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ORIGINAL

Digital intervention for active aging: design of a web application for older adults

Intervención digital para el envejecimiento activo: diseño de una aplicación web para adultos mayores

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ABSTRACT

Population aging is accelerating globally, with the population of people over 60 expected to double by 2050, reaching 2,1 billions. This phenomenon, together with increased longevity due to advances in salud, education and reduced fertility rates, presents unique challenges and opportunities for society. Against this backdrop, the design of digital interventions that promote active and healthy aging becomes a priority. This work proposes the initial development of a web application aimed at supporting memory in older adults, applying a holistic approach that integrates knowledge from various disciplines. The application is based on principles of accessibility, usability and user-centered design, seeking not only to improve cognition, but also to offer a tool that facilitates social inclusion and improves the quality of life of older adults. By focusing on accessibility and inclusive design, this project contributes directly to technological intervention strategies in the field of aging, marking a step forward in the development of solutions that respond effectively to the needs of a growing population.

Keywords: Active Aging; Web Application Design; Cognition in Older Adults; Participatory Design; Human-Computer Interaction.

RESUMEN

El envejecimiento poblacional se está acelerando globalmente, con la expectativa de que la población de personas mayores de 60 años se duplique para 2050, alcanzando los 2,1 billones. Este fenómeno, junto con la mayor longevidad gracias a avances en salud, educación y la reducción de la tasa de fertilidad, presenta desafíos y oportunidades únicos para la sociedad. Ante este contexto, el diseño de intervenciones digitales que promuevan un envejecimiento activo y saludable se convierte en una prioridad. Este trabajo propone el desarrollo inicial de una aplicación web destinada a apoyar la memoria en adultos mayores, aplicando un enfoque holístico que integra conocimientos de diversas disciplinas. La aplicación se fundamenta en principios de accesibilidad, usabilidad y diseño centrado en el usuario, buscando no solo mejorar la cognición, sino también ofrecer una herramienta que facilite la inclusión social y mejore la calidad de vida de los adultos mayores. Al enfocarse en la accesibilidad y el diseño inclusivo, este proyecto aporta directamente a las estrategias de intervención tecnológica en el ámbito del envejecimiento, marcando un paso adelante en el desarrollo de soluciones que respondan efectivamente a las necesidades de una población en crecimiento.

Palabras clave: Envejecimiento Activo; Diseño de Aplicación Web; Cognición en Adultos Mayores; Diseño Participativo; Interacción Humana-Computadora.

INTRODUCTION

The demographic transition to an aging global population is one of the most significant challenges of the 21st century, profoundly impacting the social, economic, and health structure worldwide. By 2050, the population of individuals over 60 will reach 2,1 billion worldwide, doubling current figures. This aging population, driven by increasing life expectancy and declining fertility rates, presents challenges and opportunities for global health and social systems (Department of Economic and Social Affairs, 2019). In this context, cognitive impairment associated with aging emerges as a growing concern, significantly affecting the quality of life of older adults and increasing the burden on caregivers and health systems (Alzheimer's Disease International, 2019). The need for effective intervention strategies that promote healthy and active aging is becoming increasingly evident, highlighting the importance of developing accessible, user-centered tools to support cognition in this population (Infurna et al., 2020; Smith, 2016).

The design of digital technologies, such as web applications, offers a promising approach to addressing cognitive decline in older adults. These tools can provide cognitive stimulation exercises, progress monitoring, and personalized intervention strategies, thus facilitating social inclusion and autonomy support for older adults (Cheng, 2016). However, to ensure the effectiveness of these interventions, it is crucial to adopt a user-centered design approach, considering the specific needs, preferences, and limitations of this population (Escobar Reynel et al., 2023; Yu et al., 2014).

This work explores the initial development of a web application designed specifically to support memory in older adults. Through a holistic and multidisciplinary approach, we propose to evaluate the usability, accessibility, and effectiveness of this tool in improving cognition and quality of life in older adults. The objective is to contribute to the existing literature by offering valuable perspectives on designing and implementing digital technologies focused on active and healthy aging.

The initial focus on design is a common practice in developing digital health interventions, where the implementation of digital technologies is recommended in a progressive and evaluative manner. According to the World Health Organization, the strategic use of digital technologies should be systemically evaluated to ensure that they contribute effectively to health systems prior to large-scale implementation (WHO, 2019) (World Health Organization (WHO)). It is also critical to recognize that each digital tool must be tailored and responsive to the specific needs of end users, which requires careful design (Al-Shorbaji, 2022).

