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Hypothesis

Serious Games for Cognitive Rehabilitation in Older Adults: A Conceptual Framework

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Abstract: This paper presents a conceptual framework for the development of serious games aimed at cognitive rehabilitation in older adults. Following Jabareen's methodology, a literature review was conducted to identify concepts and theories that are relevant in this field. The resulting framework comprises the use of virtual reality, integration of physical activity, incorporation of social interaction features, adaptability of difficulty levels, and customization of game content. The interconnections between these concepts and underlying cognitive theories, such as the cognitive reserve hypothesis and the scaffolding theory of aging and cognition, are highlighted. As we are in the early stages of our research, our goal is to introduce and test novel interpretations of current knowledge within this conceptual framework. Additionally, the practical implications of the conceptual framework are discussed, including its strengths and limitations, as well as its relevance for future research and clinical practice in the field of cognitive rehabilitation. It is hoped that this framework will provide a guide for the design and implementation of effective interventions to improve cognitive health and well-being in the older adult population.

Keywords: serious games; cognitive rehabilitation; older adults; conceptual framework

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1. Introduction

As the world's population ages, the importance of effective cognitive rehabilitation for older adults increases. This demographic shift, which is marked by an increase in the number of people over the age of 65, implies a higher prevalence of age-related cognitive disorders such as dementia and Alzheimer's disease [1,2]. These conditions not only affect the quality of life of millions of people worldwide, but also pose significant challenges to healthcare systems and caregivers [3]. Cognitive rehabilitation, which aims to improve or maintain cognitive functioning and mitigate the impact of cognitive decline [4], represents a key strategy for managing the increasing burden of cognitive decline in the elderly population, highlighting the need for innovative and effective interventions that can be tailored to the needs of older adults [5–7]. Cognitive impairments in older adults, ranging from mild to severe, significantly diminish the individual's ability to perform daily activities and maintain an independent lifestyle [8]. Traditional cognitive rehabilitation methods, such as memory training and problem-solving exercises, have shown some effectiveness but often face limitations in terms of engagement and long-term adherence [9,10]. Moreover, these methods may not fully address the diverse and evolving needs of this population, underscoring the necessity for more innovative and adaptable approaches. The emergence of technology-driven interventions, including serious games and virtual reality, presents an opportunity to revolutionize cognitive rehabilitation. These technologies promise more engaging, personalized, and potentially more effective therapeutic strategies, aligning with the diverse cognitive profiles and preferences of older adults [11,12].

Although there is no universal definition of serious games, it is widely recognized that they serve a purpose beyond mere entertainment [13]. According to McCallum et al. [14], serious games are games designed to bring about a change in the player's knowledge, attitude, physical or cognitive abilities, or health. Susi et al. [15] define serious games as computer-based mental and physical contests that utilize rules to promote entertainment while engaging players for a specific purpose, such as training, education, or health. Wattanasoontorn et al. [13] describe serious games as a combination of rules or gameplay, challenges, interaction, an explicit objective (fun), and an implicit objective (serious goal). These games provide a safe and immersive way to experience situations that may be unsafe, costly, or time-consuming in real life. This aspect is particularly valuable for older adults who are seeking more engaging and diverse leisure activities [16], especially when they may have limited access to outdoor experiences [17]. In fact, Eichhorn et al. [17] argue that serious games, particularly those utilizing modern technologies such as Virtual Reality (VR), can offer older adults a means to explore and interact with the world beyond their physical limitations. Furthermore, Rodriguez et al. [18] found that older adults exhibited enthusiasm in testing serious games and embracing new technologies.

In recent years, serious games have emerged as a promising solution for cognitive rehabilitation in older adults, leveraging the power of interactive and immersive gaming technologies to enhance cognitive function [6,12]. Serious games have surpassed their initial scope to serve educational, therapeutic, and rehabilitative purposes in various healthcare domains [13,19]. In contexts ranging from physical rehabilitation to mental health, these games have demonstrated their efficacy in improving patient outcomes through increased engagement and adherence to therapeutic schedules [20]. The interactive nature of serious games facilitates sustained engagement, an important factor in cognitive rehabilitation, where ongoing participation is essential for effectiveness [21]. Moreover, the inherent flexibility of serious game design allows for personalization of cognitive challenges, making them adaptable to the cognitive profiles and rehabilitation needs of each individual [22]. This personalization not only enhances the effectiveness of the intervention but also contributes to maintain motivation and interest among older adults, which is required for long-term adherence to cognitive rehabilitation programs [23].

While serious games have shown potential in various rehabilitation contexts, there exists a notable gap concerning their application to cognitive rehabilitation in older adults [24–27]. Current serious games for cognitive rehabilitation often fall short in addressing the physiological and psychological needs of older people [28]. Many existing games are not specifically designed for this population, lacking consideration for age-related changes in cognitive abilities, physical dexterity, and sensory perception [29], which ensures both the safety and efficacy of the interventions [21]. This gap underlines the need for a more focused approach in the design and development of serious games, one that not only considers the general principles of game design but also integrates concepts from cognitive rehabilitation to create experiences beneficial for this specific user group [30].

The purpose of this paper is to propose a conceptual framework [31] as a sketch that interconnects concepts grounded in theories to provide comprehension and understanding of a phenomenon for the development of serious games specifically designed for cognitive rehabilitation in older adults. By synthesizing theories and insights from cognitive rehabilitation and game design, this framework aims to provide a structured approach to designing and evaluating serious games tailored to the needs of older adults.

The proposed framework integrates interdisciplinary insights and focuses on user-centered design to enhance the effectiveness and usability of serious games for older adults. Key components of the framework include considerations for age-related cognitive changes, physical abilities, sensory perception, and adherence to established principles of cognitive rehabilitation.

The paper is organized as follows: Section 2 provides a comprehensive review of existing literature on cognitive rehabilitation and serious games. Section 3 outlines the methodology used to develop the conceptual framework. In Section 4, the proposed framework is presented and discussed in detail. Section 5 examines the implications of the framework for research and practice. Finally, Section 6 concludes the paper by summarizing key findings and suggesting avenues for future research.

2. Literature Review

To propose a conceptual framework for serious games used for cognitive rehabilitation in older adults, it is necessary to find the recurring aspects mentioned in the literature on serious game development. This involves identifying common patterns, key concepts, and methodological approaches. Additionally, it is essential to examine works proposing similar conceptual frameworks in related areas, such as educational technology, cognitive psychology, or digital therapy.

2.1. Serious Games for Cognitive Rehabilitation

In [32], the authors conducted an extensive literature review, examining a total of 317 articles. After applying predefined selection criteria, the articles were narrowed down to twenty-five that met the inclusion criteria, forming the basis for our review. The analysis revealed that virtual reality (VR) games are primarily used for cognitive training, with less emphasis on assessing cognitive strengths and weaknesses. This trend may stem from clinicians' reliance on established assessment tools such as MoCA and MMSE, which provide standardized approaches to cognitive evaluation. For instance, VR applications reviewed for assessment included activities such as exploring virtual museums, engaging in virtual sports, and performing daily tasks in virtual environments [33–36].

Our examination of VR serious games highlighted a predominant focus on addressing individual cognitive domains such as attention or memory, facilitating targeted and intensive training within specific areas. However, concerns have been raised about the ecological validity of this approach, questioning its translation into improvements in real-life performance. Consequently, there is a growing interest in approaches that simultaneously stimulate multiple cognitive domains, recognizing the interconnected nature of cognitive functions and the potential for broader improvements in overall cognitive functioning [35,36].

