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Master Thesis

**Interactive Tutorials for Serious
Games on a Cognitive Stimulation
Web Platform**

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*Title: Interactive Tutorials for Serious Games on a Cognitive Stimulation
Web Platform*

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Abstract

English

In recent years aging population is increasing rapidly in most developed countries. In the past years for the first time, the population of people above 65 is getting bigger than the children. As they grow older, older people acquire special needs and suffer limitations.

While major studies are focused on the physical limitation and needs of older adults, it must be considered that their needs are not limited to physical ones. Cognitive abilities such as memory, attention, speed of processing, and problem-solving are likely to decrease with aging. So, mental and cognitive health is equally important alongside physical health for older people, and unfortunately, the current health system is not committed enough to the different needs of this age group.

In order to provide healthy aging and decrease these limitations, eHealth technologies such as tools, platforms, and health services can be helpful. Although there has always been a gap between the use of technologies and older users, research shows that in recent years the use of communication technologies is increasing among older people. This means that by providing a useful system with the consideration of older adults' limitations, this technology gap could be reduced. In addition, these systems can help users with increasing their cognitive abilities.

To achieve this goal, the Center for Prevention of Cognitive Impairment with the collaboration of the Aging lab of Technical University of Madrid has developed a web platform including different serious games for cognitive stimulation. These games are designed to reduce the progress of cognitive decline. Also, this platform allows professionals to collect valuable data from the given activities. The main goal of this master thesis is to reduce users' challenges by providing interactive tutorials for two of the most difficult games on this web platform according to the user feedback collected so far. In this master thesis, interactive tutorials represent a system to manage the learning process and to guide users during this process by providing useful feedback and information through images, texts, and audio.

This document first includes the theoretical foundations used during the conception of the system, the state of the project at the beginning of this thesis, and the possible existence problems will be discussed. Secondly, the processes from the initial design until the web implementation of the tutorials will be covered.

Abstract

Spanish

En los últimos años, la población envejecida está creciendo rápidamente en la mayoría de los países desarrollados. De hecho, en la actualidad, la población que supera los 65 años es, en muchos países, superior a la cifra de niños. Desafortunadamente, las limitaciones y necesidades de la población envejecida son una realidad.

Los grandes estudios se han centrado principalmente en las limitaciones y necesidades físicas de las personas adultas, dejando en un segundo plano el ámbito cognitivo. Sin embargo, la salud mental y la cognición son tan importantes como la salud física en la población envejecida y, lamentablemente, el sistema de salud actual no se adapta a las necesidades de este sector de la población. No se debe obviar que habilidades cognitivas como la memoria, la atención, la velocidad de procesamiento y la resolución de problemas tienden a disminuir con la edad.

Las tecnologías e-Health son una gran solución para fomentar un envejecimiento saludable y para paliar estas limitaciones. Estas tecnologías engloban el uso de herramientas, plataformas y servicios de salud. Si bien es cierto que la brecha digital tiene un impacto negativo en la población envejecida, los estudios muestran que en los últimos años, el uso de las tecnologías de la comunicación ha aumentado notablemente en este sector. Esto significa que si son dotados con aplicaciones o sistemas útiles adaptados a sus necesidades y limitaciones, la brecha digital podría ser reducida. Asimismo, esta tecnología podría ayudar a los usuarios a mejorar sus habilidades cognitivas.

Para lograr este objetivo, el Centro de Prevención del Deterioro Cognitivo en colaboración con el Ageing Lab de la Universidad Politécnica de Madrid, han desarrollado una plataforma web que incluye diversas actividades que promueven la estimulación cognitiva. Estas actividades han sido diseñadas para reducir el progreso del deterioro cognitivo. Asimismo, esta plataforma dota a los profesionales de una valiosa información generada a través de las actividades propuestas.

Por todo ello, el objetivo de esta tesis es crear un tutorial cognitivo para facilitar el proceso de aprendizaje asociado a la estimulación cognitiva y al mismo tiempo generar un tutorial para que la población envejecida entienda las actividades anteriormente mencionadas de forma autónoma sin ningún tipo de supervisión.

Por un lado, este documento incluirá un marco teórico de la concepción del sistema, el estado del proyecto al inicio de esta tesis y se debatirán los posibles problemas existentes. Por otro, se incluirá el proceso desde el diseño inicial hasta el último desarrollo del sistema.

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1 Introduction

Over the past years in most countries, the aging population has been growing. In developed countries, the focal point is about to shift to old age because the population above 65 years is growing more than the population below that age. In 2018 for the first time in history, older people outnumbered children (Nations, 2019). And it is expected that the population of age group above 65 rises from 10 percent in 2022 to 16 percent in 2050. At that point, the number of this age group will be more than twice the number of children under five years old (Nation, 2022).

Older adults have diverse needs, and it is essential to provide different services for them. These needs aren't limited to dietary needs and visiting doctors regularly. It is important to focus on other perspectives like older people's mental health or cognitive problems. The aging process changes various factors in people's life such as social roles, retirement, and physical problems. All these factors can influence mental and social challenges for older adults (Hirst, SP & Lane, A, 2013).

Additionally, evidence showed that the frequency of cognitive impairment is increasing. Cognitive decline refers to the impairment in one or more cognitive functions and can be categorized into different ones. These changes could affect daily activities and communication abilities. Cognitive changes associated with the aging process are such as slow processing speed, short-memory problems, decreased attention, and inability to quickly measure and recognize information.

eHealth has been one of the World Health Organization (WHO) priorities since 2006. It refers to the use of technologies in healthcare support and health services. eHealth is not just technical development, but it is also a way of thinking and commitment to improving health care by using information and communication technologies. eHealth can increase medical diagnosis quality and acuity, and consultation efficiency. Also, using eHealth can decrease medical errors and instead increase health outcomes by increasing patient adherence to treatment and having positive psychological impacts.

Many healthcare facilities and eHealth technologies help with older adults' lives. Research shows that although older adults have a lower rate of technology adaptation compared to other age groups, this percentage of using technologies is increasing in the last years. However, there is still a noticeable difference between adults over 65 and younger people. Studies show that in 2017, four in ten older adults own a smartphone and this number is twice compared to the year 2013 (Anderson M., Perrin A., 2017).

On the other hand, the main problem is that adopting new technologies can be hard for old people. Older adults have lagged in the use of technologies, and it has caused a gap between technology and this age group. Generally, there are some technological barriers and social barriers which cause this gap. Many systems aren't adapted to the needs and limitations of older people and there is a lack of integration with existing tools. Also, many older adults lack skills, knowledge, and interest in using these technologies, which leads them to limit themselves in using technologies because they believe they do not have enough knowledge or technological skills, and they resist learning new technologies.

Older adults can take advantage of new technologies which are designed based on their needs and their abilities. Furthermore, motivation is another key aspect of this adaptation and eHealth can provide systems that motivate more old

adults when they are more suitable to their needs and their special characteristics and limitations.

To reduce this gap and facilitate the use of technology in this field of eHealth, there are several types of research centers and laboratories working. A lot of this research is focused on understanding factors of healthy aging and environmental factors which have impacts on successful healthy aging. The department of health of Madrid has created different alternatives to increase healthy aging among older people. Also, the Center of Prevention of Cognitive Decline (CPDC in Spanish) of Madrid Council is collaborating with the Technical University of Madrid on the development of a cognitive simulation system on a web platform.

This web platform includes 15 serious games or cognitive exercises that challenge different cognitive abilities of users. These games aim for abilities such as language, organization, memory, attention, and the ability to find patterns in sequences. However, as it was mentioned above, many older adults may have problems interacting with devices such as smartphones or mice, or they may have difficulties understanding the game rules. The main goal of this master thesis is to reduce users' challenges by providing interactive tutorials for two of the most difficult games in this web platform according to the user feedback collected so far. In this master thesis, interactive tutorials represent a system to manage the learning process and to guide users during this process by providing useful feedback and information through images, texts and audios.

All the games have already been developed and users can access them on the webpage. The design of the tutorials has been based on user feedback and previous studies conducted by the CPDC and the supervisors of this master thesis. Besides, the HiFi prototypes of the tutorials have been validated by psychologists of the CPDC.

The structure of the document includes an overview of the theoretical background of cognitive decline definition, older adults' requirements and limitations, and guidelines to design a tutorial for older adults. In the third chapter, the main context of the thesis is provided and the stage of the work before and after the thesis is defined. In Chapter 4 the scope and the problem statement are defined. And in chapters 5 and 6 the whole process of designing the tutorials from the initial prototypes until their web implementations will be covered. Finally in the last section the conclusions and possible future works will be discussed.

2 Theoretical Foundations

In the following chapter, some theoretical foundations about cognitive decline, tutorials and eHealth will be reviewed and discussed. Also, this section provides the groundwork for the subject of interactive tutorials on cognitive stimulations. Firstly, in older adults, cognitive impairment is a common aspect, and it can have different causes and symptoms. The purpose of this project is to help people who already have mild cognitive impairment and help people who want to prevent themselves from cognitive decline. There are different studies of effectiveness of cognitive stimulation and different methods found which can be useful.

Secondly, most cognitive stimulation is provided in digital platforms and systems. Also, there is a gap between the use of technology and older adults. To reduce this gap, the main purpose is to provide interactive tutorials designed to educate and train users.

Moreover, by examining these principal areas, this research goal is to provide an understanding of interactive tutorials for different cognitive stimulations.

2.1 Risk factors for cognitive decline

There are many risk factors associated with cognitive decline. These factors are contributed to the reduction of cognitive abilities which can cause by aging. Comision Lancet has identified some causes such as less education, hypertension, consumption of tobacco, hearing loss, obesity, depression, and low social contract. And in the new studies, three more risk factors such as excessive alcohol consumption, traumatic brain injury, and air pollution have been added. Knowledge of these factors is crucial for addressing cognitive impairment and developing cognitive simulations.

2.2 Early detection and prevention of cognitive decline

Cognitive aging is the process of how older adults' cognitive abilities changes as they age. Many studies have dedicated ways to prevent to slow down this process and prevent approaches that focus on what factors cause the cognitive aging process. Early detection of cognitive decline is crucial in addressing and reducing risk factors and preventing the progression of dementia. Identifying cognitive impairment at early bases enables healthcare professionals to understand and reduce the process with different necessary disciplines.

According to WHO dementia is a rapidly growing public health problem that affects more than 50 million people worldwide and this number is expected to grow to 82 million in 2030. According to this report, they identified some non-modifiable risk factors such as genetics, sex, age, and ethnicity. Moreover, they have established recommendations regarding factors that should be improved such as physical activity, nutrition, cognitive interventions, and weight management. (WHO, 2019)

Furthermore, by emphasizing the importance of early detection, it is possible to prevent or decrease the speed of cognitive decline with lifestyle modifications, cognitive stimulation, and reducing risk factors such as weight gain, alcohol, and tobacco consumption, early management of hypertension, diabetes, hearing problems, depression (Livingston, G., Huntley, J, 2020).

2.2.1 Cognitive training effect

Studies show, cognitive training has gained a significant attention in the early detection and prevention of cognitive decline. Some epidemiological studies suggest that the mentally active people are at a lower risk of cognitive decline in old ages (Wilson RS, Mendes De Leon CF). These benefits are including enhanced cognitive abilities, slowing cognitive decline, and neuroplasticity and brain health.

The improvement of cognitive functions might have short-term or long-term effects and training impact can be decreased over time. The study on the effects of cognitive training on older adults on 2832 persons aged 65 to 94, showed proximal continuous training, effects through 24 months, and a significant segment of trained individuals went forward up to 2 years of better cognitive skills. (Ball K, 2002)

Moreover, cognitive stimulations promote the brain's ability to recognize connections by providing challenges that improve cognitive resilience and help with healthy aging by reducing the risk of cognitive decline.

2.3 Prevention and intervention in the aging process

Promoting a healthy lifestyle is crucial in preventing age-related cognitive decline. All people have different lifestyles and personal dispositions, and these lifestyle choices can contribute to maintaining optimal cognitive function by reducing the risk factors of cognitive impairment. So, interventions should be individually designed based on their needs and from a catalog of different components. A diverse range of components and therapies can be selected from this catalog to create individual intervention plans. It includes various therapies such as cognitive stimulation, cognitive training, cognitive rehabilitation, transcranial magnetic stimulation, reminiscence, art therapy, music therapy, support and psychotherapy, sensory stimulation, physical activity, diets social activities, and others. (Yubero, 2016)

Furthermore, prevention and intervention in aging process means taking steps to keep cognitive abilities with aging. This intervention is about how to avoid risk factors that were mentioned in the previous section and cognitive stimulation and activities is a proactive approach to maintain these abilities in older adults.

2.4 Cognitive stimulation

As it's been mentioned in the previous section, cognitive stimulation is one of the key aspects of preventing and treating cognitive decline. Cognitive stimulations involve activities which challenge and stimulate the brain. These activities aim to activate some cognitive apparatus such as problem-solving, and attention with targeted stimulation by use of the different activities. Also, these activities can include generic activities such as board games, chatting, leisure interest, and specific activities designed to for each ability like memory games. (Montejo, P., & Montenegro Peña, M., 2016)

Also, Cognitive stimulation for people with dementia offers a range of activities that are not only mentioned on what it has been mentioned above but also, focuses on contribution and thinking in a social setting. There is various evidence that shows cognitive stimulation effect in people with mild to moderate dementia. (Woods B, Aguirre E, 2012)

Additionally, the theory of cognitive reserve suggests that cognitive stimulation can be helpful in cognitive decline treatment. This theory shows a direct connection between a high level of education with memory and cognitive abilities

in older people. Studies show that people with higher education often have a history of active work and participation in cognitive cultural and physical activities and other factors which may contribute to their cognitive performance. These experiences can build up a cognitive ability that helps to protect the cognitive function of aging. (de Godoy, 2020)

Engaging in regular cognitive stimulation has several potential benefits in the process of aging such as preservation of cognitive health by reducing the speed of cognitive decline. By incorporating cognitive activities regularly, older people can engage their minds and promote their overall cognitive health.

2.5 Application of computerized cognitive training

Using computerized cognitive training can be helpful in older people with cognitive impairment. Some benefits of the use of these training are improving cognitive function, convenience, and personalized training which each of these training is focused on specific cognitive skills. And it is important that training should be customized to individual needs and allow a wider range of activities to be included in the training. On the other hand, computerized cognitive training enables more accurate monitoring methods and makes it easier to measure the results. Additionally, this improves the reliability of progress and results. (Hill, Mowszowski, 2017)

Incorporating interactive elements and multimedia features such as videos makes the training more accessible and interesting for users. Computerized cognitive training is designed to get users' attention and create a more engaging experience which increases motivation and participation in the training. This can keep users entertained which leads to better outcomes in cognitive function. They can be used without the need for constant supervision and users can engage in cognitive training from in their home or day centers. This increment of accessibility and flexibility on time and location allows more people to participate in the system independently and more users can benefit from this training. (Posada Ospina, 2017)

There is a gap between older adults and the use of technology and computers, and older adults may have a problem when it comes to the use of technology. On one hand, the problem is with the lack of knowledge and adoption of older people. Most older adults do not have enough knowledge of the use of technology, and they do not have encouragement to learn how to use them. This can be solved by social support and perception of usefulness of technology. On the other hand, many systems are not designed according to their needs and limitations. (Renaud, 2008)

2.6 Usability and user-centered design

Usability refers to how easily and efficient a user can interact with the program and accomplish their goals. Since we are dealing with older adult users, it is crucial to understand their capabilities, limits, needs and preferences. Also, user-centered design factors such as the physical and cognitive abilities of older users must be considered in order to have a more user-friendly and effective program. It aims to create a program that considered age-related challenges such as vision or hearing impairments by incorporating features such as clear navigation and adjustable settings.

The International ISO Standard 9241-210 emphasizes the importance of usability design and provides requirements and recommendations for creating a user-friendly and effective system. Also, the requirements' goal is to improve general sustainability and accountability. These guidelines include involving users in the design process and understanding their needs and their limitations.

So, in the user-centered design, it is important to gather information from users through observation and have knowledge of their challenges. Moreover, the guidelines of ISO Standard improve overall usability and enhance the user experience. (International Organization for Standardization, 2019)

The main goal of user-centered design is to design a system based on the needs and interests of users so they will find the system usable and useful (Norman, 2002).

Source	Principles
Norman, 2002	<ul style="list-style-type: none"> • Make it easy to determine what actions are possible at any moment. • Make things visible, including the conceptual model, alternative actions, and results. • Make an evaluation of the state of the system easy. • Avoid complex navigation between intention and required actions.
ISO, 2019	<ul style="list-style-type: none"> • Design should be based on an understanding of the user, their tasks, and their environment. • The users are involved through design and development. • The design is driven and refined by user-centered evaluation. • The design is an iterative process. • The design encompasses the user experience. • The design team comprises a mix of interdisciplinary departments.

Table 1. Principle of user-centered design

As suggested in Table 1, user-centered design emphasizes the importance of usability and effectiveness.