This approach allows for a more seamless and sustainable integration of technology into routine practice, ensuring that interventions are innovative but also applicable and effective in real-world contexts. For example, the successful implementation of digital interventions is highly dependent on their ability to integrate into existing systems and to be accepted by end users (May et al., 2018).

METHOD

To develop a web application that supports memory in older adults, our methodology focuses on a comprehensive approach from the literature review to the design phase, ensuring that the final product is scientifically sound and highly tailored to users' needs.

This approach is structured in several detailed phases:

Phase 1: Systematic Literature Review

Using a meticulously designed search string, we focus on studies exploring subjective memory complaints, neurocognitive testing, lifestyle interventions, and web applications about aging and cognitive decline (Baptista et al., 2022; Pike et al., 2018). This approach allows us to capture a broad spectrum of relevant research, ensuring our project is grounded in the most up-to-date and relevant scientific evidence (Maruta & Martins, 2019; Onur Aysevener et al., 2018). Using the following specific search string: ("subjective memory complaints" OR "neurocognitive tests" OR "lifestyle intervention" OR "web application") AND ("elderly" OR "older adults") AND ("cognitive decline" OR "memory loss" OR "hearing loss" OR "daily living activities"). This search was conducted in academic Journals, delimiting the publication range between 2018 and 2023, resulting in the identification of 3,318 papers.

Inclusion Criteria

- Studies published between 2018 and 2023.
- Research addressing subjective memory complaints, neurocognitive testing, lifestyle interventions, or web applications.
- Studies focused on older adults experiencing cognitive decline, memory loss, hearing loss, or difficulties with activities of daily living.

Exclusion Criteria

- Research that does not include older adult populations.
- Studies that do not examine the impact of digital technologies on cognition or quality of life.

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Phase 2: User-Centered Design

We proceed to the user-centered design phase with the knowledge gained from the literature review. This phase is crucial to ensure the application is intuitive, accessible, and genuinely beneficial to older adults. We organize participatory workshops involving potential users, caregivers, and healthcare professionals to achieve this. These workshops allow us to gather valuable information about the needs, preferences, and limitations of end users, thus guiding the design of an interface and functionalities that effectively respond to the everyday challenges faced by older adults about memory and other cognitive functions (Baharum et al., 2018; Zhunio et al., 2020).

During the participatory workshops, which involved potential users, caregivers, and healthcare professionals, we gathered valuable insights that led to significant modifications in the design of our application. For example, initially, the user interface featured a color scheme that, while aesthetically pleasing, could have been clearer for visually impaired users. Based on participants' suggestions, we opted for a high-contrast scheme that significantly improves readability for our elderly users. In addition, users expressed the need to simplify complex navigations. This led us to redesign the interface to include more extensive menus with intuitive icons and verbal descriptions, thus facilitating access to critical functionalities without multiple steps or confusing commands (Saparamadu et al., 2021).

These improvements not only reflect a commitment to usability and accessibility but also demonstrate how the participatory design process can effectively adapt to the real needs of end users. The impact of these changes was subsequently evaluated in additional testing sessions, where we received confirmation that the modifications had significantly improved the user experience, demonstrating the effectiveness of incorporating direct feedback into the development cycle.

Prior to direct implementation with end users, our design phase is already profoundly informed by an understanding of older adults' specific needs and limitations derived from existing studies and literature on ergonomics and inclusive design for this population. We incorporate this understanding into every aspect of the application design, from intuitive and accessible user interfaces to the selection of functionality that directly addresses the cognitive and physical challenges older adults face. This forward-thinking approach allows us to create prototypes that are not only technically sound but also profoundly resonant with the experiences and expectations of our end users. In doing so, we establish a solid framework to facilitate a smooth transition to the usability evaluation stage, where feedback from older adults and their caregivers can be effectively incorporated for further refinements.

Phase 3: Prototype and Interactive Content Development

Interface design and prototype development are based on current best practices in interaction design and web accessibility, with particular emphasis on the needs of older adults. This iterative approach allows for rapid adjustments based on continuous user feedback, ensuring close alignment between application features and users' expectations (Escobar Reynel et al., 2023; Falzarano et al., 2020).

In the prototype development phase, we rigorously applied best practices for interaction design and web accessibility explicitly tailored for older adults. These practices include using extensive, clear iconography, high-contrast color schemes to enhance readability, and simplified menus to minimize navigational complexity. In addition, we have incorporated auditory and visual feedback mechanisms to confirm actions taken by users, an essential feature for those with visual or hearing limitations.