Despite the recognized importance of adapting the difficulty in a serious games, particularly in fostering user engagement and effective learning outcomes, its specific impact on therapy outcomes remains largely unexplored. Several authors have acknowledged its significance, emphasizing adaptability as an important ergonomic criterion for serious game design. The incorporation of Dynamical Difficulty Adjustment (DDA) has been shown to enhance fun and engagement among users, essential components for effective learning outcomes in cognitive rehabilitation [37,38]. Additionally, future research could explore the relative effectiveness of different cognitive training approaches, user acceptance, and retention of long-term benefits. Establishing clear guidelines for selecting between single-domain and multiple-domain approaches is necessary for optimizing the effectiveness of interventions and tailoring them to the individual needs of older adults.

2.2. Clinical Trials

Conventional therapy focuses on practicing activities of daily living (ADLs). These tasks are designed to help patients regain physical and cognitive skills through repetitive actions. Specialized personnel, including occupational therapists, physical therapists, and other experts, are required to administer these therapies. Patients typically receive at least 45 min of therapy per day, five days a week, with the amount of therapy adjusted according to their individual needs.

The two clinical trials mentioned, conducted by Chatterjee et al. [39] and Gamito et al. [40], were selected based on their relevance to our specific focus areas: the integration of virtual reality (VR) technology, the emphasis on activities of daily living (ADLs), and the inclusion of cognitive rehabilitation tasks within an immersive environment. These studies were chosen because they provide detailed insights into the development and application of VR-based interventions for cognitive rehabilitation. They highlight key considerations such as the design of multidomain cognitive exercises, the adaptation of tasks to individual patient needs, and the integration of physical and cognitive training elements. These aspects are directly aligned with the principles outlined in our conceptual framework, which emphasizes physical activity, multiple cognitive domains, and real-world scenarios.

Regarding virtual reality (VR), although there are numerous systems available, most are primarily designed for physical rehabilitation, with very few addressing cognitive rehabilitation [39].

In the study by Chatterjee et al. [39], stroke survivors who had issues with problem-solving, memory, and performing sequences of tasks were studied. All tasks were designed to be completed from a sitting position using a single hand-held controller so that patients could use their strongest arm. The tasks consisted of activities of daily living, such as making the bed, selecting clothes, brushing teeth, preparing breakfast, ordering a meal, or watering plants.

The study lasted 3 months and concluded that VR can be beneficial for improving activities of daily living. The authors posited that immersive VR enhances attention and reduces distraction, making it suitable for cognitive therapy. Additionally, studies like that of Huygelier et al. [41] report that the health benefits of VR applications are not affected by negative attitudes or cybersickness. In a study involving 40 participants, they conducted a safety and acceptability analysis. The participants were divided into two groups: one received VR treatment along with conventional therapy and the other group received VR treatment without gamification components, along with conventional therapy. This approach was possibly taken to ensure that the results were not merely due to the participants completing additional exercises compared to the control group.

Training was conducted 5 days a week for 2 weeks before the participants were discharged from the hospital. VR training was adjusted based on the observed benefit and tolerability, as determined by specialists. The tasks were performed while seated.

A second study conducted by Gamito et al. [40] was identified, in which traditional neurophysiological rehabilitation methods were applied to address cognitive functions affected by stroke. These activities typically involve exercises and tests performed with pencil and paper. The study included 29 stroke patients without prior neurological or psychiatric disorders, substance or alcohol abuse, visual impairments, or low scores on the MMSE. Consequently, nine patients were excluded from the study. The training sessions lasted 1 h each, and were conducted two to three times per week over a period of 4 to 6 weeks.

The game presented by Gamito et al. featured various scenarios, including activities of daily living, working memory tasks, visuospatial orientation, selective attention, memory, and calculation exercises.

From these two studies, several useful concepts for the development of our framework can be identified. Firstly, conventional rehabilitation involves training daily living skills. Additionally, it is evident that most reported rehabilitation systems primarily focus on physical treatment. Furthermore, there is a need to involve various specialties in the rehabilitation process is highlighted.

Moreover, in both studies, even though users are in an immersive system, the exercises are performed while seated. We consider that this seated position reduces the benefits of physical movement.

Other clinical studies were not considered, as the majority, to our knowledge, do not present or specify the aspects considered in the development of the serious game. While there are clinical studies available, they generally do not discuss the development aspects in detail. Our objective was to understand the considerations taken during the development phase. However, clinical studies typically focus more on the experimental evaluation of the proposed software rather than on the development processes and the underlying design considerations.

2.3. Previous Conceptual Frameworks

In conducting our research within academic databases, we aimed to uncover conceptual frameworks for the design of serious games for the cognitive rehabilitation of older adults. Our search yielded two pertinent works [38,42].

Elaklouk et al. [42] proposed a conceptual framework aimed at designing efficient and effective games to motivate cognitive rehabilitation in acquired brain injury (ABI). The authors delineated four main concepts: condition, process, activity, and output.

- *Condition:* Elaklouk et al. argued that prescribing an isolated intervention solely based on the clinical particularities of each patient might be less effective than understanding the patient's individual needs and preferences to establish therapy objectives. While clinical particularities refer to the characteristics of the medical condition or symptoms presented by the patient, individual needs encompass a broader spectrum, including psychosocial, emotional, and contextual factors that influence cognitive rehabilitation.
- *Process:* the authors elucidated that motivation could enhance patient engagement with the treatment, consequently leading to improved functional outcomes. They advocated for utilizing challenge as a tool to incrementally enhance patients' skills and familiarity with the therapy. Additionally, they underscored the utility of informatics frameworks in personalizing serious games.
- *Activity:* Here, the emphasis was on ensuring that the patient felt engaged, enjoyed the game, and had confidence in their ability to play.
- *Output:* Tracking and presenting the patient's performance were identified as pivotal factors in motivating continued use of the game.

The conceptual framework presented in [42] incorporated two feedback loops, allowing both the therapist and the patient to utilize the outcomes to adjust and personalize the serious game accordingly.

This work does not specify that the framework is designed to address specific cognitive domains. In fact, the framework by Elaklouk et al. [42] provides a guide for designing serious games to meet the needs of ABI patients, emphasizing motivation, engagement, and personalization.

The second conceptual framework, introduced by Seyderhelm et al. [38], merges Cognitive Load Theory (CLT) [43] with serious games. The authors delineate several key concepts, including the integration of suitable challenge and its adaptation, measurement of cognitive load, and the application of adaptation rules based on CLT principles. This framework incorporates the concept of flow. The flow theory refers to an optimal mental state of complete absorption in an activity, characterized by total immersion and concentration in the task, leading to a sense of enjoyment and fulfillment [44], suggesting that individuals are more engaged in a cognitive task when it continuously adapts to their performance, which is also known as Dynamical Difficulty Adjustment (DDA). However, this theory also accounts for cognitive load, which can be subjectively or objectively measured.

Seyderhelm et al. [38] also propose a template for DDA, which correlates performance with cognitive load. For instance, if the user exhibits a poor performance and high cognitive load, the difficulty should decrease accordingly.

Even though Seyderhelm's work is an extension of the framework proposed by Yusoff [45], Seyderhelm's work completes it by incorporating aspects such as motivation, affection, and previous knowledge, thereby providing a more comprehensive understanding of serious game design for cognitive rehabilitation. However, this framework is not specifically intended for cognitive rehabilitation but rather focuses on the design of cognitive learning. Nevertheless, we consider these principles to be extrapolated to cognitive rehabilitation.

The two previously analyzed frameworks provided important concepts for the development of the present work.

