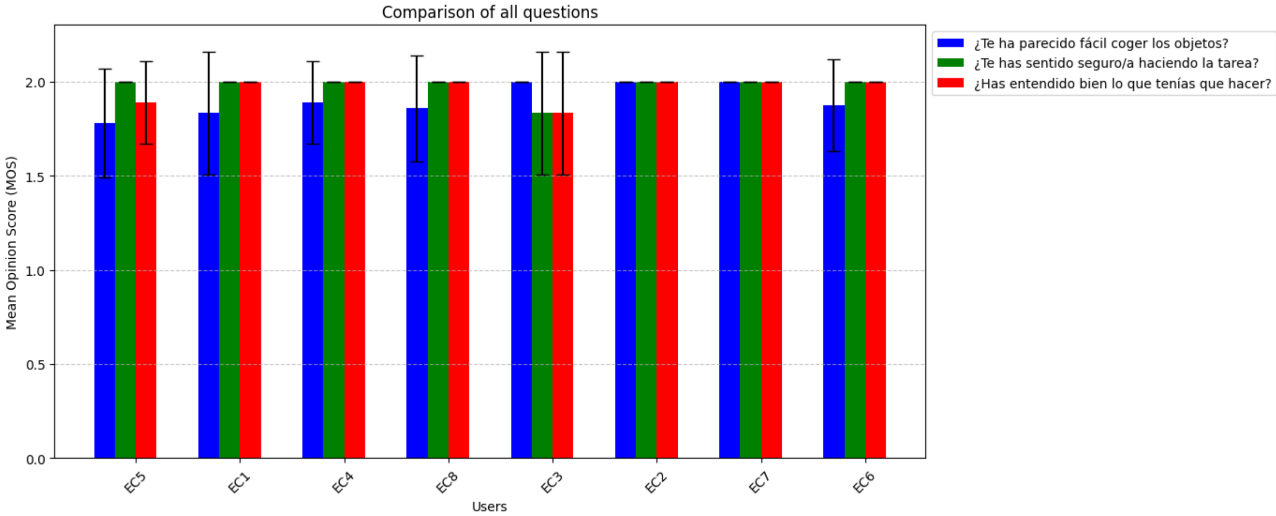


Figure 53: Comparison between perception of Ease of Interaction, Safety and Clarity of Task

In all three cases, I conducted a temporal analysis of the sessions for the users who experienced difficulties, with the aim of checking whether the problems were related to the need to get used to the technology. However, even in this case, the analysis did not show a progressive trend: the difficulties occurred sporadically and randomly between sessions. Consequently, I can conclude that the discomforts encountered do not depend on adaptation to the technology, but are probably influenced by individual factors.

Because Supermercado and Cafetería were designed similarly from a usability perspective, statistical tests were conducted with the aim of assessing whether there were substantial differences in the responses to the questions. In particular, the analysis aimed to identify any aspects of usability that generated more significant variation than others.

Again, the data do not follow a normal distribution, indicating that they do not adhere to a normal distribution. Consequently, the Kruskal-Wallis test was used to compare the three questions, with the following hypotheses:

- H0: The distributions of the three questions are the same.
- H1: At least one of the three questions has a significantly different distribution.

The test results were: $Statistic = 4.926, p = 0.08$. Since the p remains above 0.05, although it is approaching the threshold, none of the questions deviate significantly from the others.

6.4. Motion Sickness and Mental strain

6.4.1. Motion sickness

In this case, users were asked whether they had experienced feelings of motion sickness. The answer could be “Yes”, or “No”, in green, with the option to specify the reasons later. Figure 54 shows that most users reported no episodes of nausea, the red part represents the answer “Yes,” while the green part represents “No”, with the exception of EC6 and EC5, who had them only at isolated times. To get an overall view, the sessions of the two scenarios were aggregated.

The Figure 55, on the other hand, shows the trend of the two users’ sessions and indicates the times when their response was affirmative. The Figure 55, on the other hand, shows the trend of the two users’ sessions and indicates the times when their response was affirmative.