Following current guidelines on accessibility, we have also designed the interfaces to be operable both through touch and keyboarding, ensuring that users with different types of disabilities can interact barrier-free with the application (Paton et al., 2021; Smith, 2016; Zharima et al., 2023). These adjustments are based on recent studies that highlight the importance of technologically adapting digital solutions to the abilities of older adults, ensuring that they are functional but also inclusive and practical.

In addition, we have established a protocol for iterative testing with natural user groups, which allows us to collect and analyze feedback on an ongoing basis. This approach validates the effectiveness of the adjustments made and guides future design modifications to better align the application with the specific needs of end users.

Simultaneously, we develop interactive content centered on scientifically validated cognitive stimulation exercises. These exercises are designed to be engaging and compelling, using gamification techniques to foster user engagement and persistence. Personalization of the activities according to the user's skill level and preference is essential, allowing for a more relevant and enriching experience for each individual.

In the development of our application, three types of carefully designed exercises have been integrated to foster cognitive activity in older adults, with each one aiming to strengthen different essential mental skills (Dinius et al., 2023):

Memorization Exercises: these exercises are specially designed to strengthen working memory and long-term memory. Users may be challenged to recall sequences of words or images that gradually increase in number and complexity, thus facilitating working memory training and mental agility. This activity is essential

to counteract the natural decline in memory with age, supporting users in improving their ability to retain and retrieve everyday information.

Maze Exercises: aimed at improving planning skills and spatial orientation, these exercises involve navigating through virtual mazes of varying complexity. Users practice quick decision-making and develop problem-solving skills by solving these mazes. These critical skills can decline with age but are essential for independence and confidence in daily activities.

Color Exercises: using a variety of colors, these exercises are designed to improve attention and cognitive processing speed. Tasks may require users to identify colors under time pressure or quickly change tasks that demand color discrimination. This form of stimulation helps maintain and improve mental agility, which is crucial for managing multiple tasks and activities in daily life.

Feedback and Design Adjustments

Participatory workshops and initial usability testing are critical to refine and optimize these exercises. In these workshops, older adults, caregivers, and healthcare professionals will have the opportunity to interact with the exercises and provide valuable feedback on their experience. This feedback is crucial for making adjustments to the design, ensuring that the exercises are not only challenging and stimulating but also accessible and rewarding for users.

In addition, testing sessions will identify and adjust specific aspects of the exercises that may be too complex or not stimulating enough, thus ensuring that each exercise effectively supports the desired cognitive functions. This iterative and collaborative process ensures that the exercises meet the technical requirements and resonate well with the actual experiences and needs of the end users.

Phase 4 - Evaluating Effectiveness: evaluating the usability and accessibility of application prototypes is a critical stage that precedes full development.

Through usability testing with a select group of end users, we gather detailed feedback on the interface, navigation, and overall interaction with the application. This iterative process of evaluation and adjustment is vital to fine-tuning the application, ensuring that it is functional but also enjoyable and practical for end users.

As for the data collection and analysis methodology in future stages, it is crucial to specify and detail the tools to be used. Tools such as in-application digital logs for usage statistics validated cognitive assessments, and user satisfaction questionnaires are essential to collect relevant data. Analysis of these data should be performed using robust statistical techniques to assess effectiveness and thematic analysis for qualitative feedback, allowing an understanding of user experiences and identifying areas for improvement. In addition, considering longitudinal follow-up may be crucial to assess the long-term impact of the application on users' cognitive health.

This evaluation framework aligns with best practices in digital health interventions, emphasizing the importance of integrating digital tools into health systems and demonstrating significant and lasting improvements compared to traditional methods (WHO, 2019). Therefore, by applying such a comprehensive evaluation framework, one can ensure the immediate effectiveness and the sustained impact of the application on the overall health and well-being of older users.

This multi-dimensional methodological approach ensures that a robust body informs app development of research and is closely aligned with the needs and capabilities of end users. Through active collaboration with older adults and healthcare professionals and diligent use of user-centered design and development practices, we strive to create a digital tool that offers meaningful support to older adults in managing their memory and cognitive functions.

Measurement Protocols

To ensure a thorough evaluation of our app, we will establish measurement protocols that cover both quantitative and qualitative aspects of the app's use and effectiveness. These protocols will include:

- Quantitative Measurements: we will implement standardized neuropsychological tests to directly assess improvements in users' cognitive abilities, such as memory and attention. In addition, metrics of interaction with the application, such as frequency of use, duration of sessions, and progression in the exercises, will be used to measure the user's adherence and response to the intervention.
- Qualitative Measurements: we will conduct periodic interviews and surveys to collect direct feedback from users about their experience with the application. This qualitative data will help us understand the user's perception of the application's usefulness and its impact on their daily quality of life.