3. Methodology

To build a conceptual framework, Jabareen's methodology [31] presents a systematic approach with eight phases: (1) Mapping and selecting sources of information; (2) extensive reading and categorizing of the selected data; (3) identifying and naming key concepts; (4) deconstructing and categorizing the concepts; (5) integrating concepts; (6) synthesizing, resynthesizing, and making it all make sense; (7) validating the conceptual framework; (8) rethinking the conceptual framework. Given that this is our initial approach, and considering that phases 1 and 2 were already completed in our previous work [32], we have decided to focus on phases 3 to 7. Figure 1 provides an overview of the steps to be followed in this study.

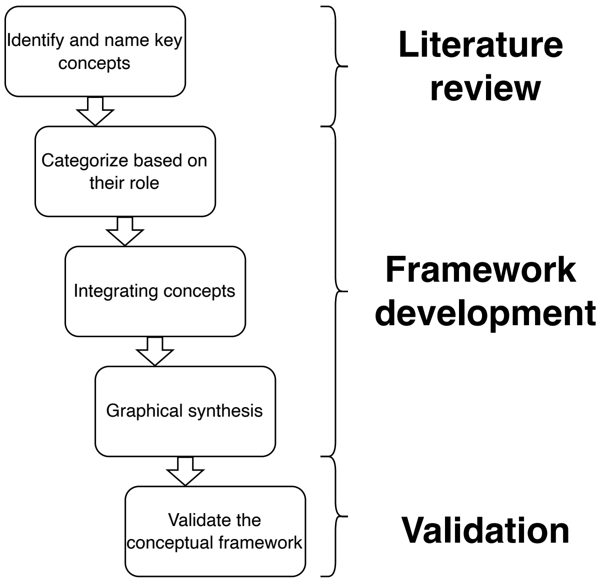

Figure 1. Steps followed in this work.

Following the completion of phases 1 and 2 in our previous work, we began phase 3 by identifying and naming key concepts. This process involved a detailed review of the selected literature to extract fundamental ideas and recurring themes relevant to serious game development for cognitive rehabilitation in older adults. We systematically reviewed peer-reviewed journal articles [32] and clinical studies [39,40], focusing on key terms such as "cognitive rehabilitation", "serious games", "older adults", "virtual reality", "physical activity", "difficulty adjustment", and "social interaction".

Once key concepts were identified, we deconstructed them into manageable categories. This step involved analyzing the ontological, epistemological, and methodological assumptions underlying each concept. We categorized the concepts based on their nature and role in the framework, such as technological components (e.g., virtual reality), cognitive aspects (e.g., memory enhancement), and physical activities (e.g., exercise integration). This categorization facilitated a structured approach to understanding and organizing the concepts.

The integration phase involved synthesizing the categorized concepts into a cohesive framework. We examined the interrelationships between the concepts to understand how they interact and support one another. For example, we explored how virtual reality can be used to enhance cognitive functions like memory and attention, and how physical activity can be integrated into game design to promote cognitive and physical health simultaneously. This synthesis process was guided by theoretical foundations, such as the cognitive reserve hypothesis and the scaffolding theory of aging and cognition.

In next phase, we iteratively synthesized and resynthesized the framework to ensure coherence and comprehensiveness. This involved multiple rounds of review and refinement. We represented the framework graphically to visualize the interplay between different concepts and to facilitate the understanding of the framework's structure and components.

To ensure the robustness of the framework, we sought feedback from experts in cognitive rehabilitation, game design, and gerontology. We conducted several rounds of revisions based on their input, refining the framework to enhance its practical applicability and theoretical grounding. This iterative process of validation and refinement ensured that the framework is both comprehensive and adaptable to new insights and developments in the field.

The expert review aimed to gather insights on the following aspects: (1) whether the expert has profession experience using technological tools; (2) the expert's specialty, including fields such as neuropsychology, occupational therapy, physical therapy, and geriatrics, among others; (3) the number of years of experience they have in their profession; (4) on a scale from 1 to 5, how relevant and effective they consider the proposed framework; (5) a selection of components that we believe could be added to the framework, rated on a scale from 1 to 5 for their perceived relevance or applicability; (6) an open-ended question requesting additional aspects or modifications to improve the applicability and effectiveness of the framework in clinical and real-world settings.

Considering that this is a preliminary stage of the proposed research, Baker et al. [46] explain that the number of expert interviews depends on various factors. However, they affirm that there is no one-size-fits-all answer, and a sample of 5 to 10 experts is often adequate to gather diverse perspectives.

4. Conceptual Framework Development

4.1. Identify and Name Key Concepts

In this section, we categorize and synthesize the information gathered from our review of literature, with the aim of identifying the key concepts presented in the literature. A concept is an idea that represents a part of knowledge. These are basic elements that can be part of broader theories [47].

Overall, the literature review uncovers several recurring themes across the analyzed works. Notably, studies such as those by Jha et al. [48] and Knobel et al. [49] emphasize the significance of virtual reality (VR) with head-mounted displays, providing an immersive experience that captures user's attention.

Ben et al. [50], Pedraza et al. [51], and Liu et al. [52] advocate for integrating physical activity into cognitive rehabilitation, highlighting its role in enhancing physical health and cognitive function. Hillman et al. [53] and Kramer et al. [54] further underscore the cognitive benefits of physical activity, which can improve the quality of life for individuals undergoing cognitive rehabilitation. Upon reviewing various immersive applications, it is evident that there are few that fully harness the body tracking capabilities offered by virtual reality (VR) devices such as head-mounted displays (HMDs). While physical activity necessitates monitoring body movements, we found that many of these applications underutilize these capabilities, indicating an opportunity for the development of more effective and immersive experiences in the realm of serious games and cognitive rehabilitation.

The integration of multiplayer features, as highlighted by Ballesteros et al. [55] and Borrego et al. [56], promotes social engagement among older adults, which is an important component for healthy aging.

Works by Goumopoulos et al. [57], Alloni et al. [58], and Caixinha et al. [59] advocate for customizable game content tailored to individual needs. This approach ensures that serious games can be adapted to accommodate diverse cognitive abilities and preferences, providing a personalized experience for each user. Furthermore, the effectiveness of cognitive rehabilitation is enhanced by the incorporation of finely graded difficulty levels [60]. By adjusting the challenge level to match the user's abilities, serious games can provide an optimal level of cognitive stimulation, promoting engagement and skill development.

Tasks engaging multiple cognitive abilities simultaneously [35,36] play a crucial role in cognitive rehabilitation. These tasks not only challenge various cognitive skills but also promote their coordinated utilization, ultimately leading to improved outcomes in cognitive function [61].

Our current objective is to identify relevant words within the context of each work. Through analyzing the frequency and importance of these words, we can gain understanding into the key concepts and themes explored in each study. Additionally, we have considered whether these concepts were thoroughly explained by the original authors or extensively employed throughout the text (Table 1).

Table 1. Key concetps.