2.7 Design guidelines for older users

Although the use of technology-facilitated health care can provide a positive impact on older adults' life, this group consistently have a lower rate of technology adaption. most older adults are not willing to use these technologies because of several factors. the most important reasons for the technology gap between older users and technology are cognitive decline which could happen during the aging process and fear of using recent technology. (Czaja S. J., 2006)

On the other hand, these barriers are not limited to a lack of knowledge in older adults. Reasons such as the cost of the technologies and equipment, complexity, lack of access to technologies, and internet and technology barriers can cause this gap. Older users have less access to the internet in comparison to other age groups. (Berry, 2011)

Type of barriers	Description
Technological	<ul style="list-style-type: none"> • Security and confidentiality • Technologies are not adapted to users' needs (professionals or patients) • Lack of integration with existing tools • Lack of Health-IT professionals & culture

Personal and social	<ul style="list-style-type: none"> • Lack of knowledge and training • Lack of skills and education • Fear of learning and resistance to change • Lack of interest
Financial	<ul style="list-style-type: none"> • Lack of financing • Lack of funds for up-front costs • Lack of incentives
Organizational	<ul style="list-style-type: none"> • Lack of legal frameworks, regulation • Liability issues • Lack of governance mechanism to assure continuity of care • Time consumption

Table 2. Barriers to the use of Technologies among older adults

It must be considered that older users have some physical barriers, such as reduced sight, hearing loss, arthritis, or other joint pain and memory problems. All these physical and cognitive barriers could be different for users. So, the design of systems must consider all these limitations and aim at the need of older users. People who are over 70 are likely to have both vision and hearing reduction (Brennan M, 2005).

2.7.1 Visual guidelines

One of the impacts of aging is the reduction of sight which is likely to happen from early ages such as early 40s. Some key recommendations can reduce the negative impact of visual problems which can cause by aging. Studies show that high contrast like using black text on a white background is very essential for older users and the use of similar colours for background and information must be avoided. Also, simplicity is an important aspect of visual presentation. All essential information should be provided in a large, conspicuous, and located in the central visual field. Also, the use of colour is important for older users. This group of users is likely to not distinguish some colours and studies show they are more likely to prefer warm colours than cooler colors. (Farage, Miller, 2012)

Furthermore, software that allows users to adjust and make text and graphics bigger or provide auditive options as alternatives to the system, can make the use of technologies easier for older users. Also, simplicity and avoidance of use of distractive visuals like fast movement are necessary. (Czaja, 2019)

2.7.2 Auditory guidelines

The aging process changes hearing capabilities in older adults. They are likely to have problems such as lower levels of sound recognition and hissing and tinnitus. All these problems can affect users in using technologies that have auditive alternatives. To reduce these limitations, the sound or messages in the system should have enough high volume. Studies show the sound signal should be higher than 60 dB. Also, the speed of the information should be adjusted to the need of this age group. Shorter sentences and pause after each statement in verbal information can be helpful to overcome hearing limitations. Furthermore, simplicity is essential in providing auditive alternatives. Background noises or unmercenary sounds should be avoided in the design for older users. (Farage, Miller, 2012)

Furthermore, since some older adults have both hearing and vision problems, auditive instructions should be always an alternative to delivering information.

2.7.3 Cognition guidelines

One of the alternatives to the aging process is changes in memory and cognitive abilities. Older adults are likely to have problems with recalling and processing complex information which leads users to get easily overwhelmed by performing activities that require multitasking or processing complex information. So, the system designed for older adults should be based on short and simple memorable user flows (Sae Farias, 2019). To deal with this limitation, it is better to not provide complex tasks which require memorizing enormous amounts of information. On the other hand, long-term memory is likely to not be reduced by age. This information such as language, history, and cultural norms are gathered over the lifetime (Czaja, 2019).

Moreover, with aging, the capability to multi-tasking and focus on multiple tasks reduces. Older users need more time for orienting their attention from one thing to another. This ability to switch focus is affected by aging and for older people it is harder to pay attention to fast-moving elements (Czaja, 2019).

In general, the system should have quite simple steps and the number of steps should be as minimized as possible. And there should be a clear point of focus on the system for users and the system must follow simple and short displays.

2.8 Design guidelines for tutorial

Aging affects the quality of life on several levels, and it does not limit to physical problems, but also older adults often experience a variety of cognitive decline. One of the strategies proposed by the World Health Organization called “Active Ageing” aims to improve the quality of life in older people through healthy lifestyle and behavioural factors.

The study of IJsselsteijn emphasized that specific digital games and cognitive stimulation and social interactions benefit cognitive abilities in adults and seniors (IJsselsteijn, 2007). However, since older adults have different limitations and condition, designing these systems require different attention to factors such as usability, accessibility, and the elder’s age-related challenges based on their physical abilities. For example, font size, colour, and contrast should be different for older users. Also, games with a low level of complexity and focused on cognitive abilities are proposed.

Maintaining users’ motivation is important for successful rehabilitation outcomes. Motivation can be boosted by many elements such as setting goals, providing feedback, reward, and challenges, and providing a visually appealing game environment (Flores, 2008). In 2006, the ElderGames project aimed to focus on cognition technology and games for older adults. In order to design this project, understanding the specific cognitive needs and preference of older adults is necessary. This study shows that older users are interested in the use of technologies despite having problems with understanding systems. (Gamberini, 2006)

A large population of older adults is not familiar with technology, and they may need supervision to overcome this issue. But the problem is that as it has been mentioned, in the computerized cognitive training system, users can be used without the need for supervision which improves the flexibility and accessibility of the system (Posada Ospina, 2017). Also, a large majority of older adults do

not have familiarity with these systems, or they may feel intimidated or fearful of using technologies that are new to them. These problems can be overcome by providing user-friendly devices, training, utilizing visual aids, and ongoing support.

One of the ways of providing mentioned assistance is by using tutorials. Tutorials in serious games are used to teach players the game mechanism, rules, and interactions. These days, video games use a variety of tutorial styles to make understanding of the system easier for players. The design of interactive tutorials is hardly dependent on the platform, the sort of the game, and the peripheral hardware used. With the use of interactive tutorials players can determine their own stories on their own and they can understand where they went wrong and try again (Squire, 2013)

2.8.1 Learning process and Aging

There are various stages in the development of the mind. From the point of view of Piaget people have a basic level of mental operation in childhood and then a more concrete and realistic way of thinking in adulthood and the level of cognition varies in different people (Piaget, 1951). And this way of thinking will become more and more realistic during adulthood. But it must be considered that by aging and reduction of cognitive abilities, older people would have problems with learning new things.

Core Mayer's Cognitive Theory of Multimedia Learning demonstrates different principles about how we can make multimedia display line up with the cognitive architecture of the human mind. The first key principle is the multimedia principle which demonstrates that using a combination of words and relevant visuals such as images, videos, and diagrams is better at teaching than text alone. The second principle is a modality that is easier to import. Modality tells us that learners are better at remembering and understanding instructions when they are presented as speech rather than in text. The other principles focus on the importance of organizing tutorials in a logical and meaningful manner, simplicity of the tutorials, and dividing complex tutorials into smaller and manageable segments. Following these principles in tutorial design can increase the chances of learning users (Mayer, 2009).

As it has been mentioned in the design guidance for older users' section, there are some necessary considerations for designing a system for older adults. All those recommendations must be considered as well as learning principles that the older users have more limitations. For example, Mayer's principle mentioned that both text and audio must be provided for the users, but since our target users are older adults, we should have text and audio according to their needs.

2.8.2 Learning design

The step before designing the tutorial is to understand the mechanisms of the game and focus on what can be complex for users. There are some main approaches that work particularly in learning from a game which also keeps users expurgate to play.

Learning support

If users cannot figure out how to engage with the game in the first few steps of the tutorials, they are likely to not continue playing. To avoid this from happening, some learning supports can be used. Users always should have

potential help offers. For normal games, this help should offer in sounds rather than text but in cognitive stimulations, both text and sounds should be offered. During learning support, cognitive loads should be minimized, and the user should emphasize learning over having to parse information.

Immediate feedback

For behavioral lessons to work the behavior should be corrected immediately. In the games, feedback should be immediately given to the users. Users must connect their behaviors with what is happening in the game and learn from it. If a player is picking a wrong answer, immediate negative feedback must be shown. This feedback should be supported with learning support with an explanation to increase the chance of learning for the user. Also, positive, and negative feedback can encourage players to keep playing.

Difficulty adjustment

In general, teachers use this method over the years to teach students. They decode and chunk a problem into smaller and more manageable problems, so the students can learn little by little and as the student learns, the teacher reduces the assistance. In games also the mechanism should be divided into smaller and more understandable bits and the assistance should be reduced over time.

3 Initial State of the Project

The master thesis contains the design and development of two interactive tutorials for cognitive games which are both focused on memory and organizational ability. Games are previously developed in an online platform called `mejoralamemoria.es` which provides elder users with 15 different cognitive activities. In the following part, we give an overview of all activities.

Mejorarmemoria is a collaborative initiative developed by the Technical University of Madrid in partnership with the Centre for Prevention of Cognitive Deterioration (CPDC in Spanish). The CPDC is affiliated with Madrid Salud, which is an autonomous organization specializing in researching and preventing cognitive decline for older people.

This project includes 15 different activities from different cognitive categories. Each activity stimulates different areas of cognitive abilities like memory, attention, language, and organization. This platform provides a range of exercises to enhance memory and overall mental performance, brain-boosting activities, and maintain cognitive health. Users can use the system to improve their cognitive abilities. Also, professional users, which can be psychologists or doctors can monitor and view the progress of users.

Moreover, users can pick games on the main page by clicking on the name or picture of the game. Also, they can choose which level of difficulty they want for themselves. In those games in which the tutorial is implemented, users can pick on the option of tutorial and play the interactive tutorial. Additionally, each user is asked to create an account when they are visiting the page for the first time. The user is asked to provide information including age, gender, and level of education. Also, this platform can be accessed with mobile devices or computers which gives higher flexibility and accessibility to users.

3.1 Software architecture

This section provides an overview of the architecture of the platform and how various parts of the platform work together. The page uses jQuery for DOM manipulation, HTML and CSS, and PHP for the backend API.

Each activity within the platform is represented by its own set of files including HTML, JS, CSS, and JSON. Each of them is called `prueba_N.html` for HTML file, `controladorPruebaN.js`. And `niveles_prueba_N.js` for JSON files with N being the identifier for each exercise. Each JSON file holds different information like the name, location of image files, and information about each level of difficulty.

Also, the homepage of the platform utilizes jQuery for DOM manipulation, HTML and CSS for the presentation layer, and PHP for the backend API. This project runs the backend on the server by providing API to the client and making queries to the MySQL Database which runs on the server.

The PHP code of the platform encompasses various REST API endpoints that support GET and POST requests for different functionalities.

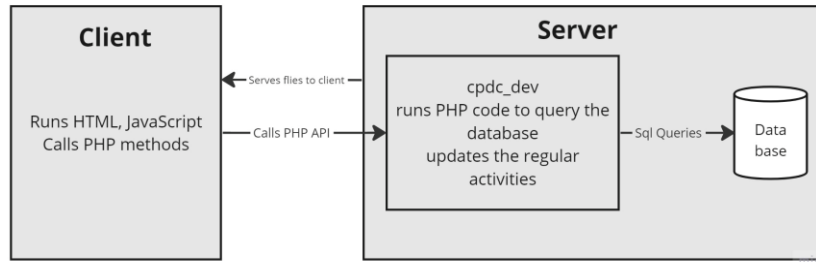


Figure 1. View of production Architecture

API endpoints include scripts which are executed and involved with construction of SQL queries which retrieve specific data. The sent data from frontend to the server can include user data for update, activity data for recording, or a value indicating the desired data type to be retrieved by the endpoint.

login.php: Accepts the email and password, compares them with the encrypted password in the database, and returns a token.

Logout.php: Removes the stored session token in the browser.

Register.php: Receives user data (email, name, surname, password, age, gender, education) and creates a new entry in the user table.

Guardar_datir.php: Takes data from a completed activity repetition (score, errors, time taken) and a JSON object with detailed action information.

Controlador_comprueba_conectador.php: It checks if a PHP session is exists for a specific user ID and returns the account type.

Each JSON file includes information about the name, location of pictures and audios. Also, it includes information about different levels of difficulty (see Figure 2).

```

{
  "gameTitle": "Descubra el refrán",
  "instructions": "Va a trabajar el LENGUAJE formando refranes.",
  "instruccionesDuranteJuego": "Blablaba",
  "textoFinal": "<p>Ha ejercitado su memoria en el <b>{nivel}</b>. Sus resultados son:</p> {graphics} {motivationalText} <p>Para vol",
  "colors": {
    "red": "#ffffff",
    "blue": "#C5E4FC",
    "green": "#FFE080"
  },
  "niveles": [
    {
      "displayName": "Nivel 1",
      "dataName": "Nivel 1",
      "refranes": [
        {
          "main": "Errando se aprende",
          "alt": ["Se aprende errando"]
        },
        {
          "main": "Las apariencias engañan"
        },
        {
          "main": "Querer es poder"
        }
      ]
    }
  ]
}
  
```

Figure 2. View of an example of information in JSON files

3.2 Activities

This platform has 15 different cognitive activities. All these activities have been developed previously, and a part of playing interactive tutorial had been added to two of them. Each of these activities aims to focus on different cognitive factors which are in four distinct categories:

- Activities which stimulate attention.
- Activities which stimulate visual memory.
- Activities which stimulate language.
- Activities which stimulate organizational ability.
- Activity which stimulates mathematical abilities.

Studies show cognitive stimulations can be used in older adults to improve cognitive functioning. Working memory training improves cognitive abilities such as attention and working memory in older people. Also, these activities can have a positive impact on mood (Mervin, 2021). In the following part, each category of cognitive stimulation type will be provided.

3.2.1 Activities that stimulate attention

This category includes simple serious games which include activities base on attention like matching icons, finding similar tiles, and finding a pattern. These activities are designed to improve attentional skills. All the activities in this section require attention, decision-making and filter distractions.

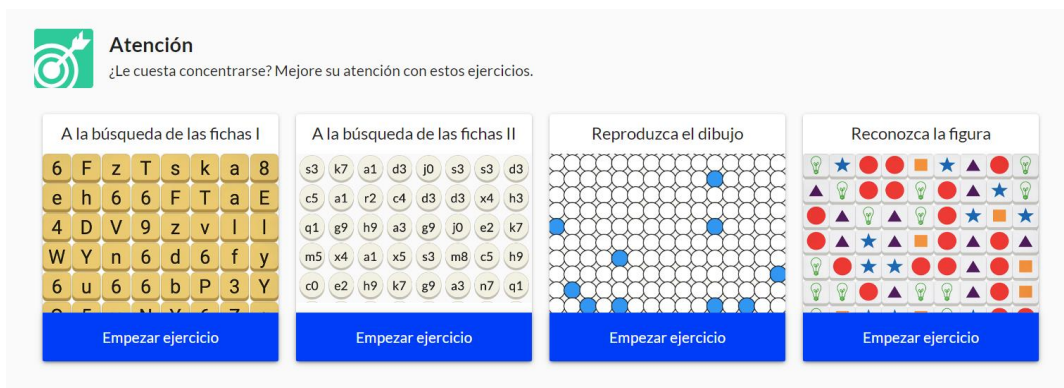


Figure 3. Overall view of activities of attention

3.2.1.1 A la búsqueda de fichas I (Find the tiles I)

In this game, there are different tiles on which each tile shows a number or letter. The user should choose a specific number of tiles that match the number shown at the top of the screen. After choosing the answer, the user can see if it was correct or not based on the positive or negative feedback of the system. When the answer is correct the tiles turn green and when the answer is wrong, the tiles turn red. Also, users can see the number of tiles left to choose from top of screen. (See Figure 4)



Figure 4. View of “A la búsqueda de fichas I” activity

3.2.1.2 A la búsqueda de fichas II (Find the tiles II)

This game has the same title as the previous game since they are both focused on attention to detail of tiles. The rule of this game is similar to the previous game. There are two tiles shown on the top of page and the user must find tiles that are like those two. Also, same as the previous game, if the user chooses the wrong title, it will turn red and if the chosen tile is correct, it will turn red.

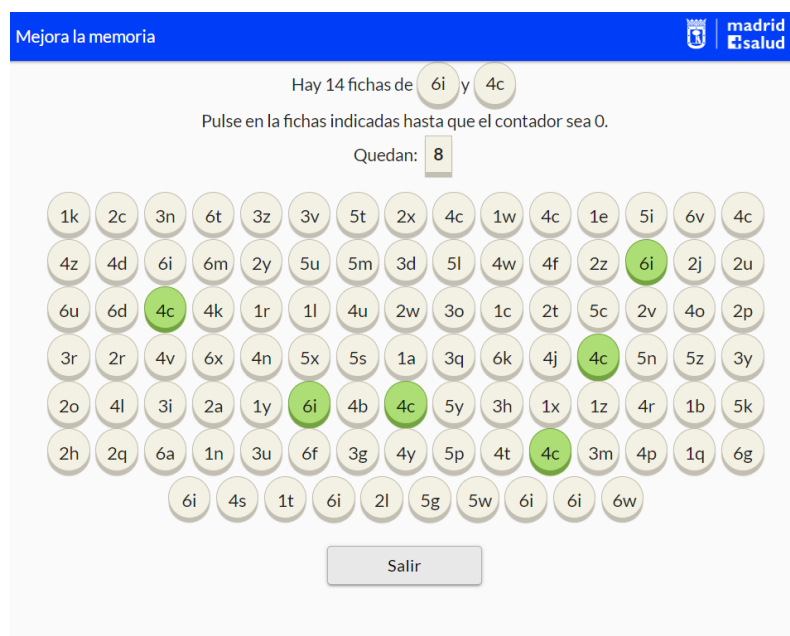


Figure 5. View of “A la búsqueda de fichas II” activity

3.2.1.3 Reconozca la figura (Figure recognition)

In this game, an icon shows on the top of screen. Users must recognize which icons are similar to the icon on top of the page and select them. Also, on the top of the screen, there is a number that shows how many icons are left to select. If the user selects a correct answer, the tile goes green and if the answer is incorrect, it turns red. (Figure 6)



Figure 6. View of “Reconozca la figura” activity

3.2.1.4 Reproduzca el dibujo (Repeat the pattern)

As can be seen in Figure 7, in this activity, a figure is shown on the left side of the screen. Users must copy the pattern on the right side by clicking on right circles. If the user clicks on the wrong circle, it turns red.