The analysis of these data will be conducted using statistical techniques for quantitative data and content analysis methods for qualitative data, allowing for a robust evaluation of the application in terms of effectiveness

and user satisfaction (Minary et al., 2019; WHO, 2019).

To ensure that our application continuously meets the changing expectations and needs of older adults, we will implement a continuous evaluation strategy.

This process will not only evaluate the functionality and accessibility of the application but will also allow for agile adaptations based on direct user feedback.

We will follow a methodology that includes iterative usability testing, which is fundamental to capturing the user experience at different stages of application use.

In addition, we will establish a long-term data collection system that will allow us to monitor key performance indicators through dashboards.

These dashboards will facilitate visualization of progress and help identify areas for potential improvements, ensuring that the application not only responds to initial needs but also adapts to emerging user needs (Tolf et al., 2020; WHO, 2019).

Success Indicators

We will define clear indicators of success for the evaluation phases of our application, including:

- Quantitative Objectives: specific improvements in cognition tests reflect increased mental abilities due to using the application. This may include, for example, improvements in memory and processing speed tests.
- Qualitative Objectives: high levels of user satisfaction and positive feedback on the application's experience. We will also look for qualitative evidence of improvements in users' autonomy and emotional well-being, as reflected in their comments and interviews.

These indicators will not only measure the success of the application in technical and usability terms but will also evaluate its actual impact on users' lives, which is essential to our goal of improving the quality of life of older adults (Vázquez et al., 2022).

Transparency in Limitations

It is critical to acknowledge and openly address the limitations inherent in the design phase of our application. Despite advances, a significant limitation at this time is the need for more direct interaction and measurement with end users, which is critical to validate the effectiveness and usability of the proposed solution.

Recognition of Current Limitations

Our project is at an early stage where interactions with real users are limited. This may lead to uncertainties about how end users will receive and use the application in real-world settings. The literature suggests that digital health interventions can face significant challenges in the early stages, especially regarding acceptance and effective integration into users' daily routines (Cuff, 2023; Zharima et al., 2023).

Strategies to Address These Limitations

To overcome these obstacles, we plan to implement pilot tests and usability studies in subsequent phases, where interaction with users will be intensive and direct.

These activities will allow us to collect vital user experience data, identify usability issues, and fine-tune the application before its full-scale launch.

In addition, we will integrate evidence-based recommendations for user interface design, including the use of predictive human-computer interaction models to improve the generalizability of usability evaluations (Paton et al., 2021).

This recognition and planning phase is crucial to establish a solid foundation for the long-term success of the application, ensuring that it aligns with the real needs and expectations of end-users.

RESULTS

Our bibliometric analysis of 3,318 papers has resulted in visual representations that synthesize current research in cognitive support for older adults.

Figure 1, a keyword co-occurrence map, shows an interconnected network where terms such as "dementia," "executive function," "randomized controlled trial," and "memory loss" appear as central nodes, reflecting their frequency and relationship within the literature (Smart et al., 2017).

In figure 2, the bibliometric density map highlights the densest research clusters around "cognitive training," "neuroimaging," "lifestyle intervention," and "web application," highlighting their relevance in the context of cognitive aging.