Category	Study	Key Concepts
Virtual Reality	[48,49]	Serious games, input system, virtual reality, head-mounted display, spatial orientation abilities, real-time guidance system, visual exploration task, difficulty levels, and stroke patients
Physical activity	[50–52]	Physical activity, cognitive rehabilitation, virtual reality, body movement, computer vision systems, combining physical and cognitive exercise, a Kinect, and difficulty level
Multiplayer	[55,56]	Serious games, cognitive rehabilitation, multiplayer features, social engagement, older adults, cognitive stimulation, rehabilitation activities, social isolation, and demotivation
Customization	[57–59]	Customization, serious games, older adults, cognitive rehabilitation, customizing settings, physical limitations, generate new exercises, executive functions, and participatory methodology
Grades of difficulty	[30,60]	Levels of difficulty, cognitive abilities, engagement, motivation, progression and achievement, cognitive rehabilitation, graded levels of difficulty and player's ability
Multitasking	[35,36,61]	Serious games for cognitive rehabilitation, multiple cognitive skills, interdependent cognitive skills, multitasking, cognitive outcomes, assessment of cognitive function, simulation environments, executive functions, enjoyable and motivating

Beginning with our first category, we explore common concepts related to VR interaction. The input system, encompassing hardware components such as the head-mounted display, serves as the foundation for immersive experiences that foster cognitive skills like spatial orientation and visual exploration. These concepts are important for enhancing user engagement and facilitating cognitive development, as indicated by the literature review.

The second category focuses on concepts related to physical activity and user interaction. Technologies like computer vision systems, such as Kinect, enable users to engage in physical movement within virtual environments, promoting overall well-being and cognitive function. By integrating these technologies into serious games, developers can provide users with interactive experiences that combine physical and cognitive exercise, further enhancing the effectiveness of cognitive rehabilitation interventions.

In modern gaming, multiplayer features enable multiple players to socialize through the game, fostering social engagement and interaction. In the context of cognitive rehabilitation, concepts such as social isolation and social engagement are recurrently mentioned as part of a successful rehabilitation process. By integrating multiplayer features into serious games, developers can create opportunities for older adults to connect with peers, participate in collaborative activities, and maintain social connections, thereby enhancing the overall effectiveness and enjoyment of cognitive rehabilitation interventions.

In the subsequent category, we delve into the customization process, which plays a role in tailoring game experiences to individual needs. Elements such as physical limitations, exercise generation, and participatory development allow developers to adapt game content and mechanics to diverse cognitive abilities and preferences.

Moving to our fifth category, we establish connections centered around the grades of difficulty in a serious game. Factors such as real-time guidance, user skill considerations, engagement strategies, and progress tracking directly influence the game's difficulty level.

By dynamically adjusting these elements, developers can create experiences that challenge and motivate users while ensuring an optimal level of cognitive stimulation.

Other concepts, such as simulated environments, executive functions, and multiple cognitive skills, converge under the umbrella term of multitasking, reflecting the multifaceted nature of cognitive rehabilitation through serious games. Through designing tasks that require users to simultaneously engage multiple cognitive abilities, developers can promote cognitive flexibility, problem-solving skills, and overall cognitive function. Additionally, there are recurring and common concepts in the literature regarding how motivation serves as a key tool for engaging users. By considering these factors in the design and development of serious games, developers can craft effective experiences to promote health that are both enjoyable and fun for users.

4.2. Categorize Based on Their Role

Building upon Jabareen's framework [31], which delineates the roles played by various concepts within specific contexts, our research framework establishes a foundation for understanding the utilization of serious games for cognitive rehabilitation. We align ontological roles with foundational concepts that establish assumptions about the nature of reality underlying the design of these games. Additionally, epistemological roles are attributed to concepts facilitating the understanding of how these games operate in practice and how their effectiveness in cognitive stimulation is evaluated. Methodological roles, on the other hand, pertain to concepts guiding the practical application of these games, delineating methods and approaches to be employed in their design and assessment.

Expanding upon the insights provided by Ballesteros et al. [55] regarding brain plasticity and its role in mitigating cognitive decline in older adults, it is crucial to consider the broader implications of health conditions associated with chronic diseases. These conditions can be significantly influenced by changes in physical activity, stress management, and meaningful social interactions, ultimately reducing comorbidity and fostering a healthier aging brain.

The previous assertions find support in several theories, including the hypothesis of cognitive reserve [62], the scaffolding theory of aging and cognition (STAC) [63], and theories highlighting the impact of social engagement on healthy aging [64]. The hypothesis of cognitive reserve posits that individuals engaged in regular physical and mental activities are less likely to develop dementia, suggesting that cognitive reserve can be bolstered by various interventions, such as physical exercise and cognitive stimulation. This theory not only underscores the importance of maintaining an active lifestyle but also provides insight into the measurement and assessment of interventions like serious games, particularly in terms of optimizing user experience through mechanisms like dynamic difficulty adjustment (DDA).

Similarly, the scaffolding theory of aging and cognition emphasizes the development of alternative neural circuits as essential for maintaining cognitive function in older adults. Mental training and exercise are proposed as means to enhance cognitive scaffolding, potentially mitigating age-related cognitive decline. The incorporation of physical activity into serious games not only enhances immersion but also affects cognitive load, thus facilitating DDA and aligning with the principles of both cognitive reserve and the scaffolding theory. Moreover, these theories inform the implementation of multiplayer features in serious games, recognizing the role of social engagement in maintaining cognitive health and well-being.

After establishing the relationship between certain concepts and their corresponding theories, our next step is to summarize these connections in a table. In this table, we will highlight how each concept relates to a certain theory and what role it plays within that theory. This will allow us to clearly and concisely visualize how the concepts intertwine with the underlying cognitive theories, thereby providing a comprehensive understanding of how these elements complement each other in the context of cognitive rehabilitation (Table 2).

Table 2. Theories and associated concepts with multiple roles.

Theory	Associated Concepts	Role(s)
Hypothesis of Cognitive Reserve	Spatial orientation abilities, difficulty levels, cognitive abilities, executive functions	*Epistemological*: They define the user's condition, serving as their tool for navigating daily life. *Methodological*: Provides guidelines on how to measure and assess cognitive reserve in individuals.
Scaffolding Theory of Aging and Cognition	Cognitive abilities, interdependent cognitive skills, multitasking, executive functions	*Ontological*: Describes the structure and interdependence of cognitive processes in aging individuals. *Epistemological*: Helps in understanding how cognitive abilities evolve with age and experience.
Impact of Social Engagement on Healthy Aging	Social engagement, older adults, multiplayer features, cognitive stimulation, rehabilitation activities	*Epistemological*: Explores the effects of social interaction on cognitive health in older adults. *Methodological*: Offers insights into designing interventions that promote social engagement to enhance cognitive well-being.
Motivation	Engagement, motivation, progression and achievement	*Methodological*: Guides the design and implementation of strategies to maintain user interest and commitment in cognitive rehabilitation programs.
Flow	Engagement, enjoyment, graded levels of difficulty, immersive experiences	*Epistemological*: Examines the psychological state of flow and its impact on user engagement and satisfaction. *Methodological*: Suggests techniques to create optimal challenges and immersive experiences in serious games.
Feedback Loop	Real-time guidance system, assessment of cognitive function	*Methodological*: Provides mechanisms for providing feedback to users during gameplay and evaluating cognitive outcomes.
Cognitive Load	Cognitive abilities, visual exploration task, multitasking	*Ontological*: Defines the cognitive resources required for different tasks and activities. *Methodological*: Offers strategies for managing cognitive load to optimize learning and performance.

4.3. Integrating Concepts

Our research led us to establish relevant concepts and theories. In this phase of creating the conceptual framework, we aim to reduce the number of concepts by grouping them based on their contribution to the development of serious games for cognitive rehabilitation of older adults.