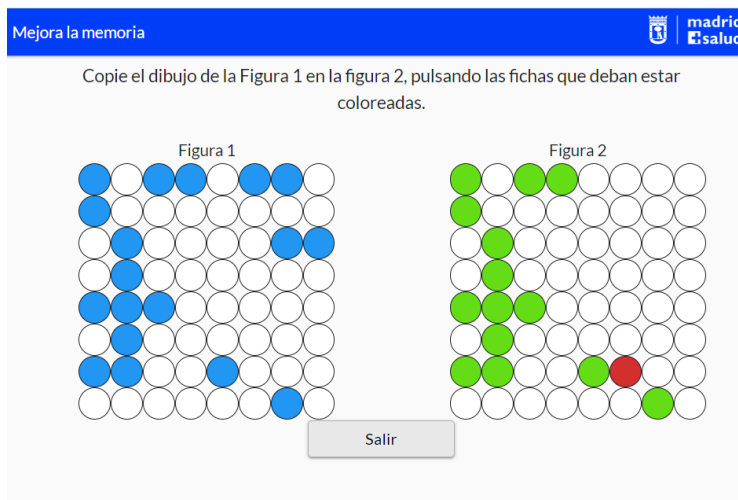


Figure 7. View of “Reproduzca el dibujo” activity

3.2.2 Activities that stimulate the memory

This category includes four games with a focus on memory. These activities are designed to challenge the visual memory of the users. All these games are time based which makes user improve fast decision-making skills.

These activities are designed to improve memory skills in a fun and interactive way. One of the designed tutorials of this master thesis is from one of the games in this category called “Visualizando escenas cotidianas”.



Figure 8. Overall view of activities of memory

3.2.2.1 Simón (Simon Says)

On the screen of the game, there is a circle which has four different colors. After a small count some colors one by one start to brighten, like the green color in Figure 9. User must memories the sequence of colors and reproduce it by clicking on each color in the same order. In the higher levels, this sequence of colors is longer. Also, in this game if the user clicks on the wrong color the activity fails.

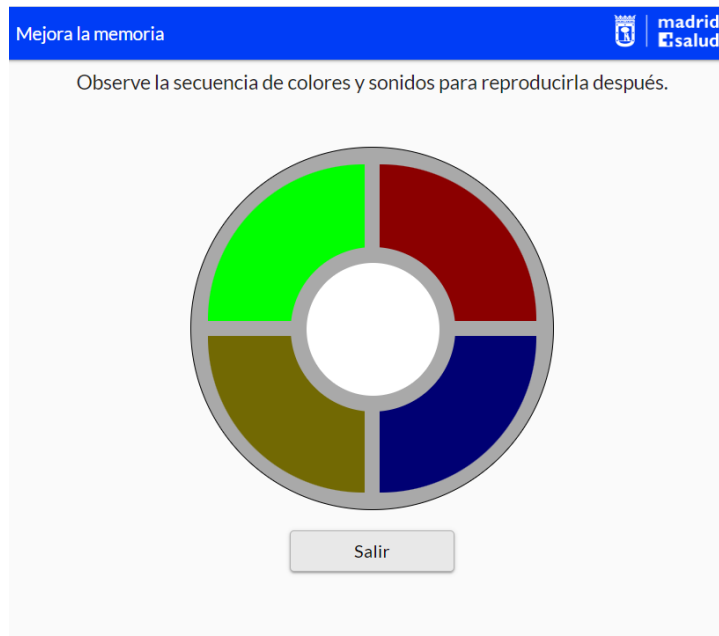


Figure 9. View of “Simón” activity

3.2.2.2 Recordando las cartas (Remembering the cards)

In this game a deck is shown to the user and the user has to memorize cards in the given time. For example, in Figure 10, there are four cards to memorize in

9 seconds. As the level of difficulty increases, the number of cards and time to memorize increase as well.



Figure 10. View of memorizing part of “Recordando las cartas” activity

After the countdown finishes, the game shifts to another screen for choosing cards like Figure 11. From this screen, the user must select the cards that were presented in the previous part of the game. In this section, it is not important to choose cards based on the order it showed in the first part of the game. Also, players can see how many cards are left to pick from the number shown on the top of the screen.



Figure 11. View of choosing part of the “Recordando las cartas” activity

3.2.2.3 Asociando las parejas (Memory)

As shown in Figure 12, the player must memorize related objects. Each pair of related objects points out to the user. For example, in the below Figure, objects of pen and pencil that are similar are pointed out to users. As the level of difficulty increases, the number of objects to memorize and the given time increases as well.

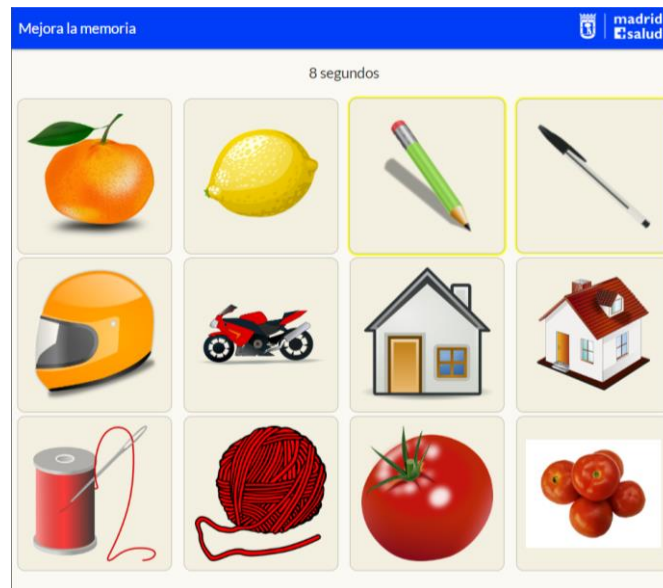


Figure 12. View of memorizing part of “Asociando las parejas” activity

After the countdown is over, the next screen is shown to users. The player must click on each card to see which object is behind the card and finally click on similar pairs. There is no special feedback for users if they click on the wrong card because it is likely to happen before choosing the right answer. At the end, the correctly picked cards will be shown like in Figure 13 and the player must continue playing to find the other right pairs. At the end time and number of faults are shown to the player and saved in the database for professional users.

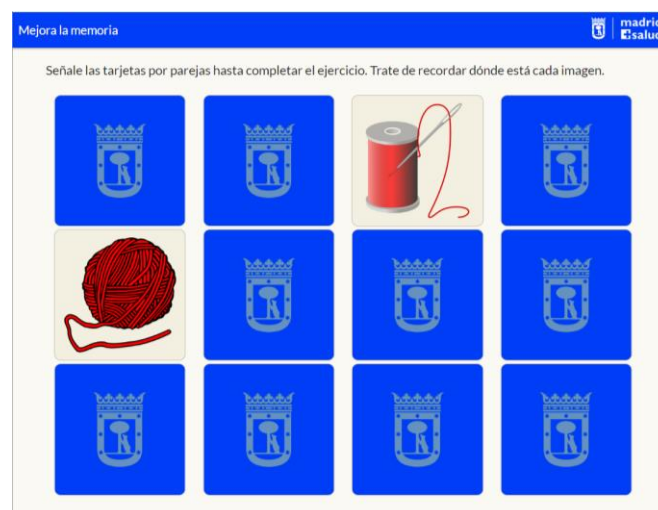


Figure 13. View of choosing part of “Asociando las parejas” activity

3.2.2.4 Visualizando escenas cotidianas (Visualizing everyday scenes)

Before starting the game, the player can choose a scene in which each one shows a different location with a different object. This game challenges the visual memory of the user in two phases. In the first phase of the game, the player has to memorize the number, location, and color of all objects at a given time. (Figure 14)



Figure 14. View of memorizing part “Visualizando escenas cotidianas” activity

When the countdown is over, the user must answer some questions about the memorized objects. The number of questions and the given time increases in the levels with higher difficulties. Also, if the answer is wrong the screen turns red and if the answer is correct the screen turns green. (Figure 15)

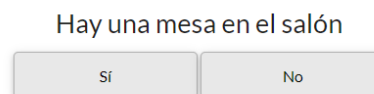


Figure 15. Example of question “Visualizando escenas cotidianas” activity

As has been mentioned this game has two phases, and the second part of the game starts after answering questions. Some objects and persons from the screen start disappearing, and the user must choose them by clicking on the person or object buttons and choosing the disappeared object. After choosing the right object, the user must now click on the location which the object was located previously. And the same as the previous part, if the answer is wrong the screen turns red and if the answer is correct the screen turns green. (Figure 16)

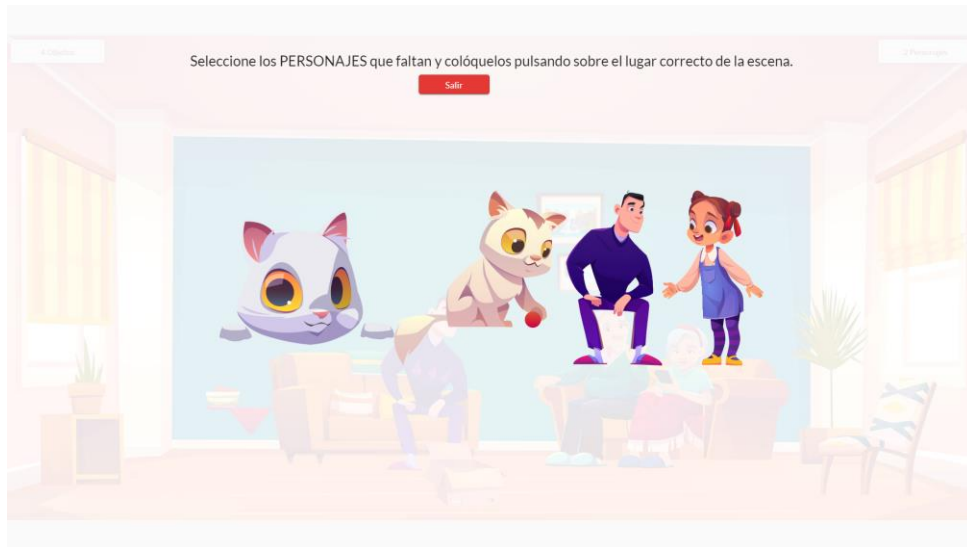


Figure 16. View of choosing object “Visualizando escenas cotidianas” activity

3.2.3 Activities that stimulate language cognition

The language cognition category consists of four stimulations of language cognition to enhance various aspects of language processing including vocabulary and overall language skills. Word puzzle games involved challenges to stimulate linguistic knowledge and cognitive flexibility of users. These activities’ goal is to improve communication and language-related skills in older adults.



Figure 17. Overall view of activities of language

3.2.3.1 Anagramas (Anagram)

In this game, several letters have been given to users and they must form a new word. As the level of difficulty increases, the length and complexity of the given word increases too (see Figure 18).

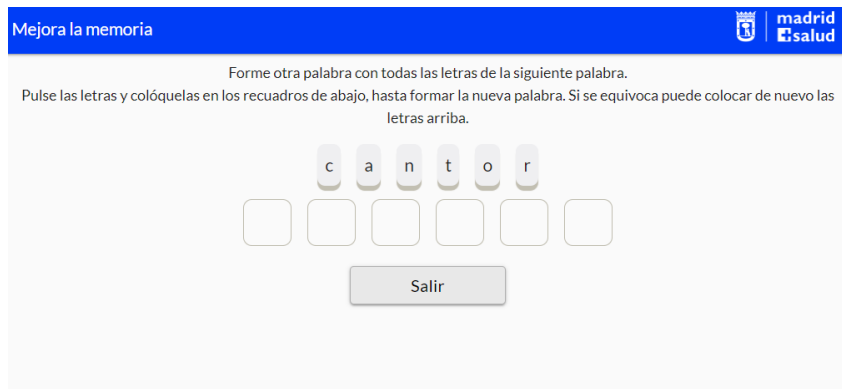


Figure 18. View of “Anagramas” activity

3.2.3.2 Logogramas (Logograms)

Same as the Anagrams activity, in this game the user must form new words using the letter. But the difference is that in this game, users can pick words with different lengths, and it is important to pick more words. And in this game, the number of letters and complexity of words increases higher level of difficulty (see Figure 19).

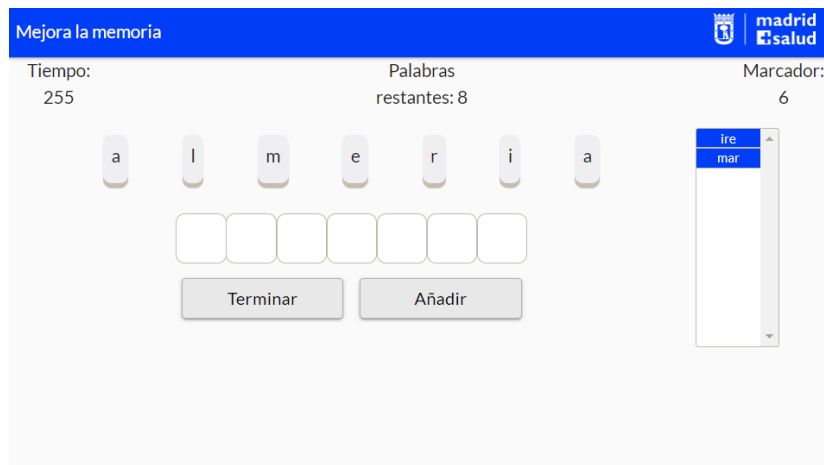


Figure 19. View of “Logogramas” activity

3.2.3.3 Sopa de letras (Word Search Puzzle)

This activity consists of several letters and the user must find a word by picking a series of letters. This series of letters can be chosen horizontally, vertically and in diagonal directions. And the number of letters and complexity of words increases in higher level of difficulties. The words are already given at the top of the screen and user should find those words (see Figure 20).

On the next part of the game some words are provided, and the user must choose which words are the same as the previous part of the game.

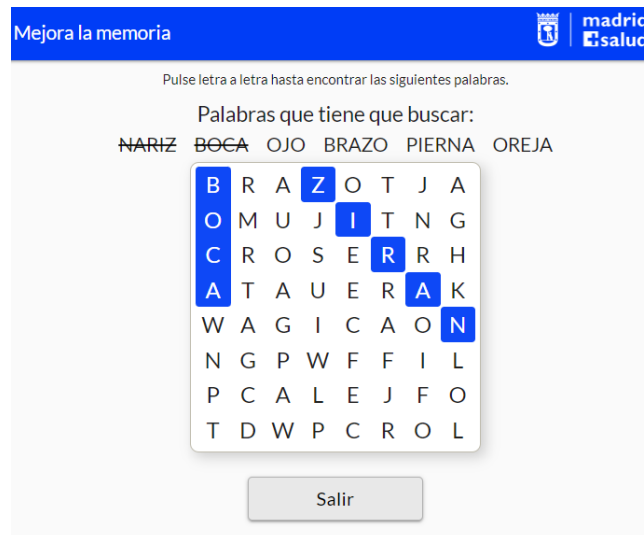


Figure 20. View of “Sopa de letras” activity

3.2.3.4 Descubra el refrán (Find the proverb)

The main task of the game is to arrange the words shown on the page in a correct order by dragging the right word for each place (Figure 21).

The difference between this game and previous language cognitive games is arranging the whole sentences. In previous games such as Anagramas, the goal of the game was to create words by letters. This game focuses on ab grammar ability of the player.

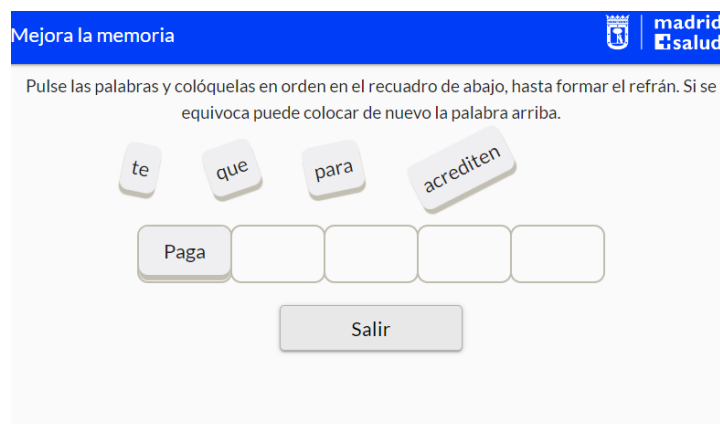


Figure 21. view of “Descubra el refrán” activity

3.2.4 Activities that stimulate organizational ability

This category contains two games which aim the logical perception of cognitive abilities. The user should find a sequence or relationship between objects. Also, one of the tutorials designed on this master thesis is for one of the games of this category (see Figure 22).



Figure 22. Overall view of activities of Organizational ability

3.2.4.1 Secuencia de cartas (Playing card sequence)

In this game a series of cards is provided to the user. Players must understand the sequence between the cards and this sequence can be positive or negative. After understanding the pattern between cards, users can pick the next card which should appear in the sequence by clicking on the blank card. This process should be continued until the player picked all sequence between cards. (See Figure 23).