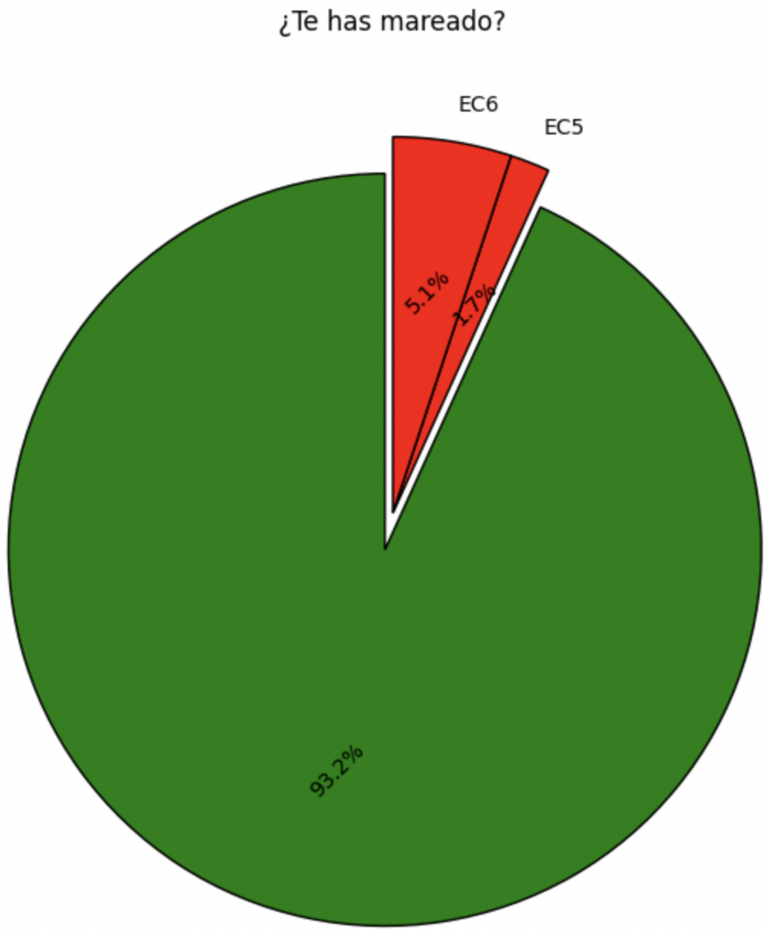


Figure 54: Motion Sickness Pie chart

In the case of EC5, it is observed that motion sickness episodes were reported exclusively in the first session, but completely disappeared as the sessions progressed.

For EC6, however, two isolated episodes are noted in the last two sessions. The user attributed the discomfort to the proximity of the objects within the HMD, as also highlighted in the paragraph 6.3.1.

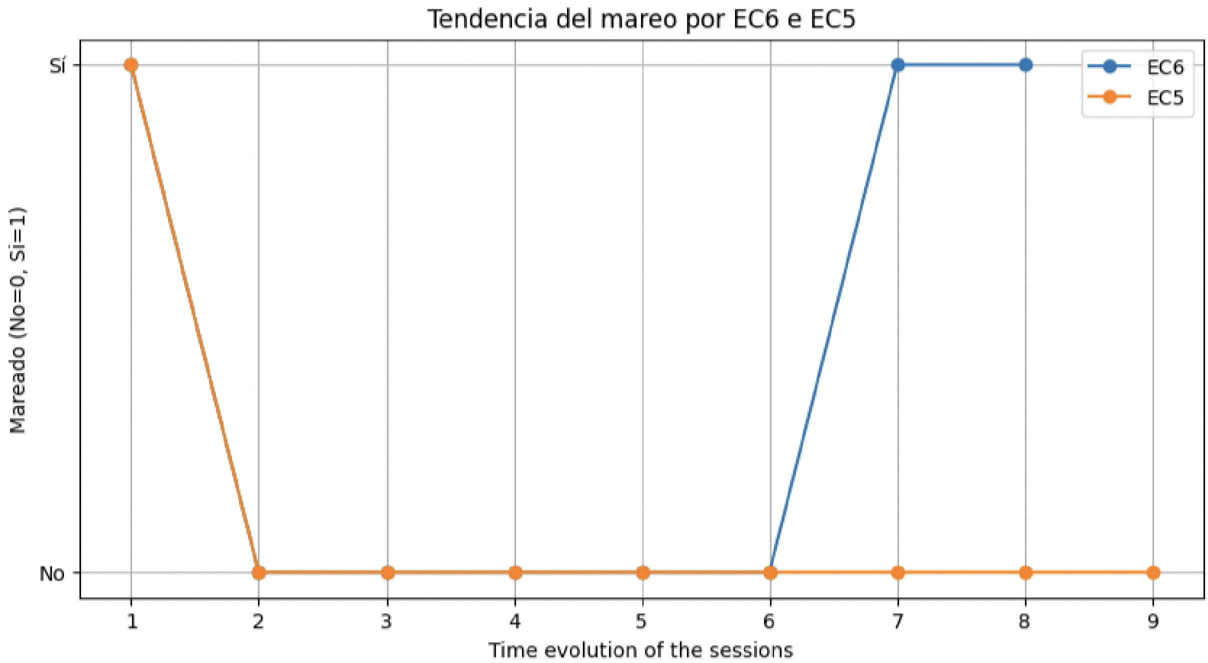


Figure 55: Motion Sikness tendency of EC6 and EC5

6.4.2. Mental strain

This section analyzes the four questions related to mental strain: "¿Has sentido que podías hacer la tarea con calma?","¿Te has cansado de pensar haciendo la tarea?","¿Te has cansado de moverte haciendo la tarea?" and " ¿Te has puesto nervioso/a haciendo la tarea?"

I found it useful to conduct a preliminary analysis on the two scenarios because the two tasks were different from each other. Next, I compared the results and analyzed individually the questions for which I found different responses. Finally, I went into the specifics of each user. Among the four macro-topics analyzed, this is the part where I found the biggest differences in responses.

In the Figure 56 it is possible to observe the differences between levels for different questions in both the supermarket and the cafeteria. It can be seen immediately that, in the cafeteria, the values are more stable across levels, while in the supermarket there is more dispersion. This is also evident from the CIs, which are wider in the supermarket, suggesting greater variability in the responses.