1. User interaction: Concepts associated with virtual reality (VR) now form part of considerations for user interaction.
2. Game settings: Regarding game parameters, help systems, and progress tracking as a method to recommend difficulty levels, collectively, these concepts constitute the game settings, understood as configurable task parameters.
3. Exergame: We also understand, thanks to theories like scaffolding, that users need to exercise both their minds and bodies to maintain proper mental and physical health. Therefore, everything related to body movement and systems that monitor this movement will be integrated into the broader concept of Exergame.
4. Development: The development process of serious games differs from that of games created for commercial purposes, as a high degree of customization is required to meet users' needs. Therefore, methodologies involving extensive inclusion of interested populations in the final product are necessary.
5. Game features: Identified concepts such as the development of multiple cognitive skills, multiplayer gaming, and simulated environments suggest that these are fundamental features of games.
6. Patient condition: While the development process considers patient needs, there are more abstract concepts that the end-user may not be aware of but which the developer

must consider, such as maintaining motivation, commitment, social improvement, and aspects related to cognitive rehabilitation itself. These concepts are part of the patient's condition.

The resulting diagram, depicted in Figure 2, visually encapsulates these interrelated concepts.

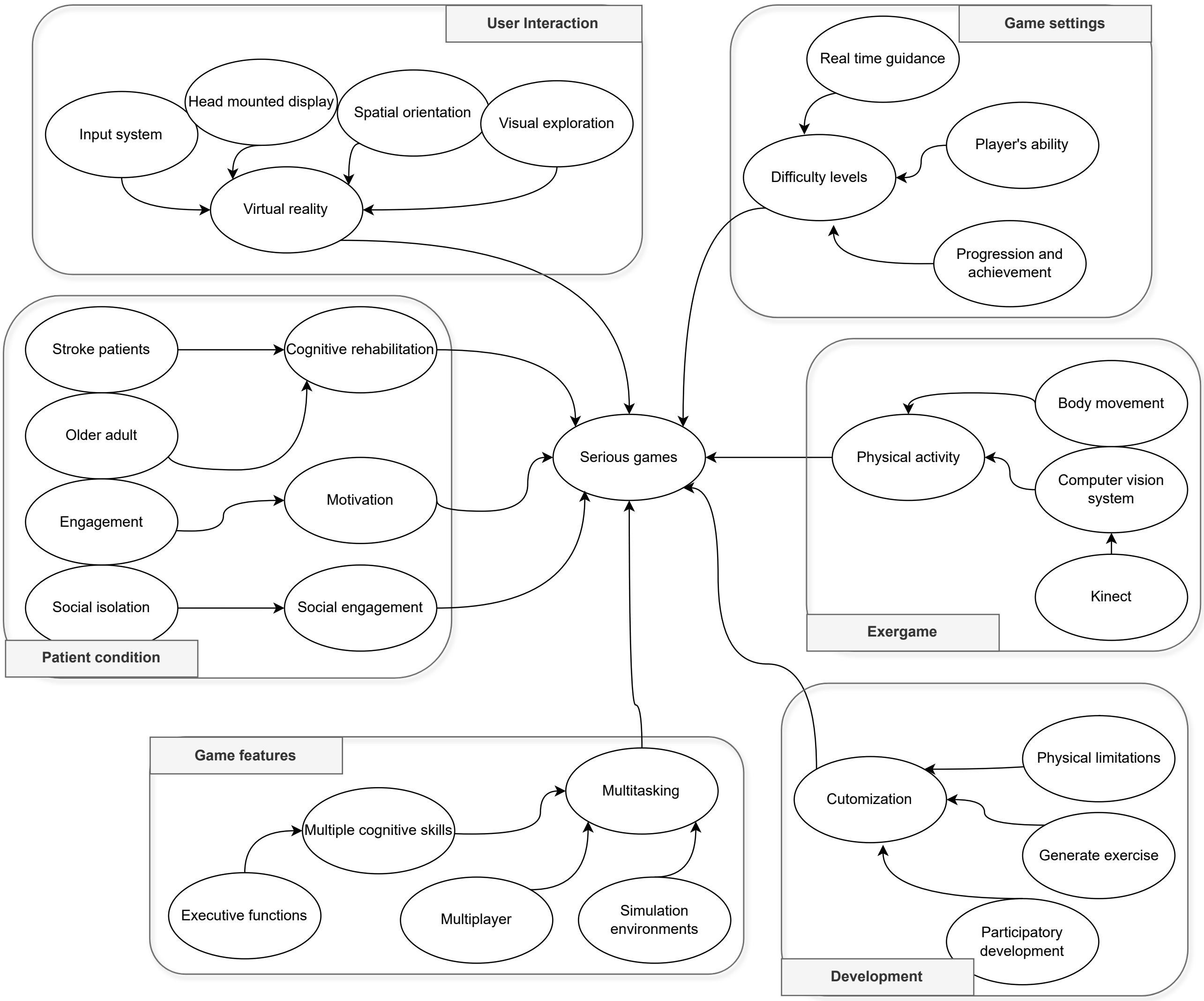

Figure 2. Relation diagram between key concepts found.

4.4. Graphical Synthesis

The synthesis of our progress thus far is presented in Figure 3, where our aim is to illustrate that the development process of a serious game for cognitive stimulation in older adults is not a linear process, starting with goals and delivering a generic product, but rather an iterative and incremental exercise that requires continuous understanding of user progress and limitations.

Figure 3 illustrates the organization of integrated concepts identified in the previous section into three distinct development phases. These phases serve as guiding principles throughout the development process, with user interaction being shaped by both software and hardware components. These components offer insights into the level of physical activity that can be incorporated.

Subsequently, factors such as physical exercise, multiplayer functionality, multidomain scenarios, and simulated environments contribute to the determination of adjustable game mechanics or parameters.

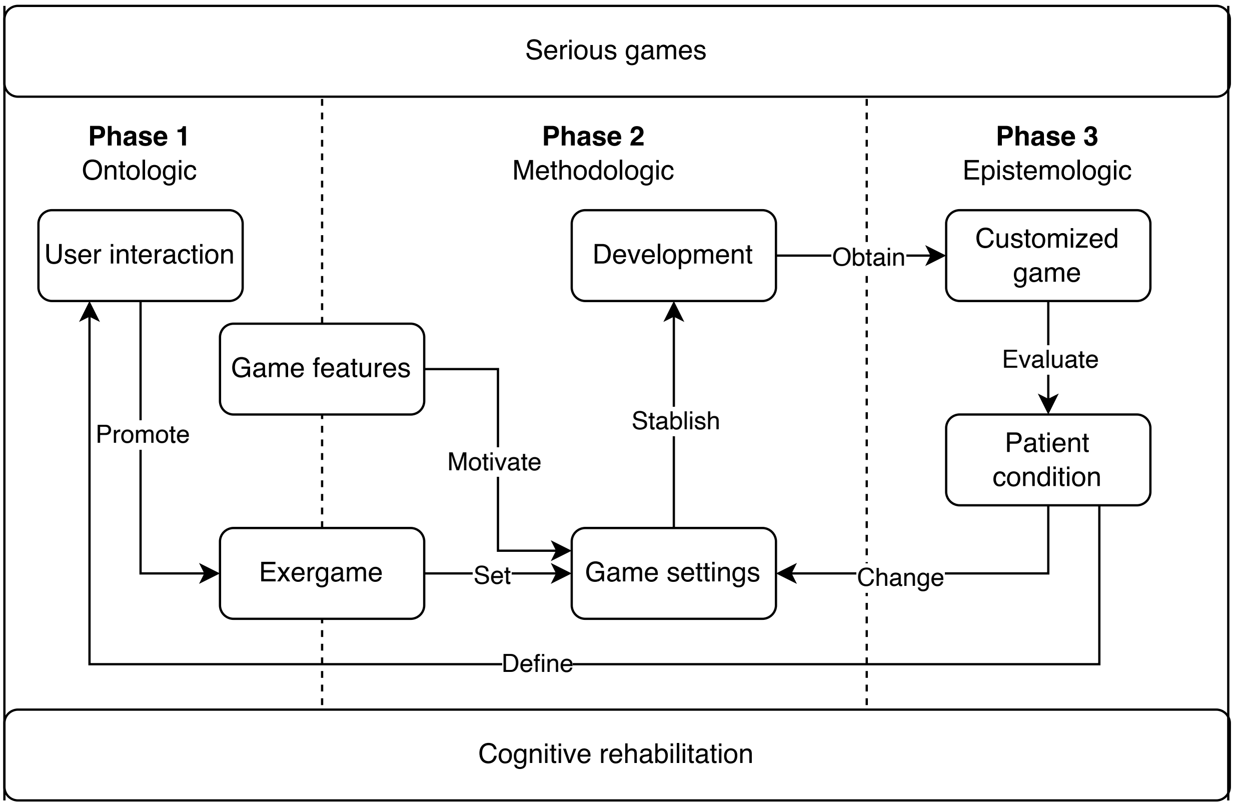

Figure 3. Conceptual framework for developing serious games for cognitive rehabilitation of older adults.