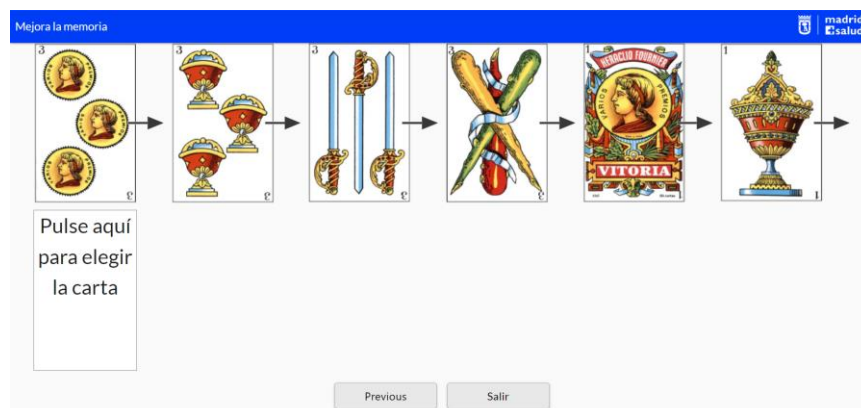


Figure 23. View of “Secuencia de cartas” activity

3.2.4.2 Encuentre la secuencia (Find the sequence)

This game consists of sequences between numbers same as “Secuencia de cartas” game. The player must find the sequence and pick the next number. Each sequence consists of a letter and a number which both follow a sequence. Also, another important part of this game is paying attention to the color of the pattern as well (see Figure 24).



Figure 24. View of “Encuentre la secuencia” activity

3.2.5 Activities that stimulate mathematical cognition

This part consists of just one game which is focused on mathematical cognitive abilities.

3.2.5.1 Cálculo (Arithmetics)

In this activity the user must answer simple mathematics functions. Each mathematical function is represented by a different color and the user must recognize which color is for which function (see Figure 25).



Figure 25. View of “Cálculo” activity

4 Problem Statement

This section discusses issues and objectives that were defined for the implementation of the master thesis project and what would need to be worked on.

The main aim of this project is to help older users understand and clarify the use of cognitive stimulation by using interactive tutorials. During aging, understanding and speed processing decreased, which can cause learning difficulties. Younger adults often have a better capability to learn new things. But this does not mean that the process of learning is impossible for older adults. This age group has different limits and capabilities which can affect their way of learning.

So, the first step before designing the tutorial is to understand older users' limitations and capabilities. Although older people may have a slower process of speed of decrement of attention, they have other capabilities in comparison to younger adults. For example, long-term memories are likely to not be reduced during the aging process. And information such as language, history, would be the same during the years (Czaja, Boot, Charness, & Rogers, 2019). It means older users do not need a tutorial focused on explanations of these skills and mainly have problems with understanding the system's general structure.

In this project, the first step of this process was to clarify which part of the system could be more confusing to understand for users. After understanding the possible complex parts of the system, a high-fidelity prototype was designed and then validated by CPDC and after validation it was developed.

Previously in chapter 2.7 of this document principles of user-centered design has been explained. Also, later in chapter 2.8 design guidelines for tutorial been discussed and reviewed. Here with consideration of both principals, some general principles will be explained for designing the interactive tutorials of "Mejorar la Memoria" platform.

4.1 General principles for designing the interactive tutorials

Tutorial instruction

Mejorarmemoria consists of 15 different activities two of them needed a tutorial. These games are focused on memory and finding sequences. Each tutorial starts with explaining the main logic of the game in which these explanations are provided by text and audio for users. Users can have access to previous explanations whenever they need it. Also, they can quit the game by pressing the "Salir" button.

The main gameplay of the game is divided into small logical terms so the learning process would be easier for users. After viewing the explanations, users should try to solve small exercises. During solving these examples, game will explain the users' which answers are correct and in case of making mistakes, an explanation about the correct answer will be provided for the users and they will be allowed to try again to solve the simulations. Also, users can have access to tutorials whenever they need it by pressing a button in the main screen of the game.

Guidance and learning support

All exercises should be aimed to increase users' information about the game rather than challenging their cognitive abilities. The main goal of using tutorials is to teach users about the main logic and how they play the game. Since older users have lower concentration, they would have difficulties on focusing on different tasks. So, the provided exercises should not challenge their cognitive abilities and use examples, as were already mentioned in the guidelines.

The International ISO Standard 9241-210 provides requirements and recommendation for a user-centered design. One of the principles of ISO is to avoid complexity and design based on users' understanding, tasks, and their environment. We must consider the main task of using tutorial for the user is to learn the game and we must consider their limitation in processing information. So, the tutorial should have logical step-by-step instructions with consistent learning support to help users to understand the tutorial. Tutorials shouldn't follow a complex process, and it should be as simple as possible. All information should be given in straightforward and respectful language.

Another important point in providing learning support and feedback is the way of providing information. All information should be straightforward, direct with short sentences.

Chunking information/ difficulty adjustment

Each tutorial includes guidelines at each stage of the game. In the first stage, the main logic and gameplay is explained to users. Since usually older adults have a slower processing speed, they may have a lower ability to process information quickly and efficiently. Because of this very reason, all explanations are divided into small chunks of information to reduce cognitive overloading the users. During the tutorial, users must have constant interaction with the game by pressing needed buttons or choosing answers. And meanwhile of these interactions, users can use system supports and guidance to increase their speed of learning.

Breaking down the information and tutorial content into smaller and manageable pieces makes older users process of learning easier. They would have more time to process new information and they would be able to solve exercises little by little on their own without the need of assistance. Presenting too much information at once may overwhelm users and lead them to lack of interest in using the tutorial. The assistance of the system should be reduced over time and not immediately.

Timing information

The timing of information is a very important factor in the learning process because older users need more time for processing. Also, attention, concentration and active memory is reduced by aging. The speed of the information should be adjusted to the need of this age group. The information should be provided in shorter sentences with pauses between each state.

Tutorial instruction should include pauses during each state of the game. Using pauses allows users to reflect on information, process them and organizing their

thought and information. Pauses can be placed after each guideline and give time to the users to process and prepare their minds for the next step.

Feedback

Learning support and feedback should be provided in different terms. Aging effects older users' physical status and some of the users may have hearing or vision problems. Studies show most users above 70 are more likely to have both vision and hearing decline. So, providing both alternatives could be more useful for this age group.

As it's been mentioned in Chapter 2.8, Mayer's Cognitive Theory of Multimedia Learning demonstrates different principles about how to make tutorials more efficient. One of these principles shows that it is better to provide information to users in all possible ways such as videos and audio. Also, feedback that indicates users' progress can be valuable as well as inform users about their status.

Repetition of information

This principle refers to the repeated practice of key aspects and information within the tutorials. This can increase users' knowledge and increase learning progress by repeating key information. Older users have lower cognitive abilities like memory and processing information. To ensure comprehension, it is beneficial to repeat some information to help users to recall them. In addition, summarization feedback also can aid older users in connecting guidance with what they have learned.

Visual cues and reminders which are provided in this project by small animations also can be helpful as an additional way of pointing out information. These visual aids can be used as a repetition factor for better understanding and to point out the information which the users should pay more attention to.

4.2 Problem statement for “Secuencia de cartas” tutorial

The first step before designing an interactive tutorial for the “Secuencia de cartas” activity was to understand what possible complex parts which can be difficult to understand for older users. The main logic of the game is to provide some cards and the user must find what is the sequence between cards. After understanding this sequence, users should select the following card of the sequence.

During the design of hi-fi prototype, some issues had to be considered such as:

- **Accuracy**

The gameplay of the tutorial needed to be as similar as possible to the actual game. On the other hand, in the actual game users must select the right cards and follow the sequence but, in the tutorial, we couldn't continue the examples as in the actual game. So, we had to choose which short examples with increasing difficulty would be more useful for the users.

- **Similarity of visual design**

The tutorial needed to be similar in the visual aspect to the main game. So, we couldn't provide buttons for having interactions between the information of the game and it had to be done automatically using time. Each of the information would be provided at different stages of the tutorial. The change of the information mostly depends on the time. Moreover, this time is adjusted to the time needed for processing the information.

- **Complexity**

To make the learning process more useful we had to reduce complexity. This was because the main goal of the tutorial was to learn the logic of the game and we had to reduce the cognitive overload to boost the learning process.

4.3 Problem statement for “Visualizando escenas cotidianas” tutorial

Another game that needed an interactive tutorial was “Visualizando escenas cotidianas”, which is one of the games which is focused on the memory abilities of the users. During this game users must memorize objects' positions and features and later answer some questions about them.

In the designing of the second tutorial, we tried to avoid the mistakes which had been made in the design of the Hi-Fi prototype for the first tutorial. But there were still some new difficulties during the designing of this tutorial, such as:

- **Complexity and Similarity of visual design**

To reduce the complexity of the tutorial, we decided to make the provided scene as simple as possible. But the problem provided by this decision was that it would harm the visual similarity of the tutorial with the actual game. So, having this balance between making the game simple for the users so they can understand the logic of the game and the accuracy of visual design with the real game was the most challenging part in the design of this tutorial.

5 Development of Tutorial 1: “Secuencia de Cartas”

This chapter includes the process of design and development of the interactive tutorial for the “Secuencia de cartas” activity during this master thesis. And all steps from initial design until final development will be explained. It must be mentioned that the validation of the design and development of this project has been done with the cooperation of CDPC, Professor Jaime Ramirez, Elena Villalba, and Maximilian Menschel from the Aging Lab at the Technical University of Madrid.

“Secuencia de cartas” is one of the games which aims to stimulate users’ cognitive ability by challenging their logical perception and to find sequences and patterns in the system. The main logic of the game is to find the sequence between cards and later complete the sequence of the card. This interactive tutorial focuses on explaining the basic of the game and how to choose the right answer.

This tutorial becomes interactive by asking the user to participate in choosing answers. The learning process of the tutorial is done by helping the users to walk through all steps and providing the needed information for the user to complete a task to help users to understand the logic of the game without the need for any supervision. This information and guidance are provided at different stages of the game and in case of incorrect answers immediate feedback is provided to the users. During all stages of the game, the limitations and abilities of older users have been considered to raise their awareness of cognitive stimulation.

In the first step of the project after undressing users' needs and where they are having problems with learning, an initial design was provided. After the validation of this initial design with the supervisors, a first Hi-Fi prototype was designed to test and validate with CPDC. And after correcting the problems identified in this validation, a final Hi-Fi prototype was designed including all changes and later the same prototype is implemented as part of the web platform.

5.1 Initial design

In the first step of the master thesis project, it was necessary to understand the target audience and gather information about what are their needs from the system, their cognitive and technological abilities, and any specific challenges they may face while using the system.

In this step, we needed to gather requirements for the system, including the goals, objectives, and users' needs which were done by having constant meetings with Aging Lab researchers. One of the important ideas of this stage was to make the tutorial as accurate as possible. We should have the same design as the game because any small difference between the tutorial and the game could make users confused.

Also, in this stage, it has been decided that in the first part of the tutorial, the user will face only one sequence and after explaining this sequence the tutorial will be followed by asking users to pick the right answers following the card of the sequence.

Figure 26 shows the first sequence of the game which is between the card of the suits of gold. The first number of this sequence is 7 which jumps into number 10. But it must be considered that the Spanish cards, doesn't include number 8 and 9. So, this sequence is increasing with 1 number.

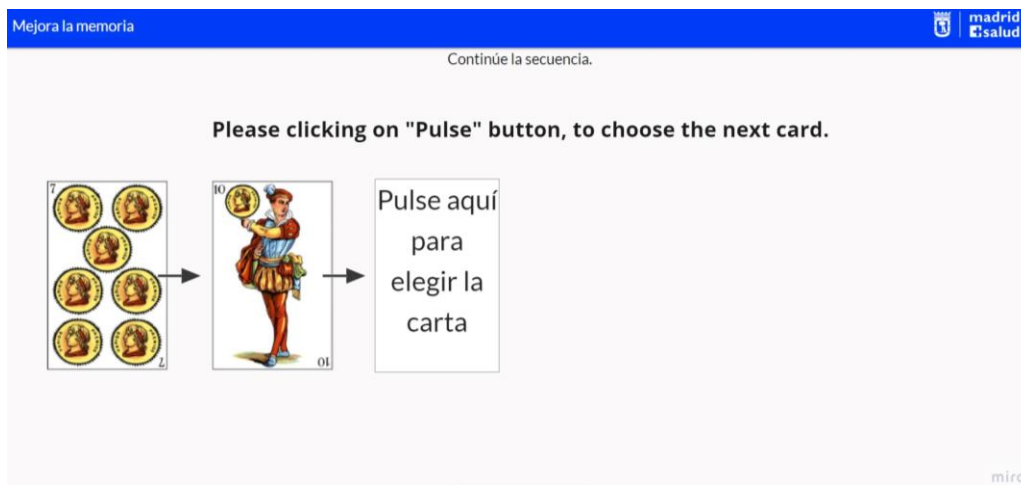


Figure 26. The first sequence of the "Secuencia de Cartas" tutorial

After this stage, in the second part of the game the user faces two different sequences (positive and negative) to understand that the game can include more than one sequence and sequences can be both positive and negative. Each sequence can be between different suits of cards.

The positive sequence is between the gold cards. The first card increases from number 6 to 10, and this is the first sequence that the user should guess. The second sequence is now between the cup cards which are decreasing from number 6 to 5. Users have to first guess about the first sequence and then the second sequence. (See Figure 27)

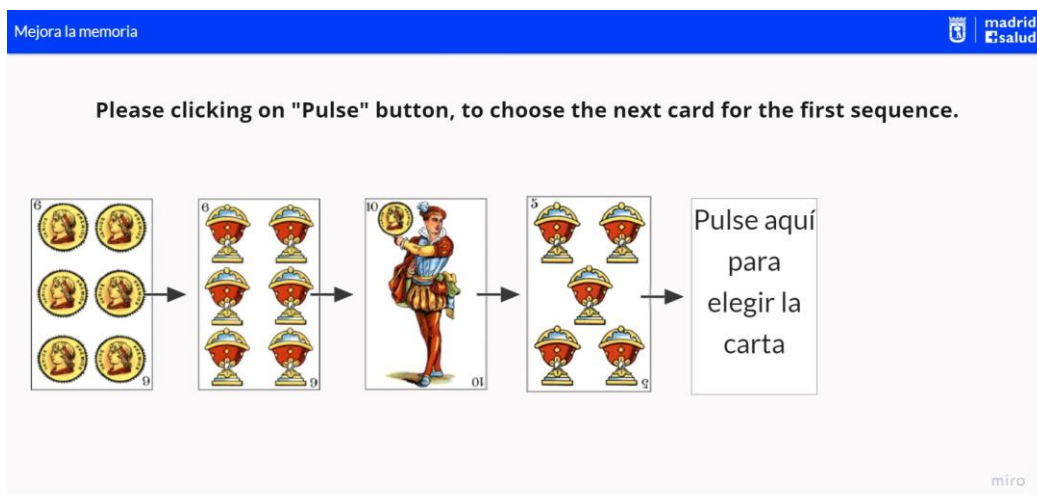


Figure 27. The second sequence of "Secuencia de Cartas" tutorial

To design an efficient tutorial, it was essential to gain insight into the target audience and create a system map that outlines the overall structure and

organization of the system. Determine the main pages and how each module is interconnected. This state focused on visualizing the layout and placement of different elements within the system. And small information was not defined in this stage of the work and the focus was on the overall structure, navigation, and hierarchy of the tutorial.

The main goal of designing information architecture is to create a structure that is meaningful to navigate for users. Also, different examples during this stage are divided into smaller examples to make users understand the logic of the game better. Organizing plays an essential role in usability and overall satisfaction of the system.

Organization

The hierarchy of the system is very similar for the first and the second sequences. Both sequences start with an explanation to point out the important elements and sequences of the example and follow up by asking users to solve the example.

Labeling was another part of this process which cleared the navigation elements and structure information architecture. Some languages in pages with similar labels should be like help users understand the gameplay better.

Navigation

The navigation of the system is decided in this process. This navigation refers to links and elements that enable the user to move through the system. And it was decided that in the explanations at the beginning of the first and the second sequences, they should be changed automatically based on the time of the audio and the time needed to read the text and process the information. A time is assigned to each piece of information in the system based on the time the user needs to process them. After the given time, this information will be changed to the next one in the system.

And in the stage of “Choosing card pages” the navigation is followed by pressing the button for choosing the right answer. In the case of choosing a wrong answer, the game will show a message including an explanation and the user will have a second chance to select the right card.

The navigation provided in Figure 28 shows the navigation of information which should be provided for the users.

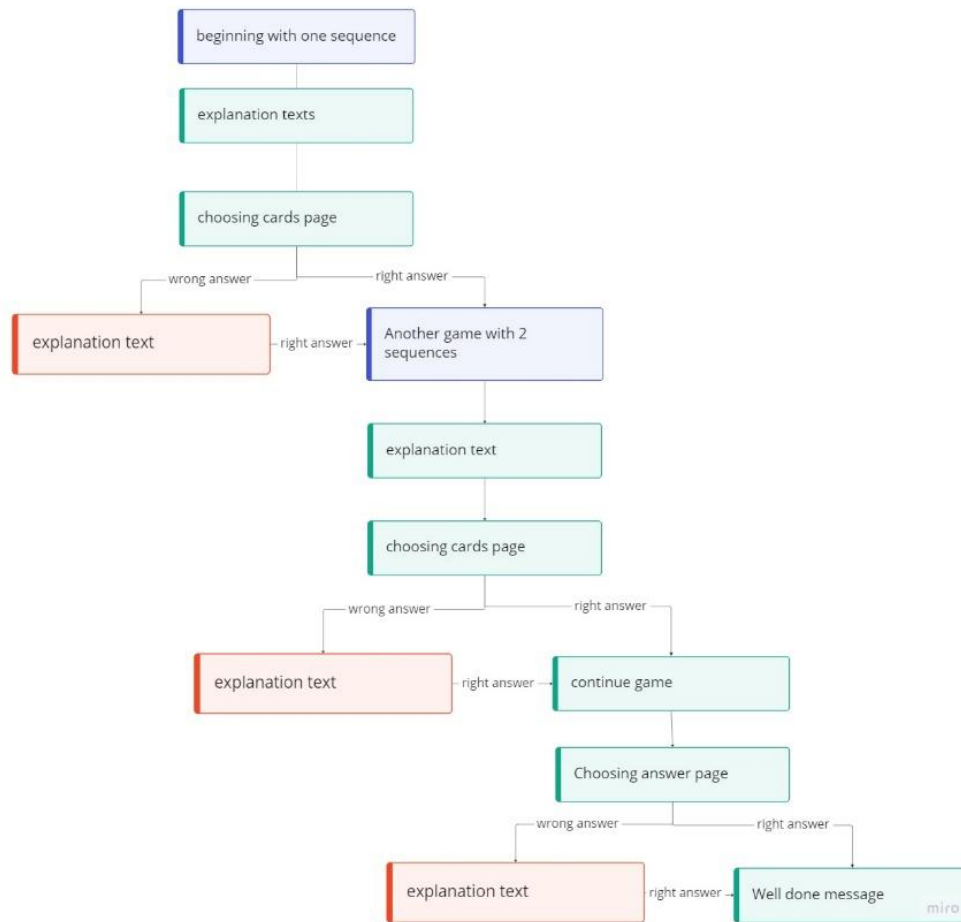


Figure 28. Instruction and navigation of the- “Secuencia de cartas” tutorial

5.2 First Hi-Fi prototype

This section consists of the design of the first high-fidelity prototype of the system and how it was used to showcase a realistic representation of the tutorial. This design is more advanced and detailed compared to the initial design. It has more visual futures and includes images, buttons and interactive features which will be used for the development of the system. This prototype shows a realistic practice version which can be used to get feedback from experts, in our case, the psychologists of the CDPC. This prototype points out users’ interactions with the tutorial.