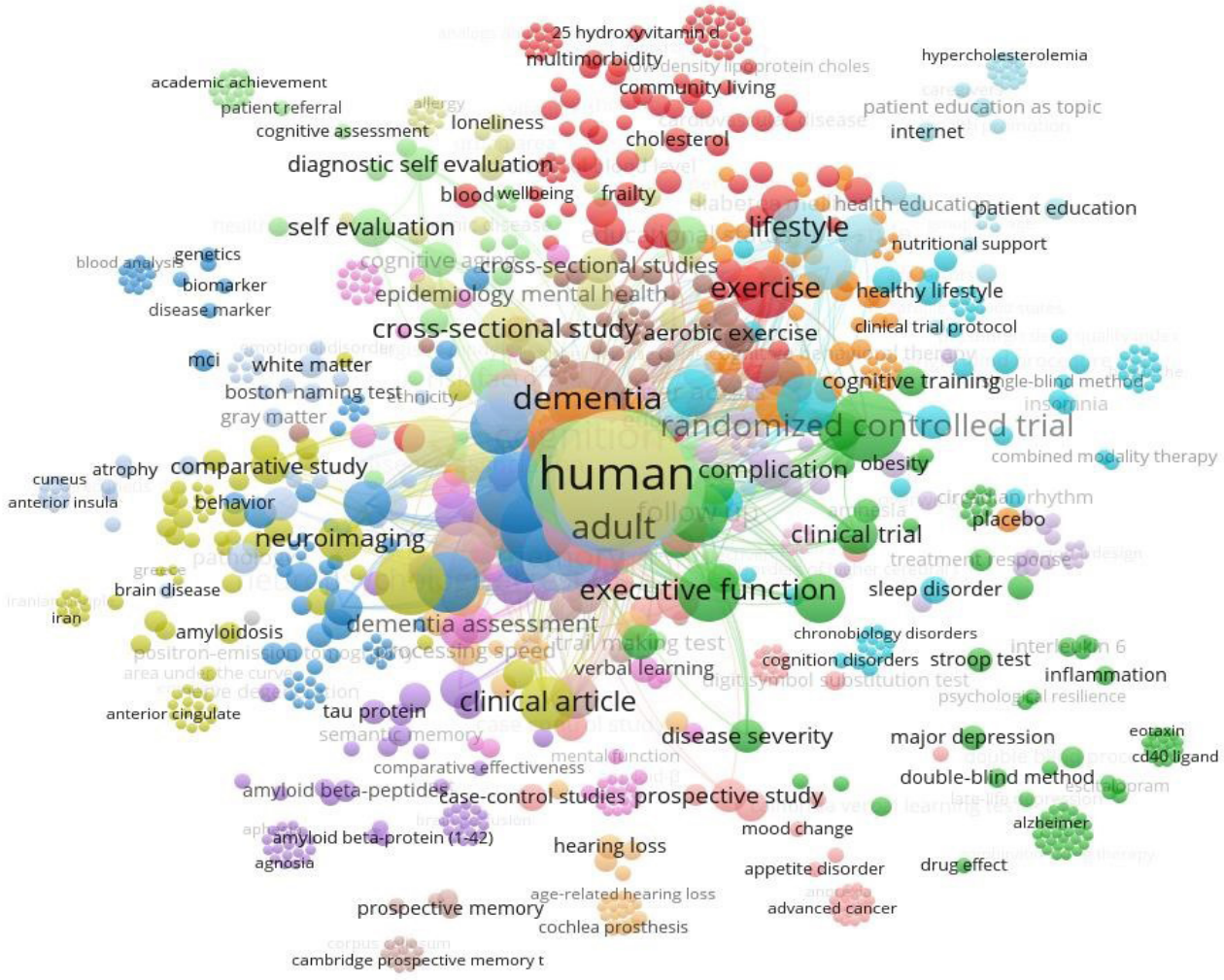

Figure 1. Bibliometric Density Map of Terms Related to Cognitive Interventions in Aging

The bibliometric maps highlight the interdisciplinarity in cognition, health, and technology studies, highlighting key areas and potential research gaps. These results validate our search methodology and underscore the importance of digital interventions to improve cognition in older adults, guiding future research toward developing technologies focused on this population.

Several recent studies provide a detailed analysis of various strategies and their effects within the research landscape on cognitive interventions in older adults. To illustrate advances in this field, table 1 compiles and compares crucial data from selected research. These studies range from assistive listening devices and their relationship to cognitive function to novel approaches to managing Alzheimer's disease. They highlight the complexity and interconnected nature of factors affecting cognition in older age.

This table synthesizes research that reflects the diversity of approaches taken to improve cognition and quality of life in the older adult population. The included studies reveal how interventions targeting one aspect of health, such as hearing or vision, can significantly impact cognitive function, as well as the potential synergy or lack thereof between combined interventions. Alzheimer's research highlights the importance of systems approaches to understanding and treating this complex disease. Together, these papers underscore the need to develop evidence-based interventions further and tailor existing strategies to the individual needs of older adults.

Integrating digital interventions in cognitive care for older adults has been highlighted as a promising approach to mitigate the effects of brain aging. This approach is illustrated in this paper, which corresponds to a resource designed to facilitate the use of technology and demonstrate how digital tools can be effectively employed to support cognitive health. Figure 3 introduces users to the application ecosystem, emphasizing an intuitive registration process essential to ensure accessibility and ease of use for the target audience.