The development process adheres to agile and participatory methodologies, involving input from both experts and end-users. This collaborative approach ensures that user perspectives are consistently integrated into the development cycle.

Although it may appear that the serious game is finalized at this stage, the individualized needs of users necessitate tailored adjustments. These adjustments are informed by user feedback, including preferences for interaction with the system and specific exercise configurations tailored to their requirements. Consequently, we perceive development as an iterative and incremental process.

4.5. Expert Review

Results were obtained from one clinical psychologist, two occupational therapists, and two physical therapists. According to the surveys, three of the five have used technological tools in their professional practice, while the remaining two have not. The years of professional experience among the respondents range from 2 to 30 years. Regarding the conceptual framework, on a scale of 1 to 5, three experts consider the framework to be relevant and effective, while two experts find it highly relevant and effective.

Regarding the inclusion of additional concepts in the conceptual framework, Figure 4 shows that the majority of the proposed components were deemed "Highly Relevant" by the experts, particularly the Integration of Augmented Reality (AR), Artificial Intelligence (AI)-Based Personalization, monitoring of physiological variables, development of educational modules for caregivers, implementation of motivation and reward systems, integration with portable medical devices, ongoing training for healthcare professionals, and enhanced security and privacy mechanisms. Some components, such as compatibility with mobile platforms and support for multiple languages, received a mix of "highly relevant" and "relevant" ratings, with some neutral or less relevant responses. These results provide clear guidance on which areas to prioritize in the development of the conceptual framework to enhance its effectiveness and applicability in clinical and real-world settings.

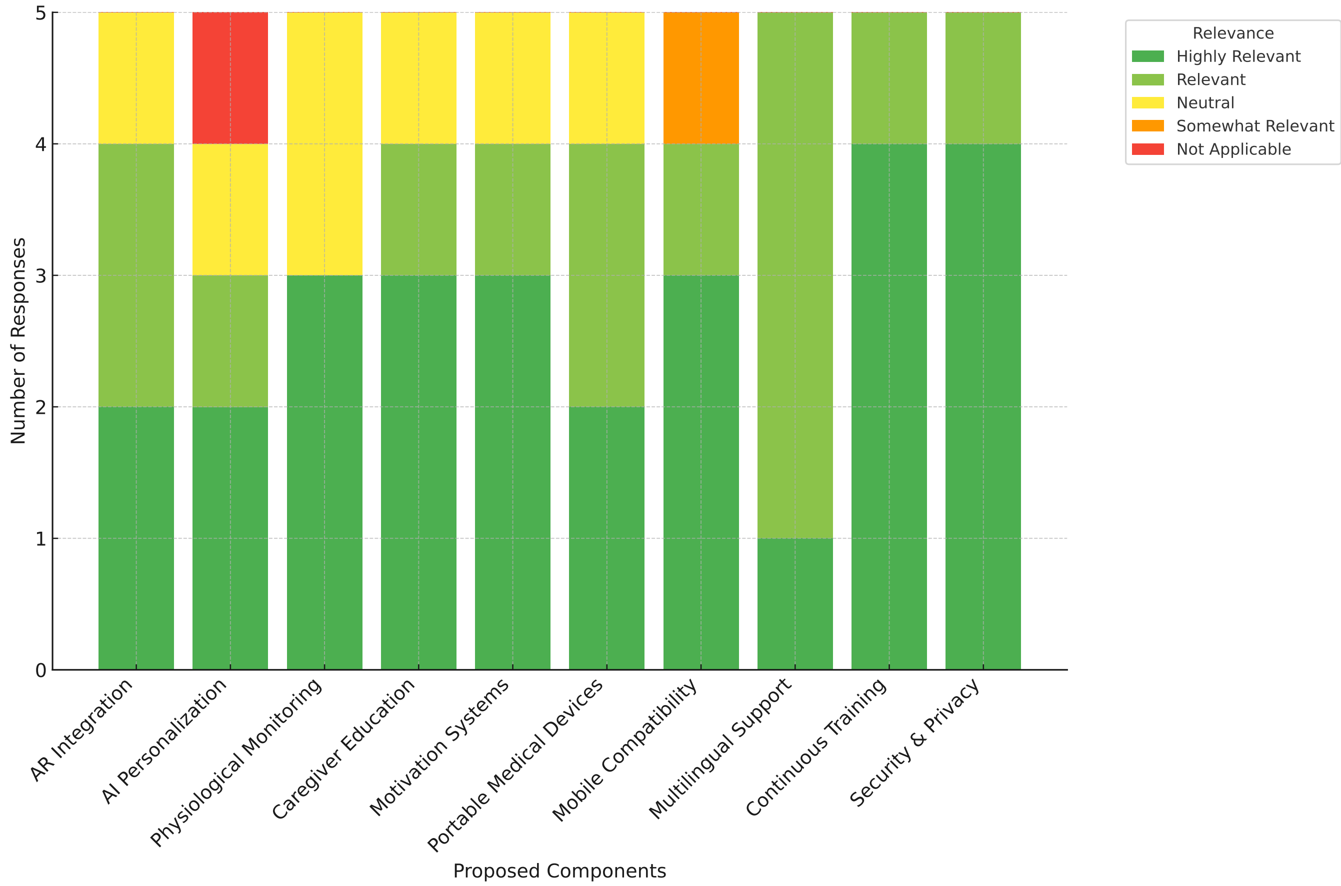

Figure 4. Relevance of proposed components according to experts.

To evaluate the concordance among the experts, we utilized the Fleiss's Kappa statistical method, which is specifically designed for assessing the reliability of agreement between multiple raters. This method provides a measure of inter-rater reliability that accounts for agreement occurring by chance. The Fleiss's Kappa values were calculated for each individual question as well as a global Fleiss's Kappa across all questions. The results are summarized in Table 3.

Table 3. Fleiss Kappa results by question and overall.

Question	Fleiss Kappa
1	−0.05
2	−0.03
3	−0.02
4	−0.03
5	−0.01
6	0.02
7	0.08
8	0.17
9	−0.25
10	−0.25
Global	−0.05

The open-ended responses provided by the specialists offered several suggestions to improve the applicability and effectiveness of the framework in clinical and real-world settings. The key points are summarized as follows:

Experts recommended integrating voice commands during the game to facilitate patient interaction and ease of activity execution. Additionally, they emphasized the adoption of national and international standards to ensure compatibility and accurate data interpretation.