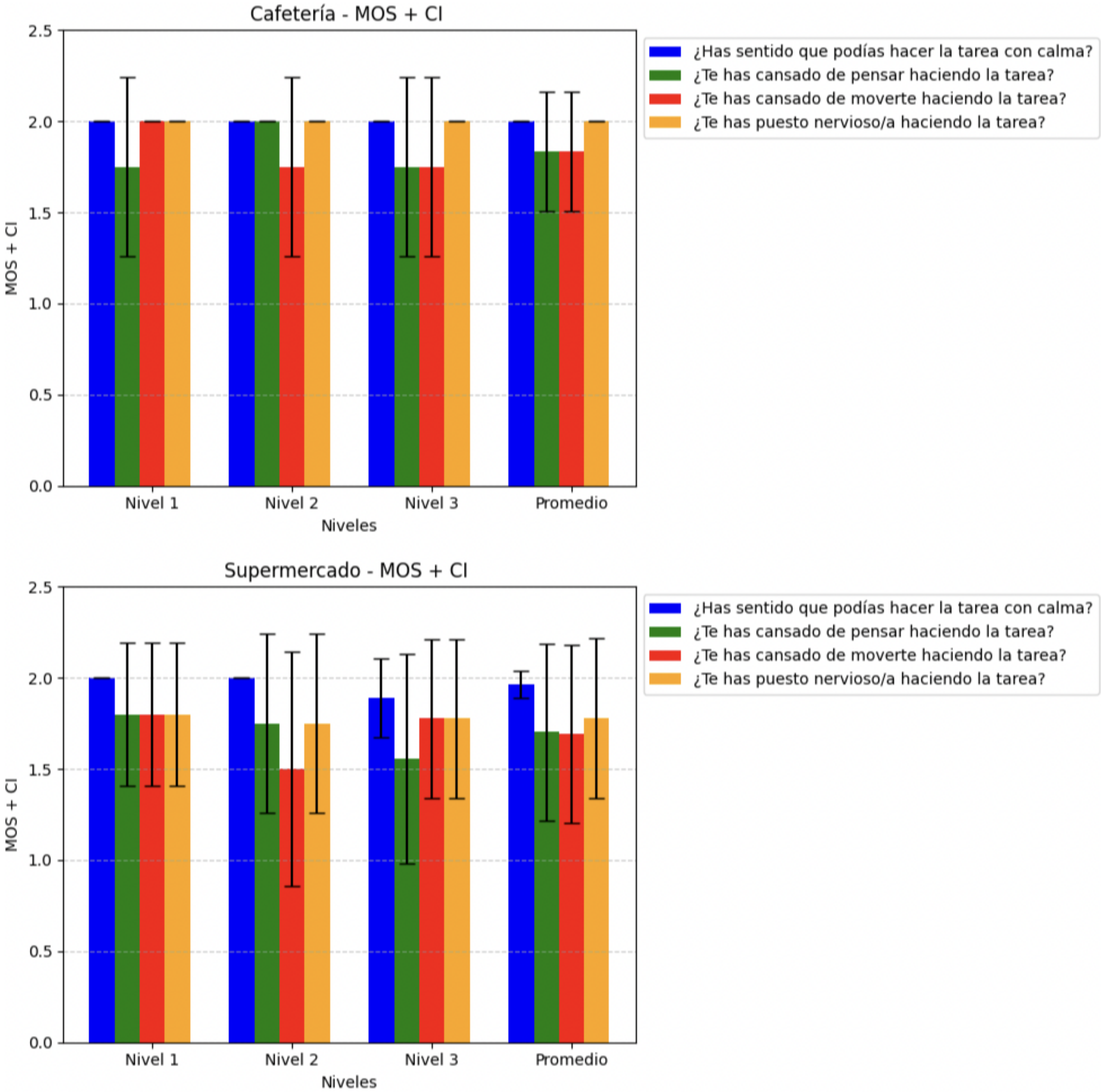


Figure 56: MOS + CI in the different scenarios according to levels and questions

Next, I averaged the responses for each scenario in order to get a clearer picture of the differences between the two contexts (See Figure 57). The analysis revealed greater diversity in the responses to the questions "¿Te has cansado de moverte haciendo la tarea?""¿Te has cansado de pensar haciendo la tarea?""¿Has sentido que podías hacer la tarea con calma?" and "¿Te has puesto nervioso/a haciendo la tarea?"