After the validation process, another prototype was developed including some improvements.

This prototype was designed in the Miro platform in order for other collaborators to manage and see the stage of the project.

5.2.1 Visual design

After deciding about the initial design concepts and creating a low-fidelity design, we continued by designing a more visual design. This included deciding about a more appropriate visual design. The design of the tutorial is as similar as possible to the actual game because the smallest difference could make users confused.

Since we were adding new features into the system, deciding about the interaction design of the system would get more difficult. Since the tutorial should have been as similar as possible to the system, we had to decide how to provide information and how users could follow through information in the system.

Figure 29 shows an example of design of the prototype and how the actual game looks. The green box in the prototype indicates that the card is not blocked to be pressed by the user.



Figure 29. Example of the design in Hi-Fi prototype- “Secuencia de cartas” tutorial

With the use of the similar design, users would be more familiar with the environment of the game, and they could recognize similar patterns easier and have a better interaction with the actual stimulation. Besides, users would expect to have the similar experience during the actual game, so it is better to avoid differences as much as possible.

With the use of the similar design, users would be more familiar with the environment of the game, and they could recognize similar patterns easier and have a better interaction with the actual stimulation. Besides, users would expect to have the similar experience during the actual game, so it is better to avoid differences as much as possible.

When the tutorial and the game have similar design elements users would spend their mental effort on the interface and understanding new visual cues. This can reduce cognitive load and allows users to focus more on learning rather than paying attention to learning about the new interface and design.

The first sequence in the prototype is much easier than the sequence provided in the actual game. This is because the aim of the tutorial is not challenging users’ cognitive abilities, but to show how the game works and what is the main logic of the game. The tutorial is a learning tool to develop users understanding and competencies about logic and gameplay. By having easier examples, users can practice, and improve their skills and knowledge about the game environment. This process helps users to prepare for more demanding and challenging sequences in the actual game.

In general, easier examples motivate users to maintain their engagement with the actual game by expecting their success. This sense of achievement encourages users to the game.

In general, easier examples motivate users to maintain their engagement with the actual game by expecting their success. This sense of achievement encourages users to the game.

5.2.2 Interaction design

In the following section, we will discuss how the user must interact with the prototype.

The second phase on designing Hi-Fi prototype was to decide about which information should be provided to the users and how they should divide. Since older users have lower capability of processing information, if a large amount of information is provided for them, they would feel overwhelmed and have a cognitive overload. So, during this project it was essential to divide this information into small but meaningful stages. Another important task was to decide how users should move from one piece of information to another information.

This part of the design consists important structure of the tutorial such as:

- **Navigation:** the navigation design is about how users can move between different sections or pages. In this prototype design, most of the navigation is done automatically by using timers. Only in pages that include the questions and selecting the answers, users should interact with the game by pressing buttons and cards.
- **Interactive elements:** Interactive elements respond user's action. In this game these elements are the "Pulse aquí para elegir la carta" button and the cards in the card deck.
- **Feedback and response:** the prototype should provide appropriate feedback from the last user's action. These responses are provided by both visual cues such an animation and sounds in case of right and wrong interactions. Also, feedback instructions by both audio and text messages.
- **Consistency:** In this game similar actions through the game have similar interaction patterns. This helps users to have a better understanding about how to interact with the actual game.

5.2.2.1 Interaction description of the first sequence

This tutorial consists of two different sequences of cards. The first part of the game includes the easiest sequence which is just one increasing sequence. This part of the game includes six different pages (see Figure 30).

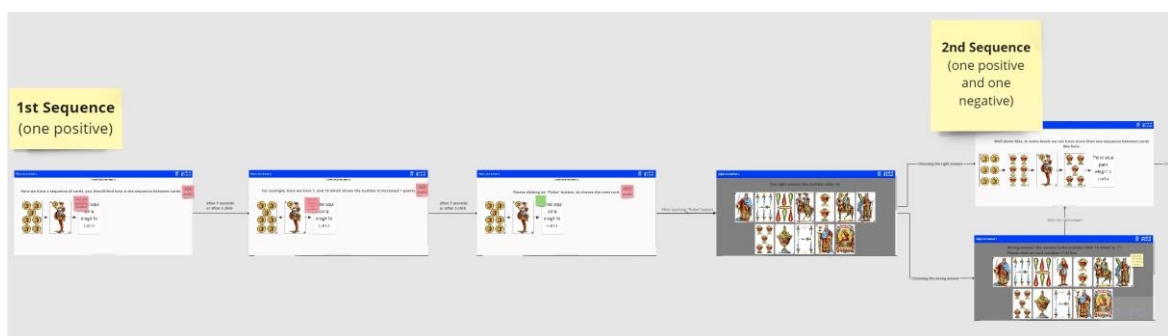


Figure 30. Overview of the Hi-Fi prototype of the first sequence- "Secuencia de cartas" tutorial

First, the tutorial explains the main idea of the game to the users by starting a game with just one sequence. Meanwhile, it explains how the player could guess which card is the right answer. Also, this information is provided by both text and audio.

The transition between these two pages is done automatically after a few seconds. Also, to play audio there is not button to be pressed, and audios will be played automatically by reading the displayed text. In these stages of the game the button “Pulse aquí para elegir la carte” is displayed to click. (See Figure 31)

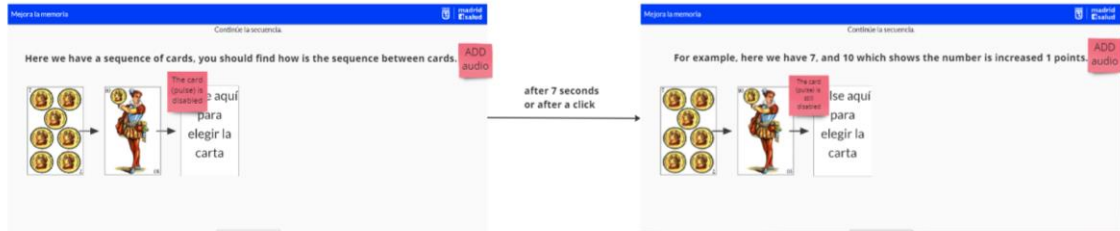


Figure 31. The First stage of the Hi-Fi prototype of first sequence- “Secuencia de cartas” tutorial

In the second stage of the tutorial after providing the information about the game, the system is asking users to select the right card of the sequence by clicking on the “Pulse aquí para elegir la carta” button. As it can be seen here the interaction of the tutorial with the user is different because in the previous stages, the transition has been done automatically and here users have to interact with the system by clicking on the button for opening the card deck.

Also, after clicking on the button, the user can now select the right answer among a set of cards (card deck) on the screen. To make the game easier, the message is reminding to the user that the previous card of the sequence was 10 and the user should choose the following card of the sequence. (See Figure 32)

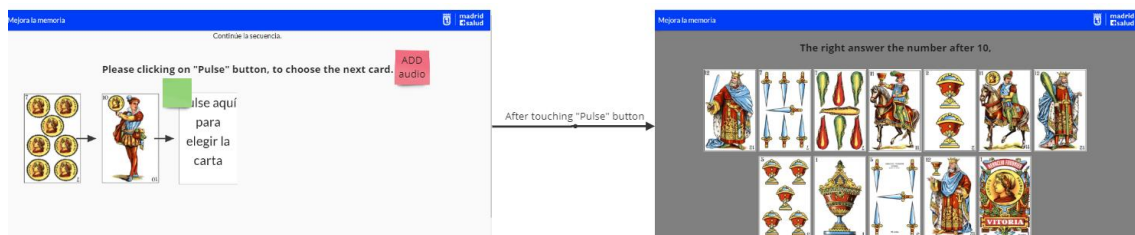


Figure 32. The second stage of the Hi-Fi prototype of the first sequence- “Secuencia de cartas” tutorial

The third stage of the tutorial depends on if the user chose the correct or the incorrect answer. In case of choosing the right answer, the game follows with the second sequence. On the other hand, in case of picking the wrong answer, a message is provided for the user with the explanation of why this answer is wrong and which card is the right card. Users will have another chance to pick the right answer and continue the game with the second sequence (see Figure 33).

During all stages of the game, information is provided by both text and audio.

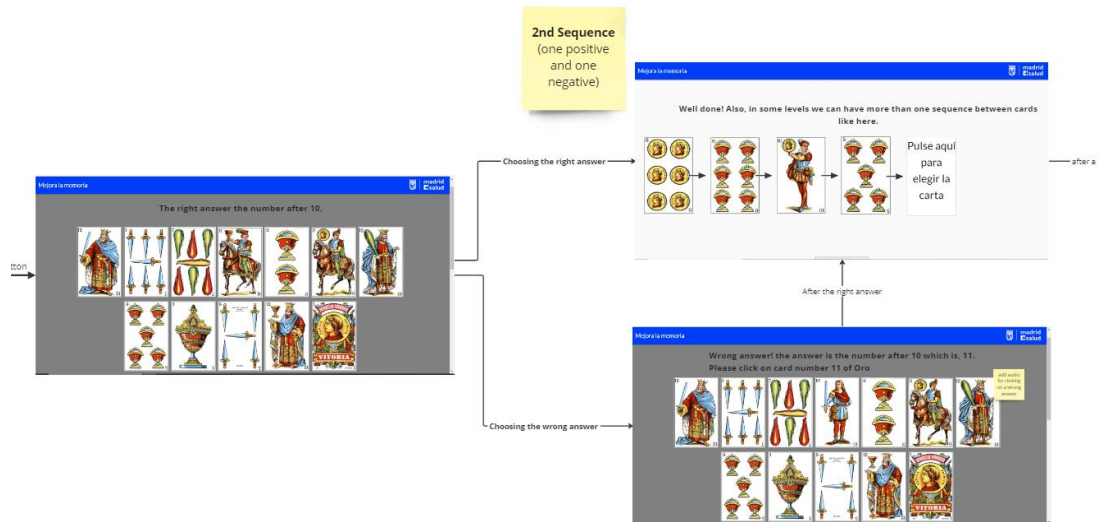


Figure 33. The third stage of the Hi-Fi prototype of the first sequence- “Secuencia de cartas” tutorial

5.2.2.2 Interaction description of the second sequence

The second part of the game consists of two sequences on the same page. One of the sequences is increasing and another one is decreasing. The reason for having this is to show users that in the actual game, the sequences could be both increasing and decreasing.

As it was mentioned before, in the last stages of the tutorial, the examples will get more difficult. However, they shouldn't get very to avoid causing cognitive overload for the user. By focusing on this, the interaction hi-fi prototype can create an engaging interactive experience.

The first stage of the second sequence of the prototype is very similar to the previous sequence. The information of this stage is provided for users to understand that this example consists of two different sequences. For this very reason, the information is provided on three different pages to point out each sequence. (See Figure 34)

In this stage as in the previous sequence, the button “Pulse aquí para elegir la carta” is displayed to be clicked.

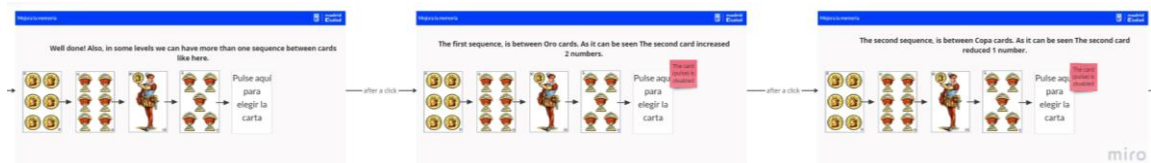


Figure 34. The First stage of the Hi-Fi prototype of the second sequence- “Secuencia de cartas” tutorial

As can be seen in Figure 35, the second stage of the game is also the same as in the previous sequence. The card “Pulse aquí para elegir la carta” now enables clicking and the user can interact with the system by clicking on this button.

After clicking on this button user can choose the answer in the card deck. And the displayed hint is helping users to know which card would be the possible

answer. Again, in this stage, the aim is to not have a hard example to avoid cognitive overload of the user.

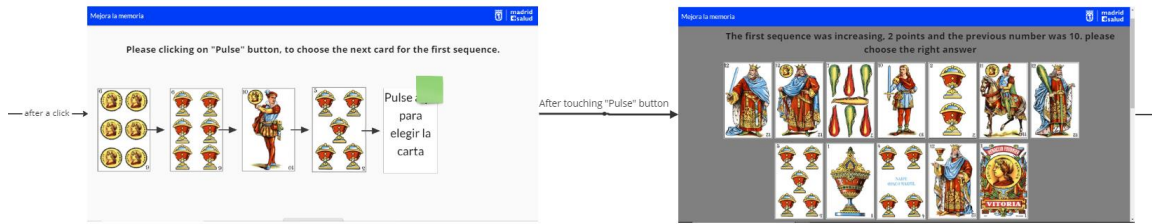


Figure 35. The second stage of the Hi-Fi prototype of the second sequence- “Secuencia de cartas” tutorial

To increase consistency of the system, the third stage follows the same structure as in the previous sequence. The only difference between this example and the previous one is that as we have two different sequences, users must complete the stage by choosing two right answers. (See Figure 36)

And in both steps, if the user selects the wrong answer, feedback with an explanation of the correct answer will be provided. Also, as in all the previous stages, all information and feedback will be provided by using both texts and audios.

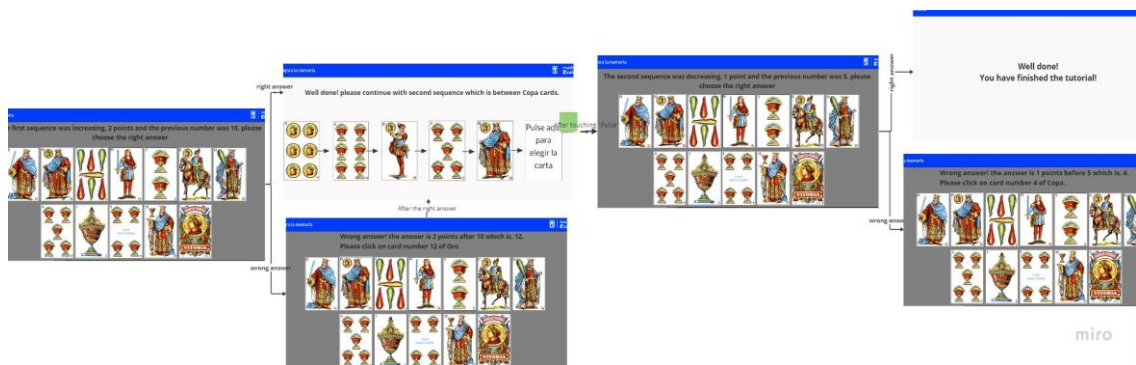


Figure 36. The third stage of the Hi-Fi prototype of the second sequence- “Secuencia de cartas” tutorial

Finally, in the last stage of the prototype a message of “Good job” will be displayed to users. (Figure 37)

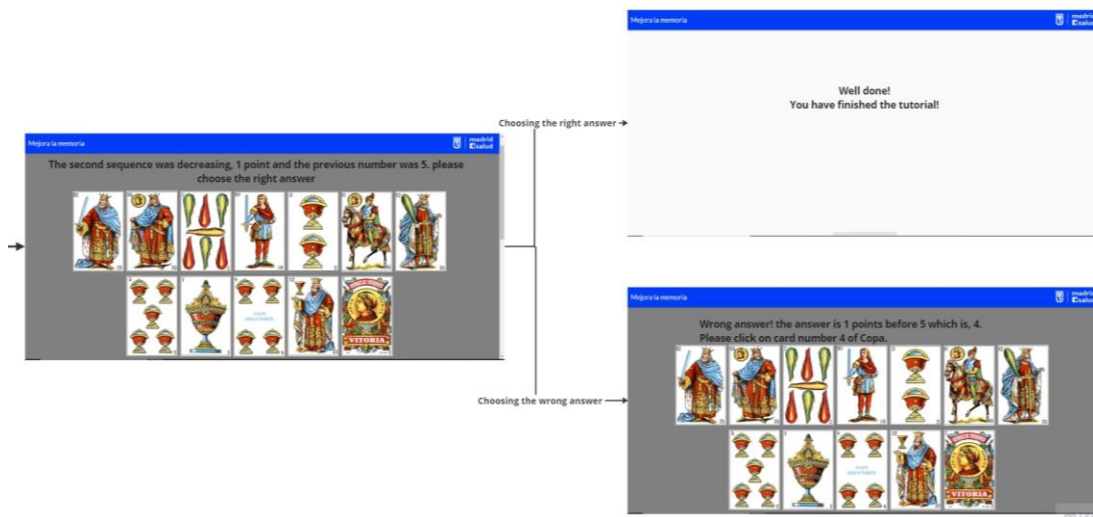


Figure 37. Last stage of the Hi-Fi prototype- “Secuencia de cartas” tutorial

5.3 Validation process with CPDC

The validation process of the hi-fi prototype of the tutorial was conducted with the cooperation of CPDC. This validation involves evaluating functionality, usability, effectiveness, and if the design meets the intended goals and requirements of the system or not. During meetings with this centre, the prototype was tested and evaluated by the professionals of this centre who have a better understanding of the older users' needs and limitations.