A strong emphasis was placed on user-centered design, highlighting the need to create user-friendly, intuitive, and easy-to-use interfaces for both healthcare professionals and patients. Furthermore, it was stated that the framework should adhere to universal design principles, making it accessible to individuals with various disabilities.

The incorporation of portable devices and sensors for continuous monitoring of the patient's condition was also highlighted as an essential feature. Additionally, experts suggested that the framework should allow for ongoing review, adaptation, and improvement to meet evolving needs and standards.

Finally, the implementation of robust security measures to ensure the protection of patient data and the data of healthcare institutions was important.

4.6. Proposal of a Serious Game Based on Our Conceptual Framework

The activities incorporated within the serious game were selected to ensure they are representative enough to draw sound and generalizable conclusions. The game was proposed following the theoretical and practical principles presented in the development of our framework, such as physical activity, multiple cognitive domains, and activities of daily living in real-world scenarios.

First, the use of Virtual Reality (VR) technology, specifically the MetaQuest 2, was chosen not only for its immersive capabilities but also for its potential to promote physical activity, an important aspect of cognitive rehabilitation. The flexibility in user interaction—allowing exercises to be performed while seated, standing, or with a range of movements—ensures that the game can accommodate varying levels of physical ability, reflecting real-world rehabilitation settings where patients have diverse capabilities.

The core activity of the game, placing objects in their correct locations, was selected for its multidomain cognitive engagement. This task simulates activities of daily living, whose objective is to maintain independence in older adults. Organizing items, preparing meals, and managing household chores are integral to cognitive rehabilitation as they require the integration of various cognitive functions, including memory, attention, and executive functioning.

Moreover, the inclusion of a social component through a leaderboard fosters motivation and engagement, which are essential for adherence to rehabilitation programs. The competitive element encourages repeated gameplay, which can enhance cognitive benefits through sustained practice.

The game settings were designed to be adaptable, with customizable parameters such as the number of objects in the scene (which affects the level of cognitive load), the inclusion of auditory feedback (to assist the user during the task), and the variety of objects to organize (which defines the difficulty levels in each scene). These settings allow the game to be tailored to the individual needs and progress of each patient, ensuring that the cognitive challenges remain appropriate and effective over time.

Finally, the selection of scenarios—seated, standing, or rotating the torso—was informed by typical physical therapy exercises and the need to engage different physical and cognitive skills. This variety ensures that the game can be used as a comprehensive tool in rehabilitation programs, addressing both cognitive and physical aspects of patient health. The proposal for the serious game is presented in Figure 5.

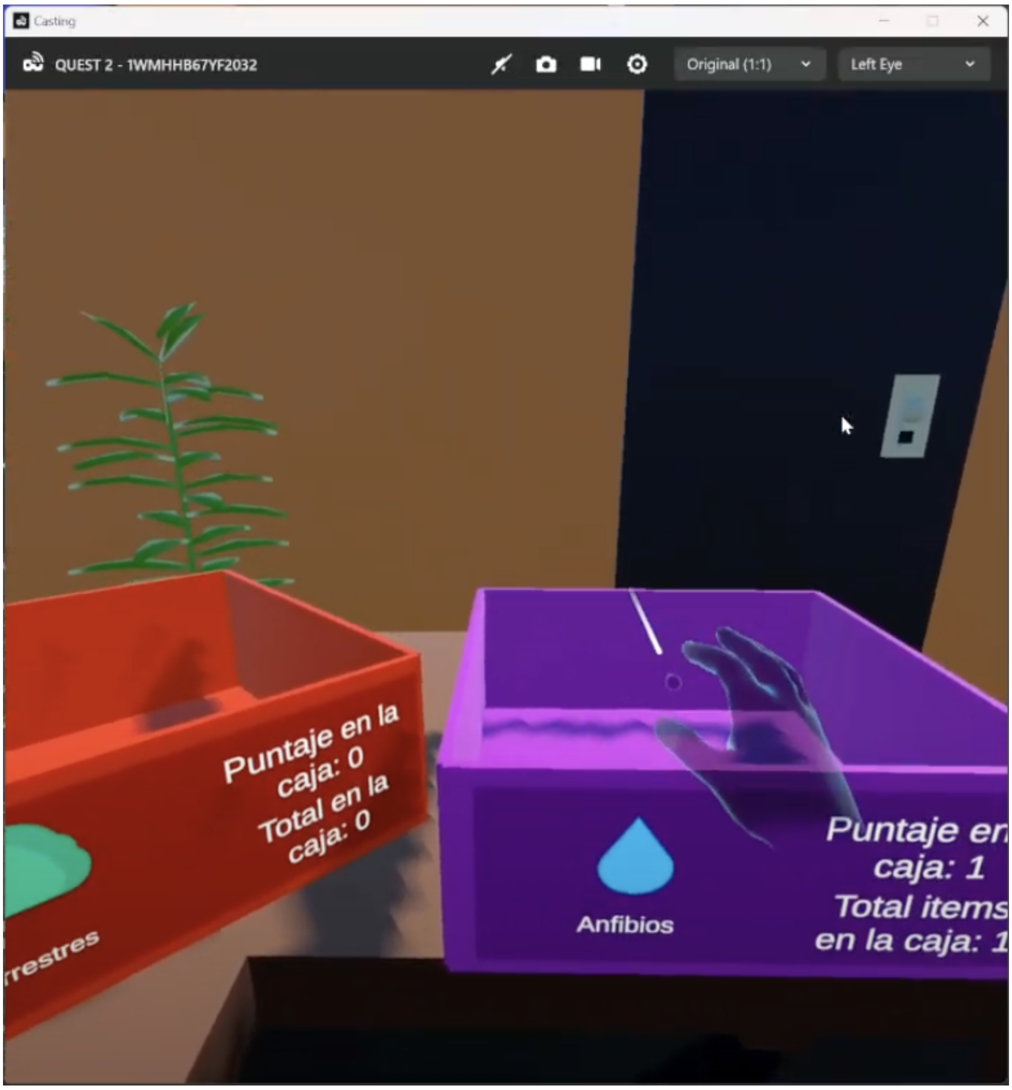

Figure 5. Proposed serious game.

5. Discussion

Our aim was to identify key concepts associated with the development of serious games for cognitive rehabilitation in older adults. According to our previous research [32], the developments presented are based on various theories of cognitive rehabilitation, sharing commonalities but also differences. For instance, some emphasize immersion through VR [48,49] to train spatial orientation and visual exploration functions, with the user seated; others expect users to engage in bodily movements [50,51], yet the systems lack immersion; in other cases, applications are multiplayer and cooperative [56], but lack bodily movement, as the user interacts exclusively on a screen. This indicates that cognitive principles have primarily been addressed independently. We decided to establish a connection among these identified features and propose a development process that incorporates them as a previous consideration. Furthermore, the expert insights provide guidance on areas to focus on for further development and refinement of the conceptual framework, enhancing its utility and effectiveness in real-world clinical applications.

In this study, the majority of the Fleis's Kappa values fall within the 'no agreement' to "slight agreement" categories, indicating that the experts did not strongly concur in their ratings. Specifically, according to Fleis [65] the global value of -0.05 (Table 3) supports this observation, reflecting a lack of substantial agreement among the raters. This may be due to the fact that the experts have different specialties and varying amounts of experience, leading each of them to interpret the necessity of the proposed components from different perspectives.

To validate these findings, it is important to recognize that the observed low agreement levels align with previous studies in similar contexts. Research indicates that the novelty and complexity of specific subject matter can result in diverse expert opinions, as highlighted by the benchmarks provided by Fleiss [65] and Landis and Koch [66]. These benchmarks place our results within the larger framework of inter-rater reliability assessment, supporting the notion that complex and novel frameworks frequently produce lower levels of agreement among experts.