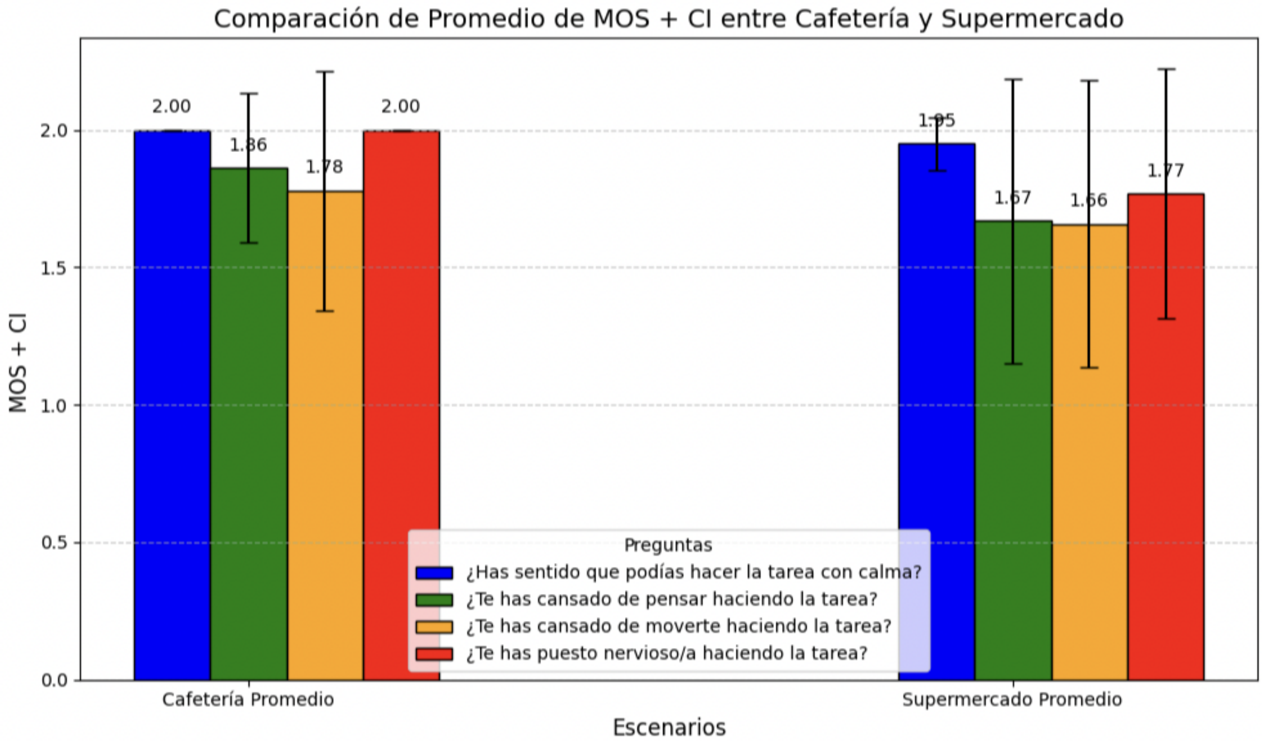


Figure 57: Comparison of cafeteria and supermarket for mental strain

To better understand the subjective perception of mental effort, an analysis of the responses with greater difference of each user in the two scenarios considered (cafeteria and supermarket) was conducted. In the Figure 58, Figure 59 and Figure 60, individual ratings with respect to the three questions with most discrepancy between the two scenarios are depicted. The data show that most users gave responses with high values, while some participants gave very low ratings, showing a significant discrepancy between individuals.

To further explore these differences, a detailed analysis was conducted for each user, observing in which session, level, and scenario they perceived more fatigue. This approach allows us to identify any individual variations.