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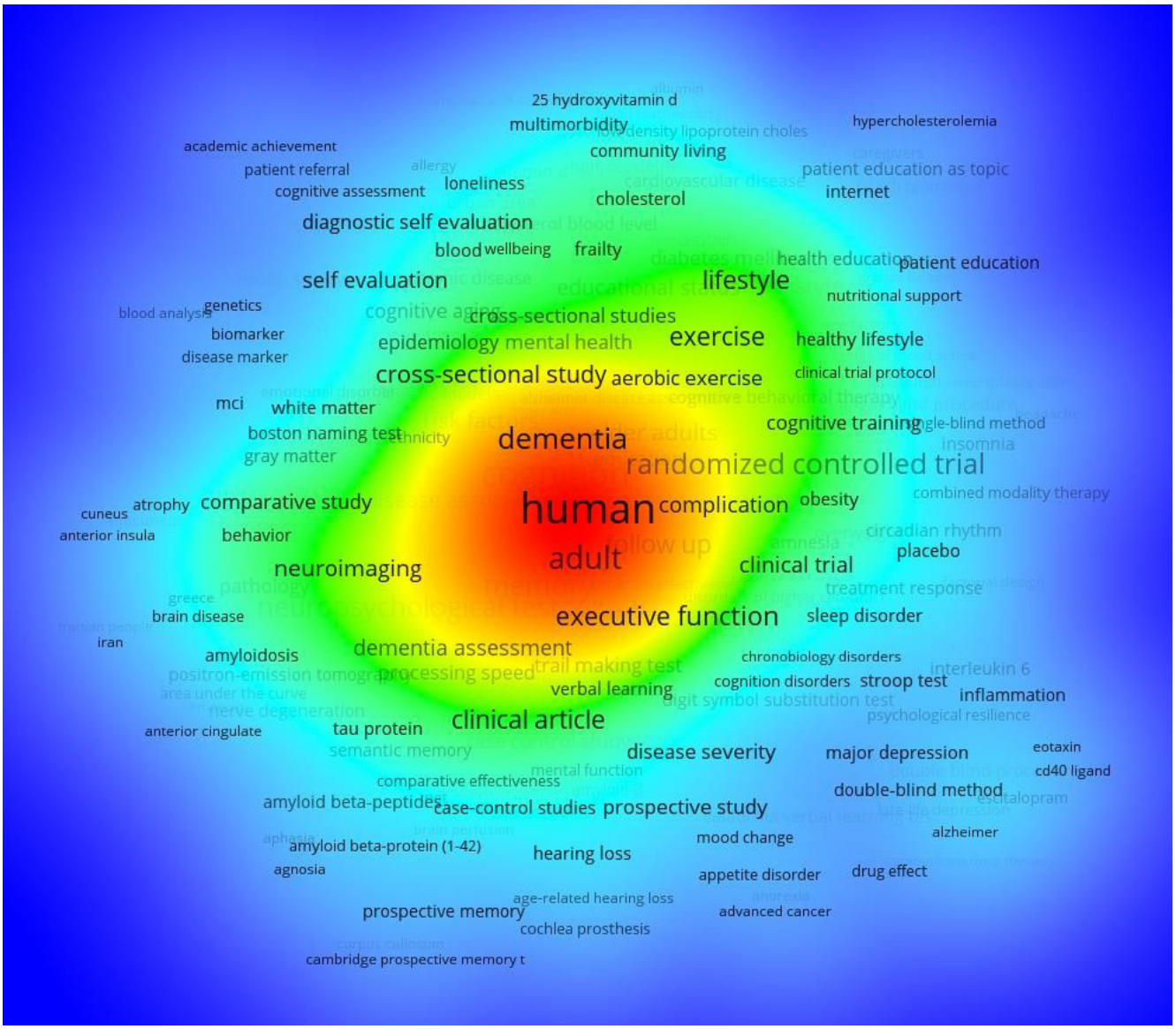

Figure 2. Bibliometric Density Map of Terms Related to Cognitive Interventions in Aging

Table 1. Comparative studies on cognitive interventions in older adults

Article title	Objective	Main findings	Contribution	Relevance	Future implications
"The Effect of Hearing Aid Use on Cognition in Older Adults: Can We Delay Decline or Even Improve Cognitive Function?" (Sarant et al.,2020)	Effect of hearing aid use on cognition in older adults	Improvement in executive function after 18 months of use	Highlights the relationship between hearing and cognition	Emphasizes the importance of treatment of hearing loss	Use of hearing aids
"Vision impairment and cognitive decline among older adults: a systematic review" (Nagarajan et al., 2022)	Relationship between visual impairment and cognitive impairment	Association between visual impairment and increased cognitive decline	Establishes a connection between vision and cognition	Emphasizes the need to address visual impairments	Research on interventions for visual impairment