While the Kappa Fleiss coefficient provided a quantitative measure of agreement, it was one of several tools used to shape our framework. The combination of theoretical grounding, empirical evidence from the literature, practical feasibility, and expert feedback collectively informed the final decisions on what to integrate and how to implement the components of our framework.

Regarding previous frameworks, Elaklouk et al. [42] focused on individualizing therapy objectives based on the patient's needs and preferences. This approach ensures that the therapy is tailored to the unique conditions of each patient, enhancing the effectiveness of the intervention. Our framework extends this personalized approach by emphasizing the integration of virtual reality (VR) concepts into user interaction considerations. VR provides an immersive environment that can be customized to individual user needs, further enhancing the personalization and engagement of the therapy.

While Elaklouk et al. emphasized motivation, engagement, and personalization, our framework builds upon these concepts by incorporating additional elements such as physical exercise, multitasking and multiplayer functionality, and simulated environments. These elements are designed to enhance user engagement and immersion, making the rehabilitation process more enjoyable and effective. The inclusion of physical exercise, for instance, not only addresses cognitive rehabilitation but also promotes overall physical health, which is crucial for older adults.

Seyderhelm et al. [38] integrated Cognitive Load Theory (CLT) with serious games to maintain user engagement and flow. CLT is essential for ensuring that the cognitive demands of the game do not overwhelm the user, which is particularly important in cognitive rehabilitation. While our framework shares the goal of maintaining user engagement, we expand on this concept by incorporating features such as multiplayer functionality and multidomain scenarios. These features enhance game mechanics and adaptability, allowing users to engage in social interactions and diverse activities that can further stimulate cognitive functions. Although Seyderhelm's framework is primarily aimed at cognitive learning, we believe that its principles can be effectively applied to cognitive rehabilitation.

Our framework is organized into three distinct development phases, serving as guiding principles throughout the development process. It adheres to agile and participatory methodologies, involving input from both experts and end-users. This is evidenced in Figure 2, specifically in the categories "Patient Condition" and "Development". This collaborative approach ensures that user perspectives are integrated into the development cycle, making the framework adaptable to new insights and developments. Although it may appear that the serious game is finalized at this stage, the individualized needs of users necessitate tailored adjustments. These adjustments are informed by user feedback, including preferences for interaction with the system and exercise configurations tailored to their requirements. Consequently, we perceive development as an iterative and incremental process.

By comparing and contrasting our framework with those of Elaklouk and Seyderhelm, we concluded that our framework integrates VR, physical exercise, and a collaborative, iterative development process to create adaptable serious games for cognitive rehabilitation. The proposed framework aims to enhance the effectiveness and engagement of serious games for cognitive rehabilitation in older adults. Both related works provided important insights into the design of serious games for cognitive rehabilitation, focusing on motivation, engagement, and personalized therapy objectives. By building upon these concepts and integrating them into our framework, we aim to create a more holistic and effective approach that addresses the specific needs of older adults undergoing cognitive rehabilitation.

To ensure that the proposed framework is inclusive and accessible to a broad range of older adults, it is essential to incorporate strategies to enhance digital adaptation among users. One effective strategy is to offer introductory training sessions that familiarize users with the basic functions and controls of VR applications. These training programs can be designed to gradually build users' confidence and proficiency in using the technology.

Another important consideration is the development of user interfaces that are intuitive and easy to navigate. By designing interfaces with clear instructions and visual cues, the interaction process can be simplified, reducing the cognitive load on users and making the technology more accessible. Additionally, providing continuous technical support and assistance is crucial. This can include help desks, online tutorials, and in-person assistance to address any issues or concerns that arise as users engage with the technology.

Furthermore, incorporating feedback mechanisms to gather user input on their experience with the technology is essential. This feedback can be used to make iterative improvements to the design and functionality of the VR applications, ensuring they meet the needs and preferences of older adults.

5.1. Implications

The conceptual framework developed in this study has several implications for the design and implementation of serious games for cognitive rehabilitation in older adults:

1. Enhanced personalization and engagement: VR and adaptive difficulty levels allow for personalized rehabilitation that can be adjusted to each user's needs. This personalization is necessary to maintain user engagement, which is essential for effective therapy.
2. Incorporation of physical activity: The framework emphasizes the integration of physical activity within the rehabilitation games, promoting overall health and well-being in older adults. This dual focus on cognitive and physical health addresses the needs of the target population, potentially improving both cognitive functions and physical fitness.
3. Social interaction features: The use of multiplayer functionalities and leaderboards fosters a sense of community and competition among users. These features are designed to improve motivation and adherence to the rehabilitation program, as social support and participation have been shown to positively influence rehabilitation outcomes.
4. Continuous improvement and adaptation: The framework is designed to be iterative and flexible, which allows for continuous review, adaptation, and improvement. This adaptability ensures that the games developed using the framework can evolve with new research findings and technological advancements, maintaining its relevance and effectiveness over time.

One practical application of our findings lies in the design and implementation of tailored rehabilitation programs for older adults with cognitive impairments. By integrating the identified features, such as VR immersion, physical exercise, and multiplayer functionality, into rehabilitation protocols, clinicians can create engaging and effective interventions that address the diverse needs of their patients.

5.2. Limitations

While the proposed conceptual framework has numerous strengths, it has several limitations which must be acknowledged to provide a balanced perspective and guide future improvements.

- The framework lacks comprehensive empirical validation. Although the framework has been validated through expert reviews, extensive empirical studies in real-world

settings are still needed to confirm its effectiveness. Such studies would provide concrete evidence of the framework's practical applicability and impact on cognitive rehabilitation outcomes.
- The framework's success is contingent on the digital adaptation of the users. The effectiveness of virtual reality applications and other technological components may be limited by the digital skill levels of older adults. This dependency could restrict the accessibility and usability of the framework for populations with lower technological competence. Addressing this issue requires the development of training programs and user-friendly designs tailored to older adults.
- The generalizability of the framework is limited. Since the framework is based on specific studies and theories, it may not be entirely applicable to all demographics or types of cognitive impairment. Further research is needed to adapt and validate the framework across different contexts and populations to ensure its broader applicability.
- The implementation of the framework demands significant resources. Effective application requires advanced technological equipment, trained personnel, and continuous support. These requirements may not be feasible for all institutions or regions, potentially limiting the framework's widespread adoption and scalability.

5.3. Future Works

The subsequent phases in our conceptual framework development, as delineated by Jabareen [31], involve validation and reconsideration. This will involve conducting pilot studies and usability testing with end-users to gather empirical data on the framework's effectiveness. These studies will include detailed participant demographics, usage statistics, and feedback from both users and experts. The insights gained from these empirical studies will allow us to iteratively refine the framework, ensuring it meets the practical needs of cognitive rehabilitation in older adults.

6. Conclusions

This study has provided a comprehensive and structured insight into the design of serious games for cognitive rehabilitation in older adults. By categorizing and synthesizing key concepts extracted from the literature, we have identified recurring themes and established connections with underlying cognitive theories. Our conceptual framework highlights the importance of an iterative and multidisciplinary approach in serious game development, as well as the need to consider factors such as virtual reality, physical activity, and social engagement to enhance cognitive health in older adults. By integrating ontological, epistemological, and methodological considerations, our framework offers a solid guide for future research and practices in this ever-evolving field. By adopting this holistic approach, serious game developers can create more effective and personalized interventions that address the unique needs of this growing population, thereby improving their quality of life and cognitive well-being.

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