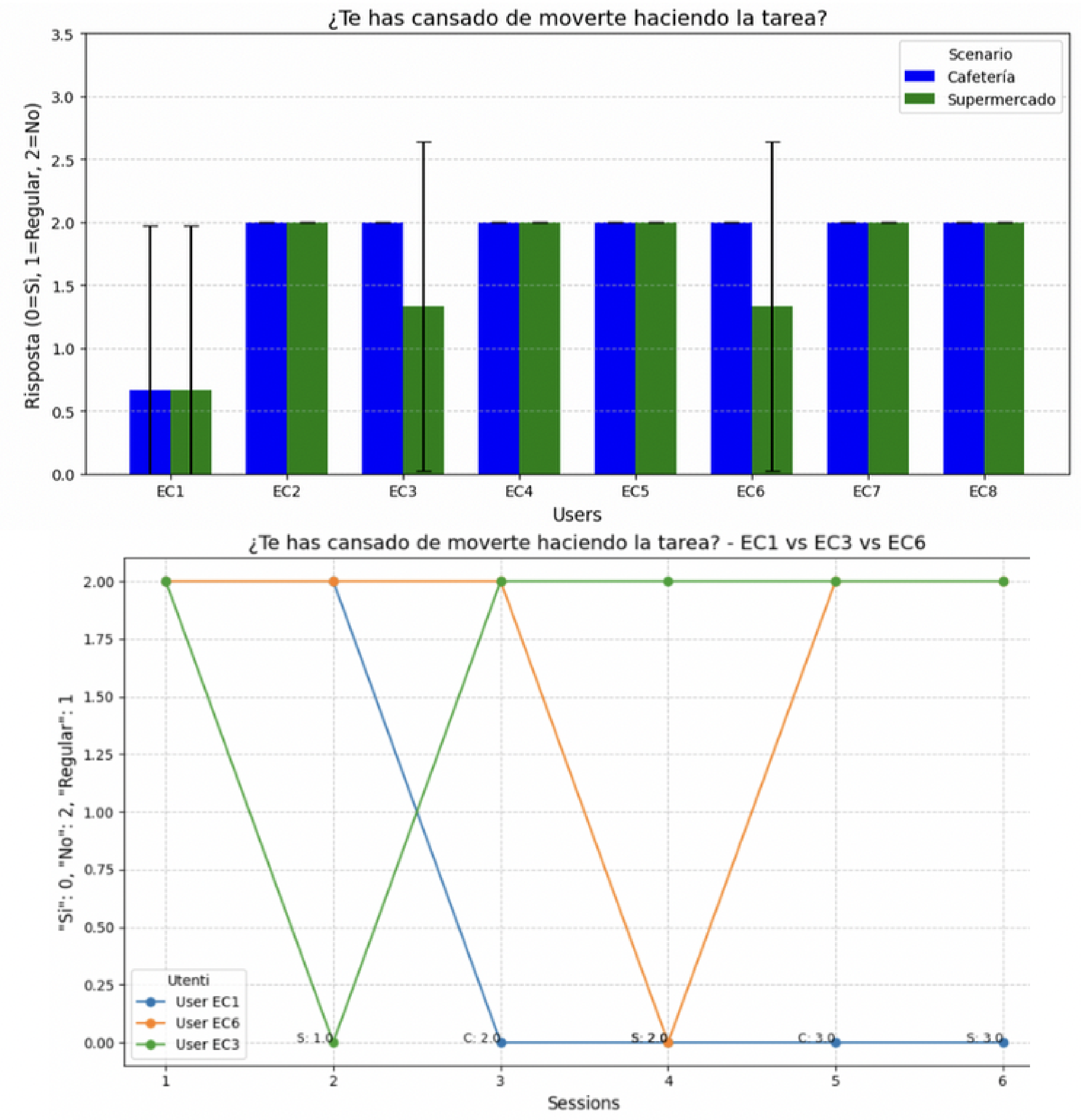


Figure 58: User perception in the two scenarios and focus on users with lower responses for "¿Te has cansado de moverte haciendo la tarea?"

In Figure 58 a more specific analysis.

Multiple users reported a feeling of physical fatigue while performing the task. EC3 felt physical fatigue in a single episode, in the same session in which he also experienced a mild fear of bumping into objects (See Figure 52). However, outside of this episode, he did not experience particular physical fatigue again in all other sessions.

EC1 did not experience fatigue in the easier levels of either scenario, but began to feel fatigued progressively as the difficulty increased, showing more fatigue in later sessions. EC6, on the other hand, reported fatigue in a single session, most likely because, on that day, he had to go through two consecutive sessions, which may have contributed to fatigue accumulation

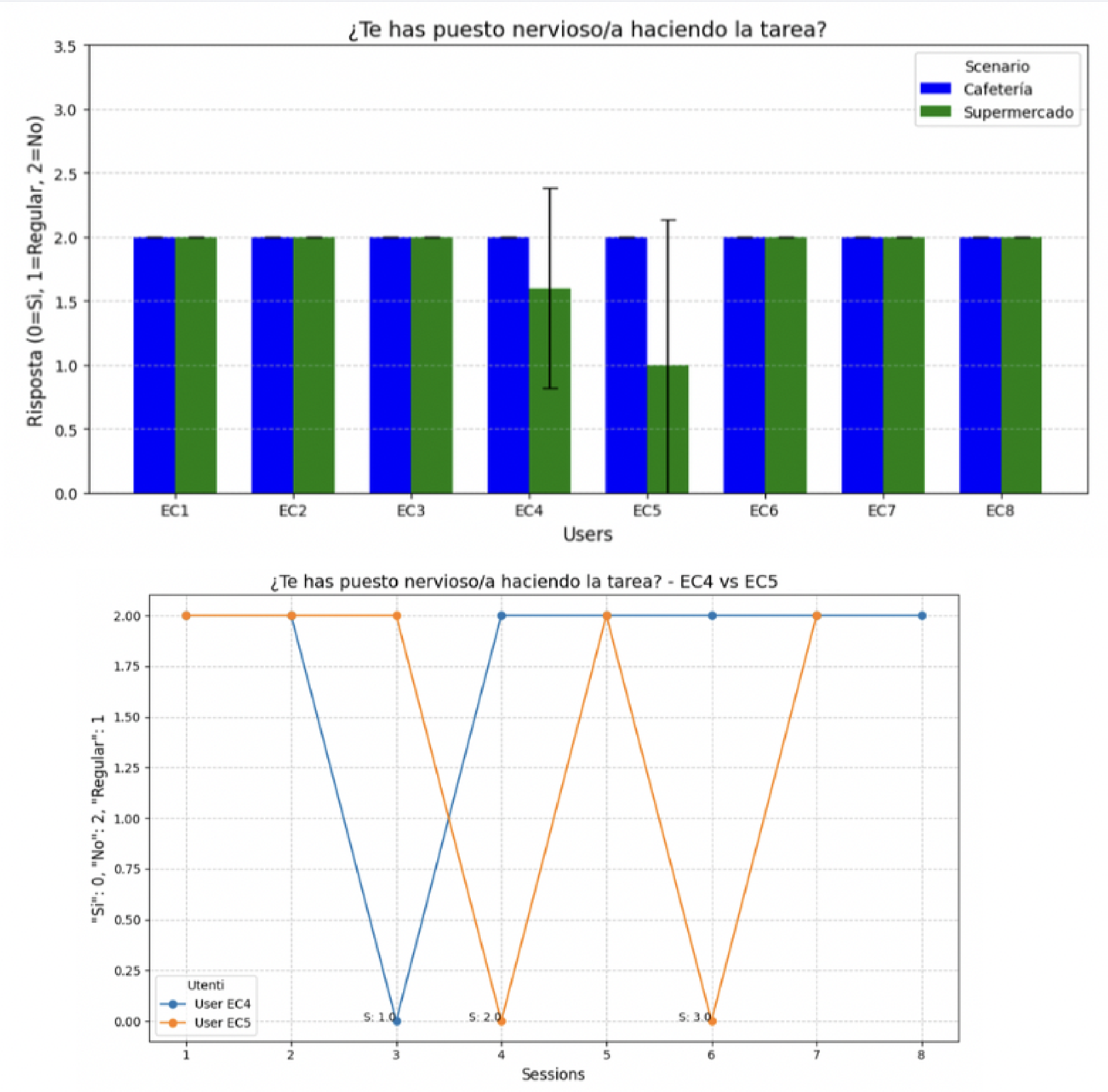


Figure 59: User perception in the two scenarios and focus on users with lower responses for “¿Te has puesto nervioso/a haciendo la tarea?”