"Brain Training and Sulforaphane Intake Interventions Separately Improve Cognitive Performance in Healthy Older Adults, Where as a Combination of These Interventions Does Not Have More Beneficial Effects: Evidence from a Randomized Controlled Trial" (Nouchi et al., 2021)	Effects of brain training and sulforaphane on cognitive function	Improved processing speed	Introduce una intervención combinada para la cognición	Resalta la importancia de intervenciones combinadas	Desarrollo de programas de entrenamiento cerebral
"Alzheimer's disease as a systems network disorder: chronic stress/dyshom eostasis, innate immunity, and genetics" (Kurakin & Bredesen, 2020)	Exploring Alzheimer's disease as a systems network disorder.	Alzheimer's as a chronic stress-driven network-of-systems disorder	Highlights the importance of combined interventions	Development of brain training programs	Investigación centrada en factores sistémicos y no solo cerebrales
"Alzheimer's disease (AD) Archimedes condition event simulator: Development and validation" (Kansal et al., 2018)	Development and validation of a simulator for Alzheimer's disease.	Proposal of a simulator to study treatments for AD	Introduces an innovative tool for AD research	Advances in AD research methodology	Use of the simulator in clinical trials and studies

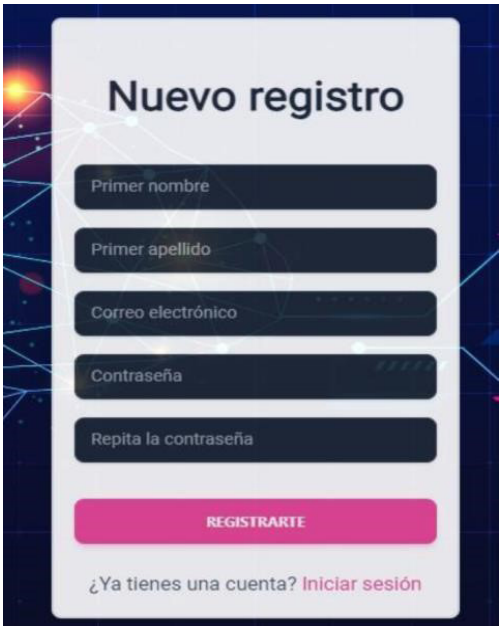

Figure 3. User Registration screen

Following registration, figure 4 provides a secure gateway to cognitive activities designed specifically for older adults.

This stage is crucial, ensuring users can access their personalized profiles and continue their cognitive exercise journey. Once inside, Figure 5 reveals the wealth of options available to users, highlighting a range of exercises aimed at improving different cognitive areas.

This diversity is critical to address users' varied needs and preferences, allowing for a truly personalized experience.

In addition, Figure 6 provides insight into tracking personal progress through the application, an aspect that reinforces motivation and adherence to the exercise program.

This tracking allows users to visualize their progress, a critical factor in maintaining a commitment to long-term cognitive improvement.

Taken together, these figures demonstrate the functionality and user-centered approach of the Memory Plugin App in this paper and underscore the potential of digital interventions to provide effective and accessible solutions in the field of cognitive support for older adults.

The app exemplifies how technology can be used innovatively to address cognitive challenges, providing a valuable resource for those seeking to maintain and improve their brain function in old age.