During this validation, some changes and new alternatives had been added to the system. These changes are such as:

- Changes in the text of the feedbacks
- Adding a previous button
- Changing the navigation of the system
- Adding animations into some objects
- Blurring buttons when they were disabled to click

5.3.1 Navigation validation

Navigation of the prototype shows the main structure of the tutorial. To improve the design, some changes are required to be done after the validation of the first version. All these changes were added to the final version of the high-fidelity prototype.

These changes were mainly required for the beginning and end of the game because, in the first version of the Hi-Fi prototype, the interactive tutorial was designed to be played only the first time when the user wanted to play the actual game. But this would limit the users and many users may need to check the tutorial again for any reason.

Also, at the end of the tutorial after choosing the right answer, the prototype would end without showing the card sequence to the users and it could make users confused since in the previous steps, the card sequence was always shown to the user after picking the right card. So, to increase consistency a similar action had to be done in the last sequence of the tutorial before showing the message which gives the final feedback to the user.

- **Change in the navigation.**

Statement before the change	Description of the change
<p>In the first version of the prototype, the tutorial was designed to play just when the player is playing the game for the first time.</p>	<p>After the validation process, a button “Ver Ejemplo” has been added to the main page of the game, where the user can select levels.</p> <p>This way, the user wouldn’t have limitations with playing the tutorial.</p>

Figure 38 shows the button which was added to the main page of the activity.



Figure 38. Added button for playing the tutorial

- **Change in the final page.**

Statement before the change	Description of the change
<p>In the first version of the prototype, the tutorial would finish right after the user answers the final example of the tutorial by providing a “good job” message.</p>	<p>To increase the consistency of the game, after choosing the final card of the second sequence, the complete sequence would be shown again for the last time before moving into the final page.</p>

Figure 39 shows the statement of the prototype before and after showing the last state of the card desk before ending the game.

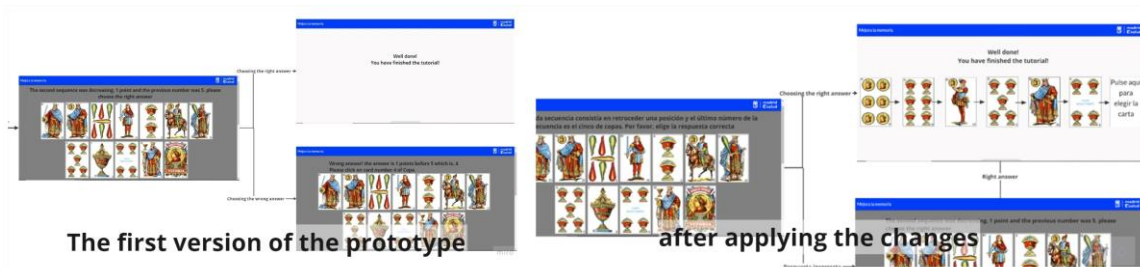


Figure 39. Statement of the change in the final page

5.3.2 Interactive elements validation

These elements respond to the users' actions and in our first version of the tutorials, these instructions could be done by clicking buttons and cards.

One of the elements added during the validation was a previous button. In the first version of the tutorial, users didn't have the possibility of going back to review the previous texts and audios, which could confuse the users. Older adults have a lower speed of processing and memory. So, they may need to go back previous pages of the tutorial and review the information.

Also, one of the problems with the first stage of both sequences was that when the button "Pulse aquí para elegir la carta" were disabled to click, the interface was the same as when the card was unable to click. This could also confuse the users. To avoid this confusion, the button needed to have a different design when it was disabled.

- **Adding the previous button**

Statement before the change	Description of the change
<p>This button did not exist, and the user could not go back to review the information and audio.</p> <p>Before, the only available button for the user was "Salir" which is used to quit the tutorial.</p>	<p>To increase the usability and efficiency of the game, this button was added to most of the stages of the game so the user can review previous information when it is needed.</p>

- **Changing the card when it is disabled.**

Statement before the change	Description of the change
-----------------------------	---------------------------

<p>The button “Pulse aquí para elegir la carta” when it was displayed at the first stage of the game had the same design as when it was not displayed.</p>	<p>To avoid confusing the users, the button has a different design without the text to show that the button is not enabled to click.</p>
------------------------------------------------------------------------------------------------------------------------------------------------------------	------------------------------------------------------------------------------------------------------------------------------------------

Figure 40 shows how the “Pulse aquí para elegir la carta” card is shown when it is disabled in the final version of the prototype. The changed part is shown by a red pointer in both versions of the prototype.



Figure 40. Statement of the change in an interactive element

5.3.3 Feedback validation

In this section, the changes related to the validation of feedback are provided. Feedback and information are given in all stages of the tutorial. And some elements related to the feedback were changed during the validation process.

One of this validation is about some small changes in the text of the game. For example, many users didn't know during the actual game that they can go to the previous part by clicking on the grey part in the card deck where users can choose the next card of the sequence. So, one of the suggestions of CPDC was to add information explaining this element of the actual game.

Another suggestion was in the pages where the information is referring to some specific card to explain the sequence between cards or to explain where the users should click on. The change added to this part was to provide an animation to highlight the card.

- **Changes in the information and feedback.**

Statement before the change	Description of the change
-----------------------------	---------------------------

<p>Some texts and information about the game needed validation.</p>	<p>In the second version of the prototype, some texts and information had been changed or added.</p> <p>For example, many users did not know about the ability to go to the previous screen by clicking on the grey part of the cloud of cards where users can pick cards of the following sequences.</p>
---------------------------------------------------------------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

- **Adding animation**

Statement before the change	Description of the change
<p>Small animation existed in the original game only when the user picked the incorrect answer.</p>	<p>For pointing out the information better and increasing the visual aspect of learning, some animations needed to be added to the tutorial.</p> <p>For example, in the first stage of the game where information is provided about the specific cards, they should be pointed out by using an animation.</p>

Moreover, Figure 41 shows an example of where the animation could be added in the final version of the Hi-Fi prototype of the tutorial. In this example, the information is explaining the sequence between the cards with the gold icon and the animation shows both cards with this icon.

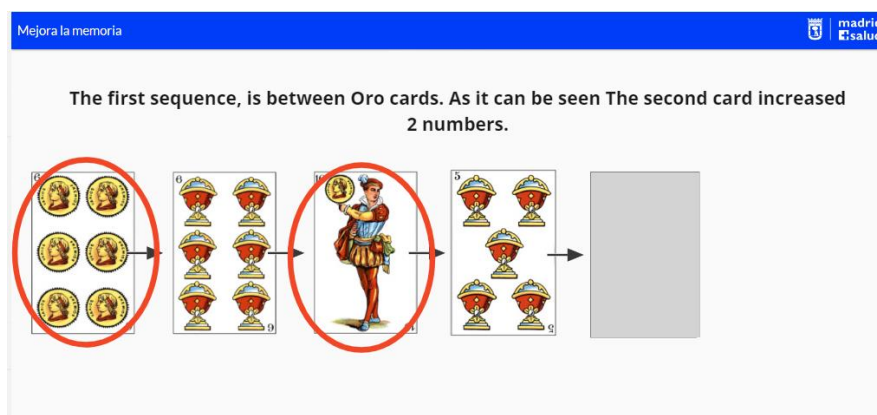


Figure 41. An example of animation in the last version of the Hi-Fi prototype

5.4 Final Hi-Fi prototype

The next step after the validation with CPDC was to implement all the changes into a new version of the high-fidelity prototype. As it was mentioned in the previous section, these changes affected the main structure of the tutorial,

information, and feedback shown in the text and audio, and changes in the elements which could be used for interaction with the user.

After the implementation of the changes, all information has been translated into Spanish because this platform is aimed at Spanish speakers' users. And at the end, these changes were again validated with the professors and researchers of the Aging lab to solve any little problems. (See Figure 42)

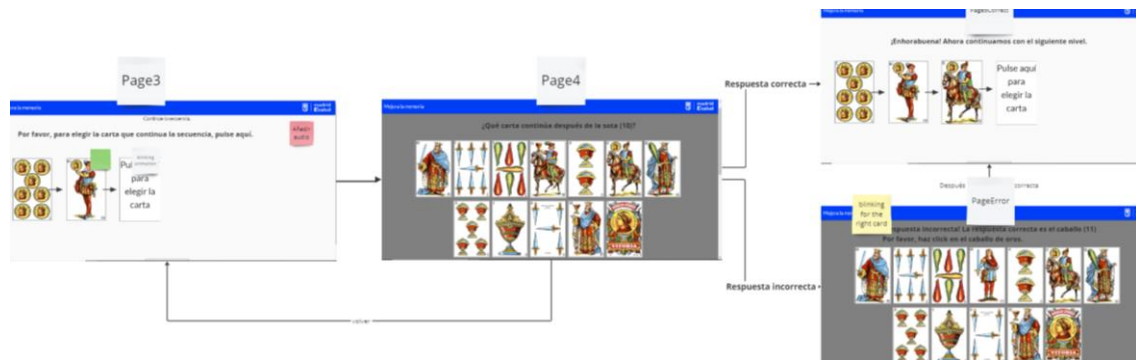


Figure 42. View of an example of the final version of the hi-fi prototype- “Secuencia de cartas” tutorial

In the implementation of this version of the prototype, some details which could not be implemented in the prototype like animations have been written and attached to each page by using notes. Also, in this step, audio notes were added to specify their presence.

Also, a number as PageN is given on each page and written in the prototype figures to make the implementation task easier. This task will be explained in the next section.

Figure 43 shows an example of details added to one of the pages of the tutorial prototype.

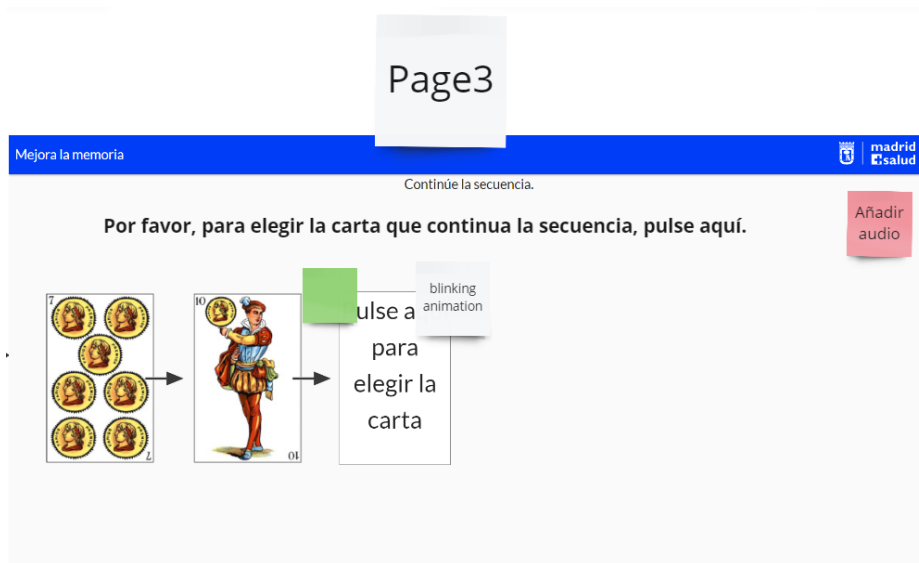


Figure 43. View of one of the pages in the final version of the hi-fi prototype

5.5 Final implementation

The first step of the development of the project was to understand how each section of the game is related to each other, which was already explained in Chapter 3. This section provides an overview of the structure of how the prototype was implemented into the final development.

The implementation process of this project has been carried out by cooperating with researchers and professors of the Aging lab of UPM.

In the actual game, each activity has its own set of files including HTML, CSS, JavaScript, and JSON files. The naming provided for the JavaScript file in an actual game is usually `controladorPruebaN` which N shows the number assigned to each activity. And since this tutorial is using a different JavaScript, the file provided for this tutorial is in `controladorPrueba23_tutorial`.

On the other hand, this tutorial uses the same HTML, CSS, and JSON files as the actual game. The JSON files for activities with tutorials include additional information such as tutorial text, audio guidance, and highlighted objects used in each page of the tutorial.

The JavaScript file of the tutorial uses the main logic as the JavaScript file of the actual game. But some logic like the logic related to the level of difficulty of the game is not implemented in the tutorial.

Also, a main function named `mainTutorial` is added to the JavaScript file of the tutorial and the main screen of the game called “`controlador_principal_pruebas`” to keep the interaction of the tutorial with the main page of the game.

Another essential function of the game is called `UpdatePage`. This function provides information at different times and manages the navigation between game pages. Some of these pages and texts should be changed based on the time or based on clicking on a button. So, to implement this option into the system we need different texts and audio to change at specific times.

The information about each page is implemented into the JSON file. the JSON file for the tutorials is the same as the JSON file used for the actual game. But the files of the activities which have a tutorial are also included additional information such as information texts, audio, and highlighted objects and cards. It is expected that the usage of this JSON file will facilitate the maintenance of the tutorial implementation.

These details of each page are provided in an array called `tutorialConfig`. Inside this array, the information of the pages is divided into `sequence1` and `sequence2`. These sequences represent the two main stages provided in the game which were previously explained in Section 5.2.2 of this document.

The management of animations is included in this function. Cards that needed to be pointed out are shown as `highlightedCard` in the JSON file (see Figure 44). And the implementation of the animations is provided in the JavaScript file and managed by the `UpdatePage` function.

```

"tutorialConfig":
{
  "sequence1":
  {
    "sequence": ["7_Oro.jpg", "10_Oro.jpg", "11_Oro.jpg"],
    "sequencePages": {
      "page1":{
        "text": "A continuación se muestran una serie de cartas, descubre cuál es la secuencia existente entre ellas.",
        "highlightedCards":[],
        "audio": "../../../../sounds/prueba23/page1-spanish.mp3",
        "cardSelectionBlocked": "true"
      },
      "page2":{
        "text": "Por ejemplo, aquí tenemos las cartas 7 y 10, lo que indica que se ha avanzado una carta. ",
        "highlightedCards":[],
        "audio": "../../../../sounds/prueba23/page2-spanish.mp3",
        "cardSelectionBlocked": "true"
      }
    }
  }
}

```

Figure 44. An example of the tutorial information provided in the JSON file

The main interaction of the tutorial including page navigation, animation management, managing audio and texts, and interaction with JSON files is done in the UpdatePage function.

Figure 45 shows the page navigation between pages of the first stage of the game. The interaction seen on these pages depends on the setting time and the duration of the audio.

In addition, each page should change after showing the text and playing audio that is implemented in the UpdatePage function, and then move on to the next page of the tutorial by calling this function again.

Management of the audio is included in UpdatePage function as well. This function controls which audio should be played and when the user clicks on the previous button, which audio should be paused or played.

```

// Page navigation:
if(currentSequence === "sequence1"){
  switch(currentPage) {
    case "page1":
      currentAudio.addEventListener('ended', function() {
        setTimeout(() => {
          currentPage = "page2"
          UpdatePage()
        }, 2000);
      }, false);
      break;
    case "page2":
      currentAudio.addEventListener('ended', function() {
        setTimeout(() => {
          currentPage = "page3"
          UpdatePage()
        }, 2000);
        $("#previousButton").off("click").on("click", function() {
          currentAudio.pause();
          currentAudio.currentTime = 0;
          currentPage = "page1";
          UpdatePage();
        });
      }, false);
      break;
    case "page3":

```

Figure 45. Example of pages interaction in the JavaScript

The interaction of this function with the JSON file allows the system to have access to information on each page. By calling UpdatePage in each switch statement, this function gets the information of the page from the JSON file.

As an example, in Figure 45 when the statement of the page is on “Page1”, the system will show the relevant information of this page and then to move to the next page, the system will put the current page as “Page2”.

To get information from the JSON file, the UpdatePage function gets this information from the tutorialConfig array (see Figure 46)

```
function UpdatePage() {
  $('tutorialInstructions').html(`${difficultyData.tutorialConfig[currentSequence].sequencePages[currentPage].text}`)
  if(difficultyData.tutorialConfig[currentSequence].sequencePages[currentPage].cardSelectionBlocked === "true"){
    $(".sequenceEmptyField").addClass("blockedandGreyedOutPlayingCard")
  }else{
    $(".sequenceEmptyField").removeClass("blockedandGreyedOutPlayingCard")
  }
}
```

Figure 46. Interaction of JavaScript and JSON file

On the other hand, some pages do not need to be changed over time. For example, on the pages where the user should answer an exercise, the next page will be depending on if the player is choosing the correct answer or the incorrect one.

As an example, Figure 47 shows a part of the tutorial in the first sequence. In this part, if the user picks the correct answer, the system should move to the page which has the label “Page5Correct” and if the answer is incorrect, the system should move to the error page.