The Figure 59 shows that EC4 became agitated during level 1 of the supermarket, particularly during the second repetition of this level. The user had difficulty relocating the products in their space because of the distance between them. As a result of this session, the idea arose to add separator bars (See section 4.5) to facilitate the placement of objects. After this modification, EC4 no longer exhibited episodes of agitation.

EC5, on the other hand, showed more agitation episodes. In the former case, the user could not remember exactly what he or she was supposed to do, while in the latter, apart from having to repeat a step, no particular episodes occurred.

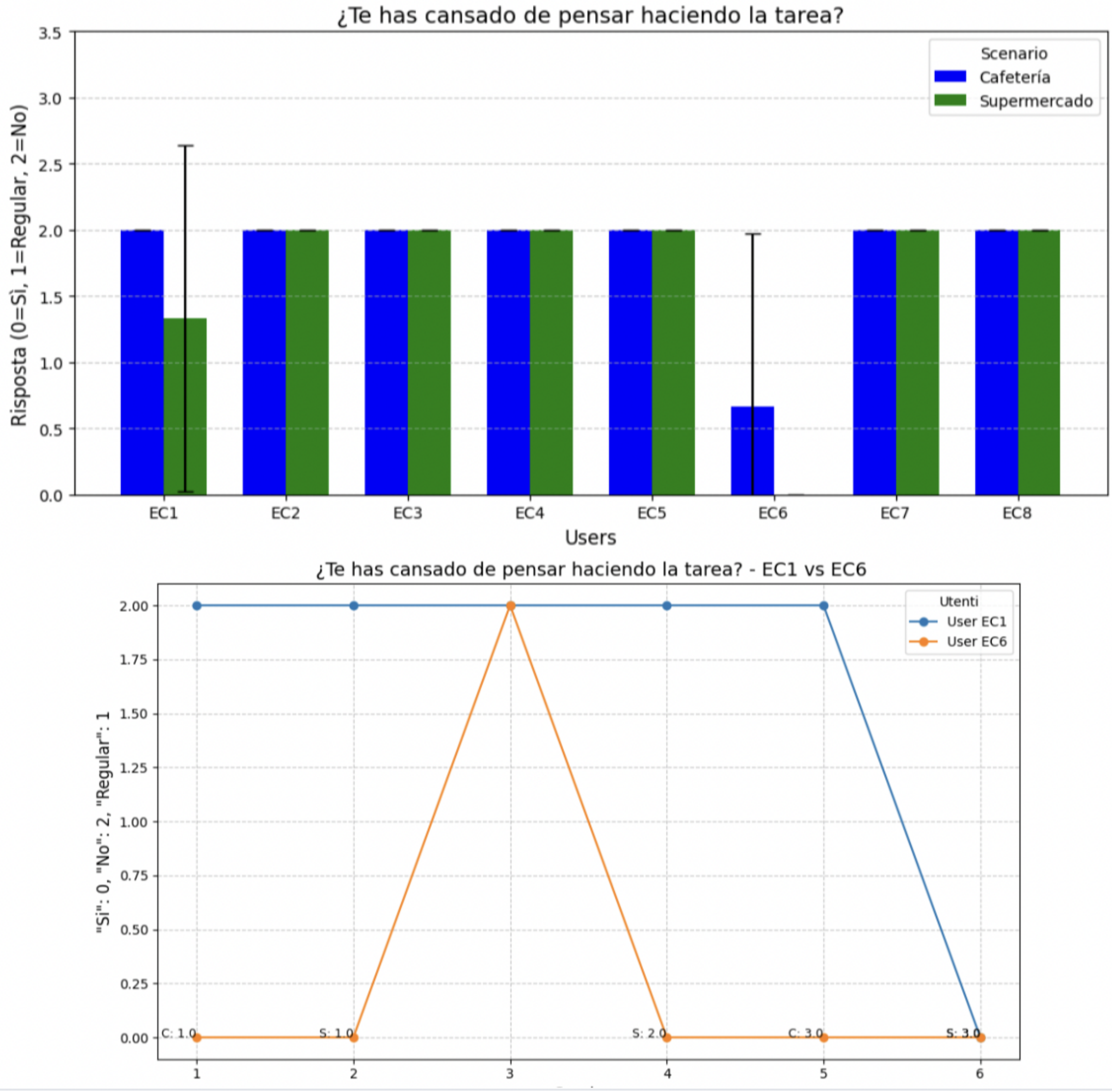


Figure 60: User perception in the two scenarios and focus on users with lower responses for "¿Te has cansado de pensar haciendo la tarea?"

The Figure 60 show a more specific analysis. While for EC6 the feeling of fatigue in having to think about what to do within the task is a recurring condition, for EC1 this was an isolated case, occurring in a specific session: the third level of the supermarket, coinciding with the transition from easy to medium difficulty levels.

Upon further analysis of this session, it became apparent that the increased fatigue was not caused directly by the user's performance, but rather by a technical problem in the game. This unforeseen issue caused EC1 to have to fix more items than expected, thus affecting the perception of fatigue and making the experience more challenging than in other sessions.