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Figure 4. Login Interface

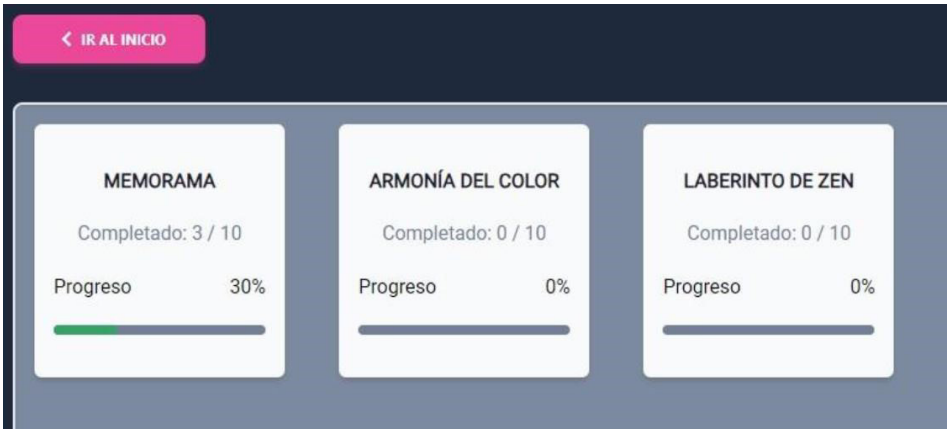

Figure 5. Exploration of Cognitive Activities

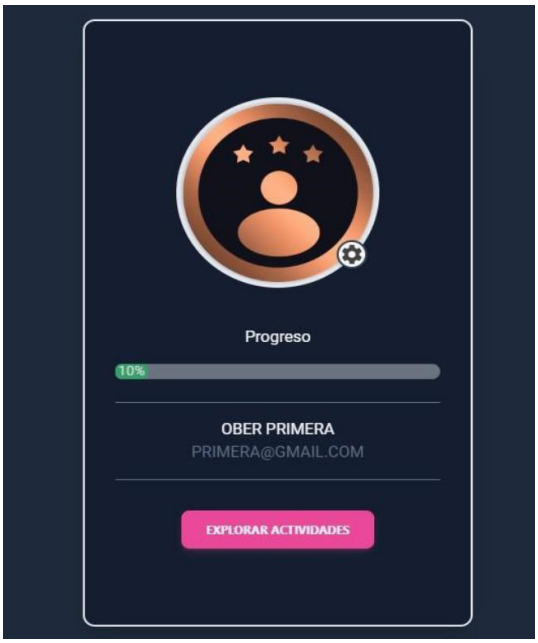

Figure 6. User Progress Monitoring

DISCUSSION

The findings of this study highlight the importance and potential of digital interventions to support memory and cognition in older adults. User-centered design and accessibility are crucial elements that effectively improve the developed application's usability and overall user experience. These results align with the work of Cheng (2016), who discusses cognitive reserve and dementia prevention through physical and cognitive activities, and Baharum et al. (2018), who emphasize the development of mobile apps focusing on the mental model of the elderly.

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The involvement of users in the design and implementation of the application has allowed the tool to be tailored to their specific needs, highlighting the importance of participatory design in developing technologies for the elderly (Zhunio et al., 2020). This direct inclusion methodology ensures that technological solutions are beneficial and accessible to their target audience.

Furthermore, the results suggest that digital interventions can significantly improve older adults' quality of life by providing a means to maintain and enhance their autonomy and mental well-being. This aligns with the recommendations of Infurna et al. (2020), who discuss the opportunities and challenges of aging in the 2020s and the need for effective intervention strategies.

The findings of this study open several avenues for future research, including the need to explore further the long-term impact of digital interventions on older adults' cognition. It is also essential to consider the adaptability of these tools to different cultural and socioeconomic contexts to maximize their accessibility and effectiveness. In practice, it is crucial to continue improving interfaces and user experiences for older adults, considering their specific capabilities and limitations. Continued collaboration between technology developers, aging researchers, and the older adult population will be essential to ensure that digital solutions meet the emerging needs of this demographic.

CONCLUSIONS

The initial development of our web application, aimed at improving memory in older adults, has highlighted the critical importance of an interdisciplinary, user-centered approach to the design of digital interventions for active aging. Up to the design phase, we have established a solid foundation that incorporates principles of accessibility, usability, and participatory design, reflecting a deep commitment to the needs and preferences of older adults. This approach seeks not only to improve cognition but also to foster social inclusion and improve this population group's overall quality of life.

Through a meticulous, systematic review, we have identified and analyzed current interventions and the cognitive needs of older adults, ensuring that our proposal is aligned with the most recent and relevant evidence in the field. The inclusion of participatory workshops in the design phase has been essential to gathering valuable insights from end users, caregivers, and healthcare professionals, guiding the development of interfaces and functionalities that effectively respond to everyday challenges related to memory and other cognitive functions.

We have successfully designed prototypes that balance best practices in interaction design and web accessibility, emphasizing meeting the unique needs of older adults. This underscores our commitment to creating a functional tool and providing an enriching and personalized user experience. Inclusive design and the active participation of end users are crucial to the success of these interventions. Future phases of the project should focus on the detailed evaluation of the usability and accessibility of the application, as well as on investigating its actual impact on improving cognition and quality of life of older adults.

Future Research

As we develop our web application designed to improve memory and quality of life in older adults, it is imperative to underscore the importance of continuing long-term research and development. Future studies should focus on evaluating the sustained impact of the app on users' cognition and quality of life, using methodologies that allow us to measure long-term effects and provide robust evidence on the efficacy and safety of digital interventions.

It is crucial to implement longitudinal studies that assess immediate efficacy and investigate the persistence of beneficial effects and users' continued acceptance of the technology. This approach is essential to ensure that digital interventions are effectively integrated into health systems and remain relevant and valuable to users over time. According to the World Health Organization and recent research, continuous evaluation and long-term monitoring are vital recommendations to maximize the impact of digital technologies on health (Hall et al., 2020; WHO, 2019).

Along these lines, it is essential to design future studies with a vision that allows the application to adapt and evolve based on the results obtained and the changing needs of users. This implies a commitment to continuous improvement and responsive innovation that can respond to emerging challenges and opportunities in the health care of older adults.

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