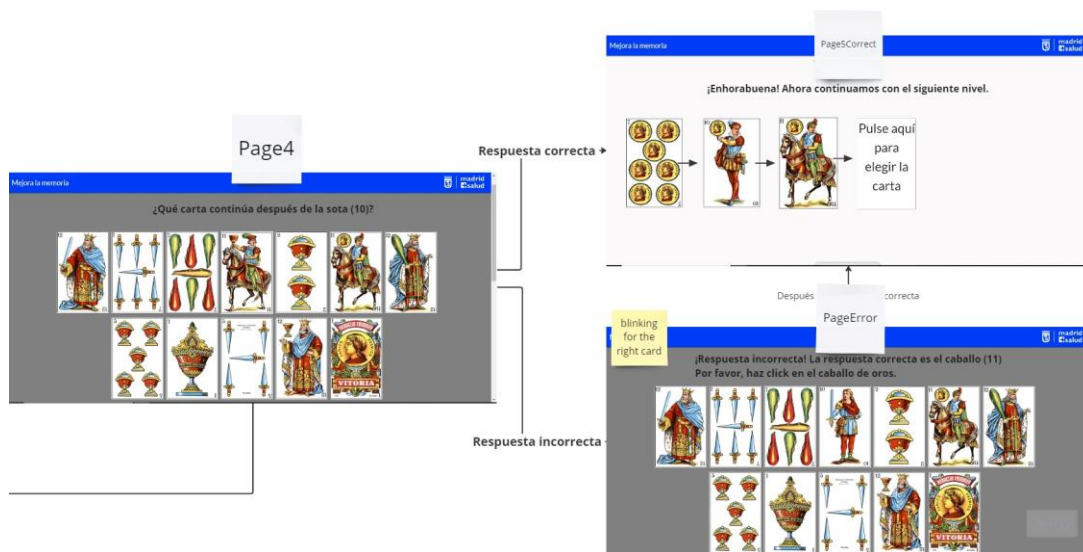


Figure 47. An example of the relationship between pages

To show this interaction between the pages, the current stage of the game will be simply divided into which card the user would pick. In Figure 48, the correct card to choose is called “11_oro” and if the incorrect card is picked, the system will move to the error page and if it is correct, it’ll move on to “Page5Correct”.

```
case "page4":
  currentAudio.addEventListener("ended", function() {
    $(".cloudContainer").one('click', function() {
      closeCardCloud()
      currentPage = "page3"
      UpdatePage()
    });

    $(".cloudCard").one("click", (event) => {
      event.stopPropagation();
      if($(event.currentTarget).attr("data-card") === "11_oro.jpg"){
        currentPage = "page5Correct"
      }else{
        currentPage = "page5Error"
      }
      UpdatePage()
    });
  }, false);
break;
```

Figure 48. An example of navigation between pages

6 Development of Tutorial 2: “Visualizando Escenas Cotidianas”

This chapter focuses on the design and development process of the second interactive tutorial for the “Visualizando escenas cotidianas” activity. The entire process from the initial design until the final implementation will be discussed in this section. As the previous tutorial, the design and development of this tutorial were validated by CDPC, Professors Jaime Ramírez, Elena Villalba, and Maximilian Menschel from the Aging Lab at the Technical University of Madrid.

The “Visualizando escenas cotidianas” activity was one of the activities which were more problematic to understand for older users. This activity is designed to stimulate the cognitive ability of challenging visual memory of the users. The user’s main task is memorizing objects in the provided scene and then answering questions about them. This game has a second stage where some of these objects will be missed from the main scene and the user must choose which objects disappeared and place them in their previous position.

In the tutorial as well, users are engaging in the same activities as in the game. But most questions and the scene are simplified because the learning process of the tutorial aims to guide users through learning the logic of the game rather than challenging the user’s cognitive abilities.

This tutorial’s goal is to improve the user’s learning process by providing useful information and guidance into different stages of the game. With the use of this tutorial, users can understand the game’s logic without requiring special supervision which could be very encouraging for older adults.

The first step in designing such a system is identifying which parts of the game could be more difficult for the users to learn. And based on this understanding an initial design was created. In the next stage of designing the tutorial, a Hi-Fi prototype was created to increase understanding of the system. Later this prototype was tested and validated with CPDC, and all changes were added to the final version of the prototype. After addressing possible problems this prototype was used for implementing the final version of the interactive tutorial.

6.1 Initial design

The initial stage of the project focuses on understanding the target audience’s needs, limitations, abilities, and any challenges they might face while using the system. This was accomplished during regular meetings with researchers of the Aging Lab Centre. The important part of this stage was to ensure the tutorial is aiming at all goals of using this tutorial. The main requirement of the tutorial was to develop a system that can help users with their learning process. To achieve this goal, we had to simplify the gameplay by dividing it into smaller challenges so the users can focus on the learning without feeling overwhelmed. In this process initial design, we had to decide how to divide each part of the game into smaller sections.

Another important and difficult part of this design was to keep the tutorial design as similar to the actual game as possible. Because any discrepancies

between the game and the tutorial could confuse users and demotivate them from using the system.

Organization

During this process, necessary information within the system was labeled to facilitate effective navigation and undressing information flow into the system. Organization of the information focuses on organizing it into a meaningful category. As it was explained, mainly the tutorial includes two parts with two different little simulated games.

The process of this design should have a meaningful structure and focus on creating a logical system map. For this very reason, we have divided the design into two different parts, and in each part, the game has several stages. As it was mentioned previously in the first part of the game, after memorizing the objects and the main scene of the game, users had to answer some questions about them. We have made this stage of the game the first logical part of the tutorial including 3 questions. And the second stage which is choosing the object which are missing from the scene and placing them into the right position, as the second part of the tutorial including the positioning of two missing objects.

Navigation

Navigation of the system should be decided in this process. Likewise the previous tutorial, some of the navigations will be automatic, and some of them by asking users to press a button or an image.

Also, navigation plays a crucial role in ensuring user satisfaction. All the information should be provided with a meaningful structure that can help the user to understand the system and create a meaningful relationship between each part of the actual game (see Figure 49).

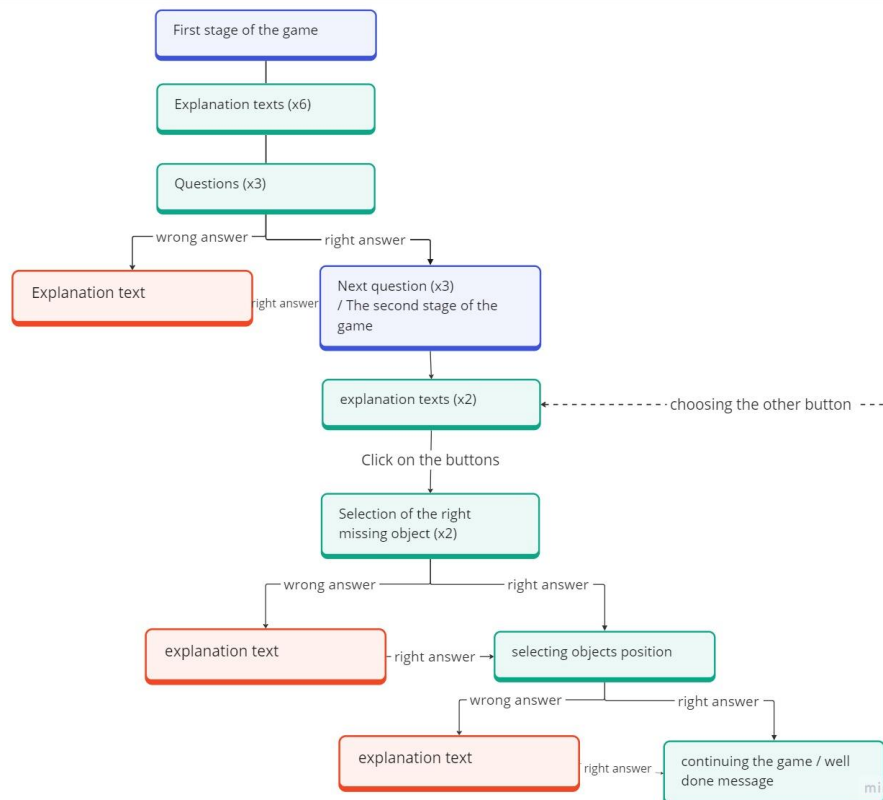


Figure 49. View of instruction and navigation of initial design - *Visualizando escenas cotidianas* tutorial

6.2 Hi-Fi prototype

This section focuses on the design of the high-fidelity prototype which aims to provide a representation of the tutorial. This prototype is more advanced and detailed compared to the initial design. Later this prototype was used for validation with the help of CDPC. The hi-fi prototype highlights users' interactions with the system. This prototype was available in the Miro platform to increase the collaboration and monitoring of the projects with others.

The provided hi-fi prototype carries more visual aspects of the developed design and highlights users' interaction through the tutorial.

6.2.1 Visual design

One of the essential parts of designing the visual aspect of the prototype is to keep the main design of the actual game as much as possible. So, we had to decide how to provide each piece of information in the design and how users can have better instruction. For this very reason, we have decided that the changes in the information should automatically depend on the time rather than clicking on a button. Because it could confuse the users who are going to use the actual game. To reduce this confusion we had to keep the design as similar as possible to the game.

The prototype includes various alternatives, such as text, and audio. By comparing the actual game and the tutorial, users become familiar with the visual style and later it'll be easier for them to use what they have learned in the actual game. If this design is very different, users' mental effort is focused on understanding the new environment.

In addition, Figure 50 shows an example of comparing the design in the first version of the prototype with the actual “Visualizando escenas cotidianas” activity. The yellow cycles show where the animations should be implemented. As can be seen, the scenes of the game are simplified to reduce cognitive overload, but the main design of the game is the same as in the prototype to increase the learning process of the user. In general, presenting easy examples in the tutorial motivates users to stay engaged with the game, as they anticipate their success.



Figure 50. View of an example of the design in the actual game and Hi-Fi prototype of the tutorial

6.2.2 Interaction design

During the design of this prototype, the second phase was to decide how the information should be presented to the users and how users should move through the information. Considering that older adults have lower information processing speed, all information should be divided into smaller stages to avoid overwhelming them.

The Hi-Fi prototype of this tutorial consists of more pages compared to the previous tutorial because of the complexity of the game.

The key elements of interaction design are:

Navigation: The navigation of the system should be very simple and meaningful. Any sort of complex interactions must be avoided. The main use of navigation is very similar to the previous tutorial. In this prototype, we have two different stages each stage starts with an explanation of that stage and ends with solving the examples by the user. In the explanation stage, the interaction would be automatically depending on the time. Also, in the solving example part, the interactions depend on the different provided elements.

Interactive elements: These elements engage users with the system and promote active learning. These elements in this tutorial are different examples that the users should solve based on the given guidelines. The element for interaction in this section are clickable objects and buttons.

Feedback and response: This tutorial provide guidelines that can be used as learning supports. Since this game is focused on visual memory, guidance in this tutorial highly depends on visual elements like animations. Also, other general information is provided with both texts and audio.

Consistency: The interaction design follows a meaningful and logical structure. When the tutorial has high consistency, users can quickly understand how to interact with the tutorial, especially during the last stages.

6.2.2.1 Interaction description of the first stage

To increase the learning process of the user this tutorial is decided into a small structure. In general, the prototype consists of two different stages. Each stage starts with an explanation and later ends with solving an example by the user. The examples provided to solve in this stage consist of questions about the objects which were previously mentioned in the explanation part of the tutorial.

As it is provided in Figure 51, these explanations start by explaining the logic of the game in short sentences. After this step, the explanations are about what aspect of objects should take users' attention.

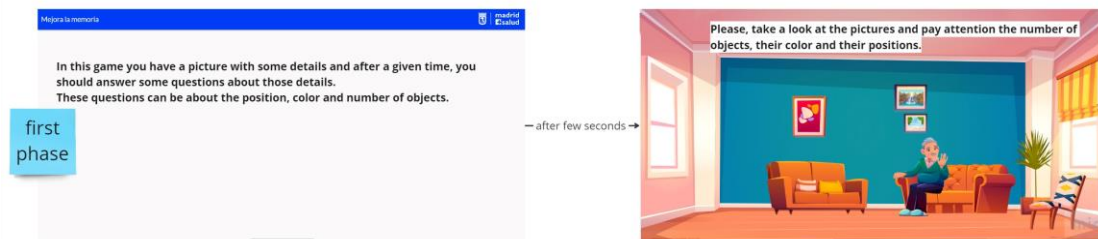


Figure 51. View of explanation of the Hi-Fi prototype - "Visualizando escenas cotidianas" tutorial

The explanation stage in this game is longer than in the previous game. This is because all the information which will be pointed out during these explanations will be used in the question stage of the tutorial. As can be seen in Figure 52, three different sorts of information are pointed out in this stage. However, later in the section on validation, some of these explanations and objects are changed, which will be discussed in the next section of this chapter.

All explanations in Figure 52 point out objects, and meanwhile, users see the scene and the text, they can as well listen to audio. Also, by using animation, the mentioned objects will be pointed out (this is shown by the yellow circles in the prototype)



Figure 52. View of explanation of the Hi-Fi prototype - "Visualizando escenas cotidianas" tutorial

The second step includes the questions which are asked of the users about all information that was previously given in the stage of explanation. The prototype includes three different questions and after answering correctly to a question it'll move to the next question. An animation with a sound is designed in this part of the system, to show the user that the answer was correct.

In case of making a mistake, the question screen will show the scene and explain the correct answer. At this point of the game, the object of the question will be highlighted with an animation. After this explanation, the system will automatically move to the next question (see Figure 53).

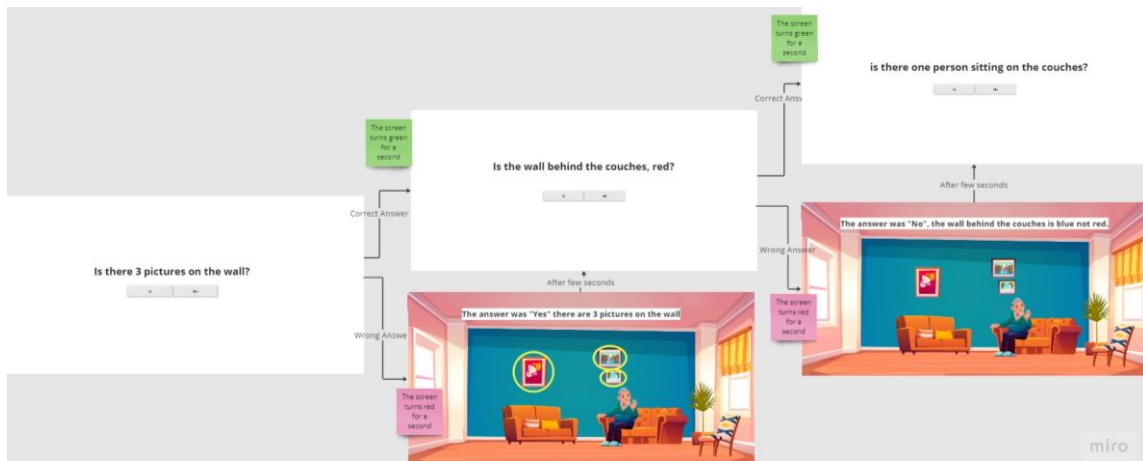


Figure 53. View of questions of the Hi-Fi prototype – “Visualizando escenas cotidianas” tutorial

6.2.2.2 Interaction description of the second stage

The second phase of the actual activity includes some missing objects which users must choose and place in their previous position. In the Hi-Fi prototype, an explanation with an example of this phase is provided. Also, additional feedback can be used when users make an incorrect action.

In the first part of this phase, after finishing the first stage of the game a message would be provided to the user to inform users about the logic and mechanism of the next stage of the game. Later, an object which will be disappeared during the game are highlighted to users by the use of animations (see Figure 54).

The reason of using a person and an object for disappearing is that in the actual game for choosing the correct disappeared object, two different buttons are provided so that the user can choose the people from one and objects from the other.

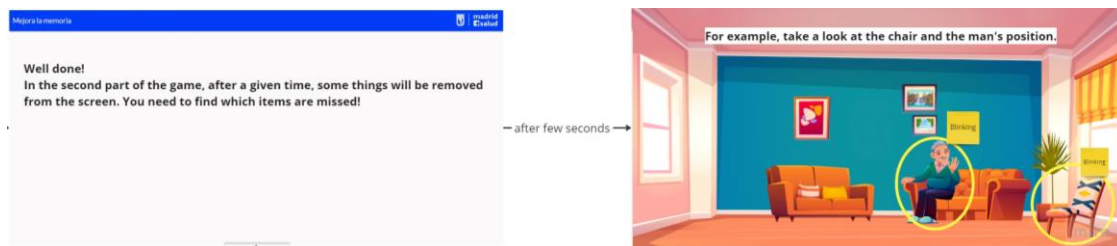


Figure 54. View of explanation of the Hi-Fi prototype - “Visualizando escenas cotidianas” tutorial

Moreover, the prototype continues with an explanation of how the user can interact with the game and how they can choose a character by clicking on them, and how they should put the right character in the right position. If the user selects an incorrect character, feedback would be provided to help users to know which character was the correct one. To make the feedback more efficient, the right character will be pointed out by the use of an animation (see Figure 55 with selection of character).



Figure 55. View of picking objects in the Hi-Fi prototype - *Visualizando escenas cotidianas* tutorial

In the final stage of the game, the user has to repeat the previous action but this time by clicking on the other button and selecting the missing object from the scene (see Figure 56 with selection of object).



Figure 56. View of picking a person in the Hi-Fi prototype - *Visualizando escenas cotidianas* tutorial

6.3 Validation process with CPDC

The validation process for the high-fidelity prototype of the tutorial was carried out in collaboration with CPDC. The goal of validation was to assess the functionality of the system's intended goals and users' requirements.