From the preliminary analysis, some differences emerged among the variables considered. In this case, statistical tests were conducted to determine whether there are differences between the two scenarios. However, instead of analyzing the responses to the levels based on individual questions, the levels were considered as a whole for each scenario, as the main differences in this case arise between the various questions. As a first step, the Kolmogorov-Smirnov test was applied and Once again, since all $p < 0.05$, the distribution of all data is not Gaussian.

First Test - Significant differences between Cafeteria and Supermarket in Mental strain.

By averaging all the questions for each scenario and applying the Mann-Whitney U test, the following hypotheses were considered:

- H0: There are no significant differences between the two scenarios for the mental strain.
- H1: There is a significant difference between the two scenarios for the mental strain.

The test results were as follows: $Statistic = 5542.0, p = 0.0682$.There are no significant differences between Cafetería and Supermercado, although the p-value is very close to 0.05.

Second Test - Significant differences between Cafeteria Levels and Supermarket Levels in Mental strain. The Kruskal-Wallis test was performed to verify if there were significant differences between the levels of the Supermercado in the following variables. The results indicate that no statistically significant differences between levels were found for any of the questions analysed. To find the difference I applied the test to each question for 3 levels. Following the hypotheses:

- H0: There are no significant differences between the 3 leves in the scenario (cafeteria/supermarket) for the mental strain.
- H1: There is a significant difference between the 3 leves in the scenario (cafeteria/supermarket) for the mental strain.

For the question in the 3 different levels "¿Has sentido que podías hacer la tarea con calma?" we have the results: $Statistic = 1.9999, p = 0.3679$ For the question in the 3 different levels "¿Te has cansado de pensar haciendo la tarea?" We have the results: $Statistic = 0.5864, p = 0.7459$ For the question in the 3 different levels "¿Te has cansado de moverte haciendo la tarea?" We have the results: $Statistic = 0.9043, p = 0.6362$ and finally for ¿Te has puesto nervioso/a haciendo la tarea? the results are: $Statistic = 0.0271, p = 0.9865$

These results suggest that participants perceived the task experience in the different levels of the Supermercado in a similar way. This occurs, as you can see in the graphs, because there are very few users who have had problems of mental strain, and that has not affected the general perception of the level.

For the Cafeteria, it is not possible to perform the Kruskal-Wallis test on all questions, since two of them have the same value for all levels, making statistical comparison impossible. Therefore, the test will be applied only to questions :"¿Te has cansado de pensar haciendo la tarea? and ¿Te has cansado de moverte haciendo la tarea?" for the three levels

The test of Kruskal-Wallis for the question "¿Has you tired of thinking by doing your homework?" in the Cafetería gave the following results: $Statistic = 1.045$, $p = 0.593$. Since the p-value is greater than 0.05, we cannot reject the null hypothesis, indicating that there are no significant differences between the three levels of the Cafetería regarding mental fatigue. For the question "¿Has you tired de moverte haciendo la tarea?" the results were $Statistic = 1.045, p = 0.593$. Again, the $p < 0.05$ suggests that there are no significant differences between the levels of the Cafetería regarding physical fatigue.

So, although the graphs of the preliminary analysis showed more oscillations, statistical tests confirm that the differences are not strong enough to be considered significant.

7. Conclusions and future work

7.1. Conclusions

The use case described in this Master's thesis, currently being tested as part of the Incluverso project, aims to enhance autonomy and develop job skills through VR integration, cognitive training techniques and biometric monitoring. The project, carried out in collaboration with the Juan XXIII Foundation, aims to foster a more inclusive and accessible environment by offering participants innovative tools to improve their skills and facilitate their entry into the world of work.

For this purpose, two immersive scenarios, a supermarket and a cafeteria, were created, designed to provide an interactive and realistic experience, allowing users to practice everyday work activities and develop practical skills in a safe and controlled environment. This Master's thesis led to the creation of an interactive supermarket environment, integrating essential game dynamics and interactions, with a special focus on the development of attention and concentration skills through progressively increasing the difficulty of levels. During the experimental sessions, participants completed questionnaires and the data collected from them has been statistically analyzed to assess the user experience.

The results showed positive findings in terms of spatial presence, usability, motion sickness, mental fatigue and subjective experience, indicating that users interacted with the system without difficulty and adapted well to the technology. However, no significant changes in performance or substantial differences were found between the two scenarios, probably due to the limited amount of data available for the study.

7.2. Future work

Following this thesis work, the sessions with the participants will continue at the Juan XXIII Foundation, with the goal of completing the remaining phases of Task 1 in both the supermarket and the cafeteria. Subsequently, Task 2 will begin, where users will engage in additional activities, such as serving tables in the cafeteria and managing orders in the supermarket. One ongoing challenge is eye tracking: the technical limitations of the current headsets require the development of more precise solutions to obtain reliable and detailed data. Finally, a comprehensive analysis of all sessions, including both Task 1 and Task 2, will be conducted to gain a broader and deeper understanding of the project's impact. The hope is to confirm the positive results observed so far and to validate the effectiveness of virtual reality as a tool for vocational training and job integration.

A. Ethical, economic, social and environment aspects

A.1. Introduction

This project leverages immersive technologies to support the inclusion of individuals with intellectual disabilities, enhancing their independence and professional skills. It integrates ethical, economic, social, and environmental factors to ensure a responsible and sustainable implementation.