Based on the received feedback during the validation process, some changes were applied to the second version of this prototype. In addition, these changes were mainly applied to increase the visual similarity of the Hi-Fi prototype to the actual game. Some of these changes are:

- Adding animations
- Adding another object which has small details
- Changing information and feedback
- Providing new feedback

6.3.1 Navigation validation

The navigation structure of the prototype plays a crucial role in guiding users through the tutorial. After validating the initial version, several changes were identified to improve the efficiency of the design. Applied changes were completely different compared to the "Secuencia de cartas" tutorial. This was

because we tried not to make the same mistakes during the development of the first version of the Hi-Fi prototype as in the previous tutorial.

One of the biggest changes during navigation validation was in the second stage of the game. In a part of the tutorial, the user must click on “Personajes” or “Objetos” to choose the missing objects or persons respectively. And the possibility of choosing either of these two buttons was not considered in the first version of the Hi-Fi prototype.

- **Change in the navigation.**

Statement before the change	Description of the change
<p>The first version of the prototype did not consider the possibility of choosing “Personajes” or “Objetos” in any order.</p>	<p>The final version of the prototype considered two different possibilities.</p> <ol style="list-style-type: none"> 1. In the first possibility, the user first selects the “Personajes” button and later after finishing the example related to this button, the player chooses the other button. 2. Also in the second possibility, the user chooses the buttons in the opposite order by first selecting the “Objetos” button and then the “Personajes” button

Figure 57 shows the first possibility which is when the user first chooses the “Personajes” button and later after answering the related question, the user can select the “Objetos” button.

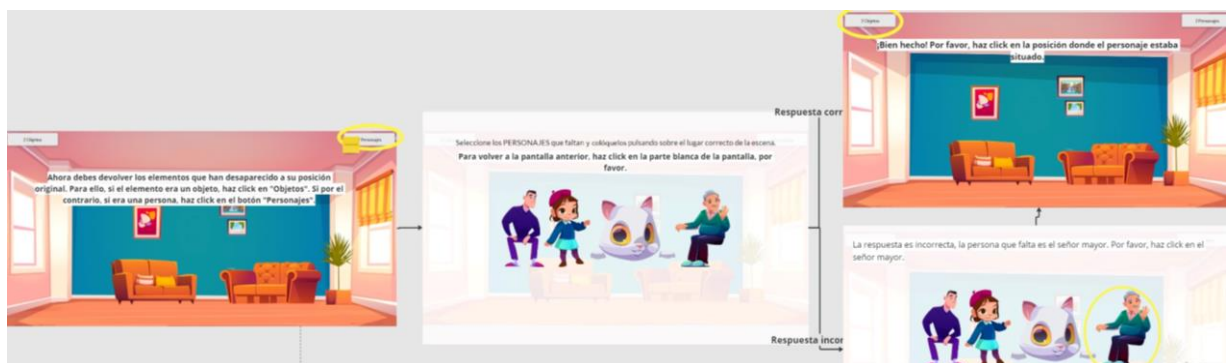


Figure 57. Change in the navigation in the Hi-Fi prototype- Visualizando escenas cotidianas” tutorial

6.3.2 Interactive elements validation

The interaction of the user with the system follows the same flow as in the previous tutorial. These elements are how users can interact with the game.

In the first stage of the tutorial, users interact with the system by choosing answers to the provided questions by clicking on the buttons. And in the second stage requires more interactions because users first need to choose the correct objects and then place them into the correct position.

Unlike the first tutorial, we didn't have any changes in these elements during the validation of the prototype.

6.3.3 Feedback validation

This section focuses on the changes made during the validation process in response to feedback. In general, feedback and information are means of providing guidance and support to users. This guidance is made with the use of audio, text, and visual elements. Based on the feedback received during the validation phase, certain elements were modified to improve the overall user experience.

One of the changes that was suggested to the system was adding more animations. These animations increase users' visual interaction which could improve the learning process. The suggestion was in pages where specific objects had to point out. For example, when the system is asking users to press a button, this button should be pointing out using an animation.

Another essential change was with some of the considered objects. As it was mentioned in Section 2.8.1, one of the principles of learning in older people is the simplification of the examples to avoid cognitive overload. To achieve this goal, in the first version of the tutorial we used simple objects.

On the other hand, CPDC suggested that one of the problems of users is that usually, they do not pay attention to small details of the object, and we should implement one related example in the tutorial. To solve this problem, the main person in the scene was replaced with another person who has more small details, more precisely, holds a phone and wears glasses. These small details were pointed out to the users and later one of the questions was dedicated to questioning these details.

- **Changes the objects**

Statement before the change	Description of the change
In the first version, we did not have a detailed object.	<p>In the second version of the prototype, a more detailed object was implemented in the scene.</p> <p>The scene shows an old lady who is holding a phone and she is wearing glasses.</p> <p>These details were pointed out to the user and one of the questions was changed to asking about these details.</p>

Figure 58 shows the added detailed person to the scene and details such as the glasses and the phone will be pointed out by using an animation.

Also, please pay attention to small details of the objects. for example the mobile and the glasses of the old lady.



Figure 58. Changes in objects- Visualizando escenas cotidianas” tutorial

- **Adding animation**

Statement before the change	Description of the change
<p>Small animations only exist to point out when the system guidance is mentioning objects.</p>	<p>In addition to objects, an animation was added for buttons in the second stage of the game, so the user will know which buttons he should click on.</p>

Figure 59 illustrates the page where the animation was added to Personajes” and “Objetos” buttons.

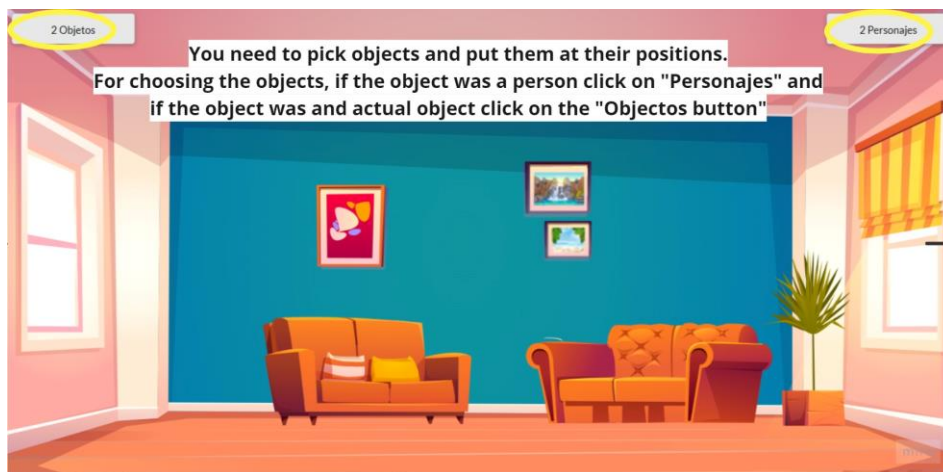


Figure 59. Adding animation to the buttons- Visualizando escenas cotidianas” tutorial

6.4 Final Hi-Fi prototype

In this step of the thesis project, after receiving all validation from CODC, a final version of the High-Fidelity prototype was designed including all necessary

implementations. This prototype represents the most recent changes, and it did not have any new changes in the final implementation process.

Since all users of this platform are Spanish speakers, in this step all texts and information of the system were translated to Spanish. To ensure users could easily navigate and interact with the system all elements were translated into Spanish. Throughout the development process, special attention was given to visual elements such as animations to improve user satisfaction and ensure their learning process.

In the end, after the implementation of all changes, this prototype was validated by researchers in the Aging lab to solve every possible problem. Figure 60 shows a view of the final prototype.

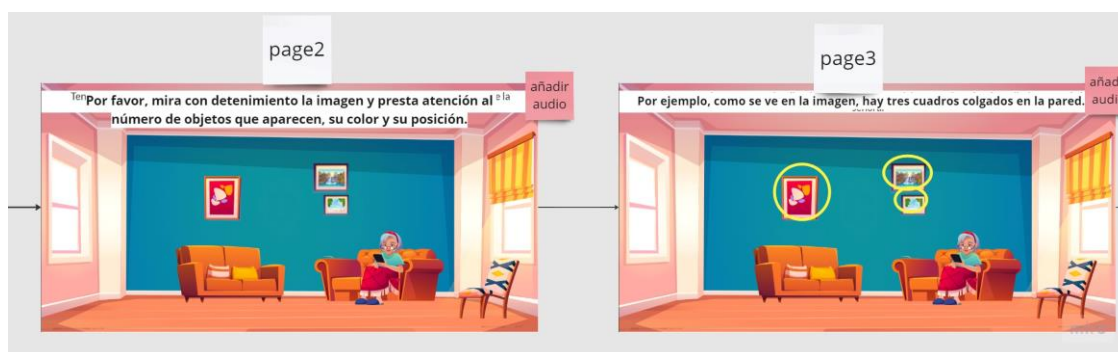


Figure 60. View of final prototype of “Visualizando escenas cotidianas” tutorial

6.5 Final implementation

The implementation of the “Visualizando escenas cotidianas” interactive tutorial was done based on the final version of the Hi-Fi prototype. The process of the final implementation of this project has been done by cooperating with researchers and professors of the Aging lab centre of UPM.

The first step in the final implementation of the project was to follow the same structure as in the previous tutorial. Maintaining the same logical structure for the development of both tutorials offer several advantages. By having a consistent structure, future work will get easier. Because of familiarity a future reviewer could have a better understanding of the structure of the project.

Also, we tried to use a reusable code structure in both tutorials. This allows future developers to reuse the same structure and code to spend less time on the development and promote a meaningful structure. This use of consistent code structure simplifies the process of the system maintenance.

In the main project, each activity has a separate HTML, CSS, JavaScript, and JSON file. This tutorial also uses the same CSS, HTML, and JSON files as the actual game. But it has a separate JavaScript file which is called “controladorPrueba20_tutorial”. An important fact about the structure of the actual game is that all the activities in the Mejorarmemoria platform have only one JSON file. But since this activity includes different scenes and pictures, it has 12 JSON files. The JSON file used for the implementation of this project is called “salon”. The reason for not using all files is that in the tutorial we are using just one of the scenes of the game.

The JavaScript file of the tutorial includes the main logic as the JavaScript of the actual activity. But some unnecessary functions are not implemented in this

file. To establish the interaction between the tutorial and the main page of the platform, the function “mainTutorial” is implemented into JavaScript files of both parts.

In the JSON file, an array called tutorialConfig provides all information needed for each page. Each of the pages includes details such as animated objects, text, audio, and objects which should be shown or hidden in each state of the game.

Figure 61 shows a view of the first two pages in a JSON file.

```
"tutorialConfig":
{
  "page1":{
    "text": "En este juego encontrarás una imagen que incluirá varios detalles a los que debes prestar atención, ya que después de visualizar",
    "audio": "../sounds/prueba20/page1.mp3",
    "highlightedObjects":[]
  },
  "page2":{
    "text": "Por favor, mira con detenimiento la imagen y presta atención al número de objetos que aparecen, su color y su posición.",
    "audio": "../sounds/prueba20/page2.mp3",
    "objectsToUse":[
      "sofa",
      "silla",
      "sofa_matrimonio_joven",
      "movil_abuela",
      "gafas_abuela",
      "abuela",
      "cuadro_playa",
      "cuadro_catarata",
      "cuadro_rojo",
      "cortinadcha"
    ],
    "highlightedObjects":[]
  }
}
```

Figure 61. An example of the tutorial information provided in the JSON file

A function called UpdatePage in the JavaScripts file of the tutorial, access to information of the JSON file. This function includes the most important parts of the tutorial such as navigation management of pages, audio management, text management, and animations. The interaction between these two files allows the system to provide information for all pages.

Figure 62 shows the aspect of page navigation in the UpdatePage function by the use of a switch statement. On “page 3” this function gets the information of the current page (which is “page 3”) and prints the text. Also, it starts and later stops the animation at the end. Also, it starts playing the audio and when this audio is finished, after 2 seconds, it’ll move on to the next page which is “page 4”.

```
case "page3":
  $("#contenidoJuego").append("<h4 id='centerText'>${tutorialConfig[currentPage].text}</h4>")
  blinkHighlightedObjects()
  currentAudio.addEventListener('ended', function() {
    setTimeout(() => {
      currentPage = "page4"
      updatePage()
    }, 2000);
    stopBlinkAnimation()
  }, false);
  break;

case "page4":
  $("#contenidoJuego > h4").remove()
  $("#contenidoJuego").append("<h4 id='centerText'>${tutorialConfig[currentPage].text}</h4>")
  blinkHighlightedObjects()
  currentAudio.addEventListener('ended', function() {
    setTimeout(() => {
      currentPage = "page5"
      updatePage()
    }, 2000);
    stopBlinkAnimation()
  }, false);
  break;
```

Figure 62. Interaction of JavaScript and JSON file

This process for some pages is slightly different, for example, on “page12” depends on if the user clicks on the “Personajes” or “Objetos” buttons, the system should show different pages with different information. In this case, navigation between pages does not depend on the time (see Figure 63).



Figure 63. An example of the relationship between pages

In Figure 64, you can see how “page12” can be navigated into different pages. Depending on which button the user would click, the next page would be “page13Personajes” or “page13Objetos”.

```

case "page12":
    $("#imageContainer").empty()
    $("#contenidoJuego > h4").remove()
    $("#contenidoJuego").append(<h4 id="centerText">${tutorialConfig[currentPage].text}</h4>)
    $("#imageContainer").append()
    let objectsToPlace = scene.objects.filter(object => tutorialConfig[currentPage].objectsToUse.includes(object.name))
    console.log(objectsToPlace)
    $("#contenidoJuego").append(
        <div id="personasButton" class="inventoryButton gameButtonStyle" data-parent="personInventory"><span id="personsCounter">1 Personajes</span></div>
        <div id="objectsButton" class="inventoryButton gameButtonStyle" data-parent="objectsInventory"><span id="objectsCounter">1 Objetos</span></div>
    )
    $("#personasButton").click(function(){
        currentPage = "page13Personajes"
        updatePage()
    })
    $("#objectsButton").click(function(){
        currentPage = "page13Objetos"
        updatePage()
    })
}
break;
case "page13Personajes":
    {
        $("#imageContainer").empty()
    }

```

Figure 64. Example of navigation between pages

7 Conclusion and Future Work

All software platforms are subject to continuous modifications and maintenance. mejoralamemoria.es has many potentials of adding new features. Since this platform contains access to a large volume of data, it would be a great opportunity for studying different aspects of cognitive games.

The key future work should involve analyzing the outcome of interactive tutorials to maintain a better platform. Additionally, the results of this analysis can be used for recognizing what users may experience during cognitive decline or by using cognitive stimulation. Besides, these data will be used for diagnosing and identifying cognitive decline or other issues that users may experience. This data-driven approach will contribute to the continuous improvement and effectiveness of the platform.

7.1 Conclusion

In this thesis, we have presented the development and validation process of two interactive tutorials. Each interactive tutorial was designed and implemented for a simple serious game, which was identified to be difficult to be used by older users in a previous study. This implementation has been done in the mejoralamemoria.es platform, which is aimed to support cognitive health by providing simple games.

Through this project, we developed high-fidelity prototypes to gather feedback from psychologists at the Center for Prevention of Cognitive Decline and researchers of the Aging lab of the Technological University of Madrid. With the use of this feedback and validations, we update the tutorial's structure, content, and interactive elements. Validation of the prototype ensured that the tutorial includes the required aspects of the system.

Meanwhile for the final implementation of the tutorials, we created a logical and reusable structure to facilitate future work of the system. The final version of each tutorial consists of a simple guidance which tries to help users with their learning process by providing different interactive elements. Furthermore, we think these interactive tutorials will provide an opportunity for the users to learn the logic of the game by themselves.

7.2 Future work

The mejoralamemoria.es platform can provide a chance for several avenues for future work focused on data analysis and evaluation of user behavior.

Continuing improvement of the tutorial is essential to ensure its relevance and effectiveness. Future work should focus on expanding the effectiveness of tutorials. This work should explore the integration of constant learning techniques by providing an experiment of users' feedback while using that tutorial. Also, since all the data is collected during all activities, it can be measured how much the tutorial helps the user considering metrics like the number of failure before and after using tutorials.

The user interaction with the tutorials can be further improved to enhance usability and accessibility for older adults. Study should focus more on conducting user studies and gathering user's feedback to increase the understanding of their problems while using tutorials. Special attention can be given to factors such as color contrast, font size, and intuitive navigation,

ensuring that the tutorials are user-friendly enough and solve any possible problem.

In addition, one of the interesting future research projects can be dedicated to introducing gamification elements into the games. Some of gamification techniques are points, rewards, and tracking. Usually, rewarding is a motivation element for users which can provide a more enjoyable learning experience for older adults. Future work should focus on exploring the integration of gamification elements within the tutorials to make the learning experience more enjoyable and interactive.

As this platform will be offered by the council of Madrid on its website, it will be able to obtain a large amount of data from the users. Analyzing this data can be a good way to understand user behavior and to be able to provide many studies. Researchers and professional users can rely on this data to supervise the progress of the user in all activities. These collected data can be used in the development of different cognitive assessment systems by analyzing user performance and the patterns which indicate a cognitive decline.

Another important aspect of designing a system for older users is ensuring the usability and accessibility of the system. Future work should focus on the improvement of these factors. Different aspects of the system such as the color contrast and fonts can have an essential role in designing systems for older users. These factors can be analyzed with the use of the system and users' feedback.

In conclusion, the development of the interactive tutorial of the mejoralamemoria.es platform is a step toward supporting cognitive health among older adults. The platform can be improved by correctly addressing the cognitive needs of older adults.

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