A.2. Analysis of impacts reflected in the work

A.2.1. Ethical aspects

To ensure the respect and protection of participants, the project has established specific ethical procedures, providing detailed information to participants and their legal representatives. This includes a project overview, outlining objectives, duration, involved entities, and contact details, as well as details on data collection, storage, protection, and disposal, in compliance with national and European legislation.

In the INCLUVERSO 5G project, personal data confidentiality is ensured in accordance with EU Regulation 2016/679 and the recommendations of the Spanish Data Protection Agency. Explicit consent is obtained for the use of biometric data and participants' images, with all necessary documents signed and inclusion criteria met.

In cases of monitoring or observation, notification and authorization are provided, always ensuring the right to voluntary participation and the possibility to refuse for justified reasons. Anonymity is guaranteed through the use of an alphanumeric code, and collected variables include age, gender, type of disability, mobility issues, and medical conditions.

Furthermore, the project members acknowledge the commitment and responsibility to ensure that research conducted during experiments involving human participation adheres to ethical standards and complies with the current laws and regulations of the European Union (EU), including those outlined in the EU Charter of Fundamental Rights and the Convention on Human Rights and Biomedicine (Oviedo Convention).

A.2.2. Economic aspects

For the realization of this project, particular attention was paid to the economic aspect, as an initial investment was necessary for the purchase of all materials.

For VR headsets, the HTC + eye tracker model was chosen, as it allows for eye tracking and, among the available headsets on the market with this technology, represents one of the most affordable options compared to competitors like Apple.

Similarly, EMG sensors are more expensive than VR headsets, but the most cost-effective model was selected among those with non-invasive features, specifically small and wireless devices.

Finally, the wristband used to measure physiological arousal in patients was chosen for its ability to provide clear and precise information, minimizing data noise. This selection ensured one of the best quality-price ratio solutions available on the market.

A.2.3. Social aspects

This project is a use case within the INCLUVERSO project, which aims to research XR technologies and advanced 5G telecommunications to create immersive communication experiences applicable in therapy, telepresence, and teletraining. The goal is to make these technologies accessible to people in situations of psychosocial vulnerability, representing a fundamental step toward the development of a fully inclusive Metaverse, known as Incluverso.

The project collaborates with the Juan XXIII Foundation, an organization that works with people with intellectual disabilities and other forms of psychosocial vulnerability. However, one of the main challenges in developing this new technology is the risk of excluding certain groups of people who, due to age, economic condition, physical abilities, or psychosocial vulnerabilities (such as intellectual disabilities or neurocognitive decline), might find it unsuitable for their needs.

To ensure universal accessibility, it is essential to promote an inclusive development approach, engaging a broad range of communities so that this technology can truly be an accessible and valuable tool for all citizens.

A.2.4. Environment aspects

The use of virtual reality headsets (HMDs) simplifies the creation of immersive environments for therapeutic purposes, allowing patients to attend sessions directly at the Foundation, avoiding physical travel and contributing to the reduction of environmental pollution related to transportation. Additionally, it enables the simulation and management of rehabilitation equipment without the need to purchase it physically

A.3. Conclusions

By following ethical standards, selecting cost-effective and efficient materials, and promoting social inclusion and environmental sustainability, the project serves as a reference model for future initiatives. The collaboration with the Juan XXIII Foundation ensures that the developed technologies are practical and effective, providing innovative solutions to address real-world challenges.

B. Economic budget

This chapter presents a detailed economic analysis aimed at identifying and quantifying the essential resources. The analysis considered labor costs, including the hours dedicated to the development of the application and the sessions by the psychologist, as well as material resources, such as essential technological devices like computers, XR headsets, sensors, and specific software, along with the application of the applicable taxes.

LABOR COST (Direct cost)			Hours	Price/hour	TOTAL
		Application development	540	25,00 €	13.500,00 €
		Psycologist's session development	200	25,00 €	5.000,00 €
			TOTAL		**18.500,00 €**
MATERIAL RESOURCES COST (Direct cost)					
	Quantity	Purchase price	Use in months	Depreciation in years	TOTAL
Computer Lenovo	1	500,00 €	6	4	62,50 €
Computer RogStrix	1	1.967,20 €	6	4	245,90 €
VIVE XR Elite	1	1.000,00 €	6	2	250,00 €
Unity Prefab in Asset Store	2	130,00 €	6	2	130,00 €
EmbracePlus	1	2.160,00 €	6	2	540,00 €
Phone	1	259,99 €	6	4	32,50 €
PicoBlue sensors	1	7.590,00 €	6	2	1.897,50 €
Eye Tracker	1	199,00 €	6	2	49,75 €
		TOTAL			**3.208,15 €**
LICENSE COST AND SOFTWARE (Direct cost)					
		Annual cost	Payment in months	TOTAL	
Microsoft 365		0,00 €	0	0,00 €	
Unity		0,00 €	0	0,00 €	
Python		0,00 €	0	0,00 €	
TOTAL				**0,00 €**	
TOTAL RESOURCES COST					**3.208,15 €**
GENERAL COSTS (Indirect costs)	15%	over DC			**3.256,22 €**
INDUSTRIAL BENEFIT	6%	over IC			**1.497,86 €**
SUBTOTAL BUDGET					**26.462,23 €**
APPLICABLE IVA	21%				**5.557,07 €**
TOTAL BUDGET					**32.019,30 €**

Figure 61: Economic analysis

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