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Gamification and Immersive Experiences: A Gamified Approach for Promoting Active Aging

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Abstract: With the global population of individuals aged 60 and above steadily increasing, the need for effective and realistic solutions to promote healthy aging has become imperative. Leveraging the potential of serious games, gamification, and immersive technologies, this study focuses on developing and implementing a practical and tailored gamified platform to foster active aging in older adults. This platform was designed to incorporate game elements such as points, badges, levels, rankings, achievements, and immersive 360-degree images to provide a realistic and captivating user experience. Six distinct games and challenges have been developed through an extensive and iterative design process, each carefully calibrated to accommodate the aging population's diverse cognitive abilities and interests. By combining the engagement-enhancing features of gamification with the immersive realism of 360-degree images, our platform offers a gamified and immersive solution for older adults. The gamified experiences are enjoyable and directly target cognitive functions, enhancing memory, attention, and problem-solving skills. The platform's design has been refined through user feedback and usability testing, ensuring its relevance and effectiveness in real-life scenarios. The outcomes of this research shed light on a practical approach to active aging, emphasizing the importance of incorporating gaming experiences to engage and stimulate older adults. This study provides insights for the design and implementation of future interventions aimed at promoting digital literacy and technological proficiency among older populations, ultimately contributing to their active and fulfilling participation in the digital age.

Keywords: gamification; older adults; active aging; immersive experiences; serious games

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1. Introduction

The rapid evolution of technology and its integration into various facets of daily life have reshaped how we perceive aging. As the global population ages, harnessing the power of technology—specifically gamification—emerges as a crucial frontier in enhancing the lives of older adults. Gamification, rooted in applying game elements and principles to non-gaming contexts, offers an innovative pathway to enrich the experiences of aging individuals. By infusing elements like points, challenges, and rewards into traditionally mundane activities, gamification has proven to be a potent catalyst, driving behavioral changes and fostering engagement across diverse age groups [1]. Importantly, games are not merely forms of entertainment; they are dynamic tools with immense potential to address the multifaceted challenges older adults face.

The aging process often brings about cognitive changes, which, if left unaddressed, can lead to various health complications, including dementia. However, studies have consistently demonstrated that mental stimulation and social interaction are pivotal in promoting cognitive reserve, thereby mitigating the risk of cognitive decline [2–4]. Games,

particularly those infused with elements that stimulate problem-solving, memory, and social connectivity, have emerged as valuable resources for older adults, promoting active aging and preserving cognitive functions [5,6].

In this context, the fusion of gamification with immersive technologies heralds a new era in older adult care. Immersive experiences, facilitated through virtual reality (VR) and augmented reality (AR) platforms, provide unprecedented engagement, transporting users to virtual environments that evoke real-life scenarios. By integrating these immersive technologies into gamified platforms, we can create an unparalleled fusion of entertainment and cognitive stimulation. VR, for instance, provides an immersive gaming experience and serves as a therapeutic tool, aiding in memory recall, reducing stress, and enhancing overall well-being [7]. The synergy between gamification and immersive technologies, especially in the form of 360-degree images, not only engages older adults but also capitalizes on their inherent curiosity, encouraging them to explore and interact with their environment.

The novel aspects of our solution include the integration of gamification with immersive experiences and social interaction. While existing platforms primarily focus on cognitive training exercises, Twist incorporates immersive, 360-degree virtual tours into its user experience. This feature supports cognitive stimulation and enriches emotional and sensory engagement by transporting users to familiar or new environments. Existing systematic reviews show that, while gamification and VR [8–10] provide cognitive benefits for older adults, there has been limited exploration of combining gamified training with immersive elements to support a holistic approach to active aging. This work extends beyond the scope of purely cognitive training applications.

Additionally, the widespread use of smartphones, tablets, and computers among older adults presents an opportunity to seamlessly integrate gamified applications into their daily lives, promoting consistent mental agility and social connectivity [11,12].

Against this backdrop, the primary objective of this pilot study is to explore the untapped potential of combining gamification principles with immersive technologies to design a gamified platform. This platform aims to entertain while actively enhancing cognitive functions, encouraging social interaction, and fostering active aging among older adults. By immersing users in captivating virtual environments rich in cognitive challenges and social opportunities, we strive to create an ecosystem that promotes continuous learning, mental agility, and emotional well-being among older adults. By exploring gamification elements, immersive technologies, and their impact on cognitive health, this study endeavors to pave the way for a future where aging is not synonymous with decline but represents an era of vibrant engagement and intellectual fulfillment. As we delve into the depths of this innovative amalgamation, we aim to unlock new possibilities where technology serves as a bridge, connecting generations and empowering older adults to lead fulfilling, active lives.

2. Background

2.1. Active Aging and Addressing Ageism Through Digital Interventions

With the global population of individuals aged 60 and above expected to double by 2050, supporting healthy aging has become a critical priority for societal well-being [5]. The World Health Organization (WHO) defines active aging as "the process of optimizing opportunities for health, participation, and security to enhance the quality of life as people age" [5]. This approach emphasizes physical well-being and psychological, social, and economic stability, all of which are essential components of aging well. Active aging is grounded in three pillars: participation, which ensures older adults remain socially engaged and integrated into their communities; health, which focuses on preventive measures to promote a healthy lifestyle and delay dependency; and security, which provides protection and support, preserving dignity and safety [6].

Active aging involves maintaining physical and mental health while improving the quality of life for older adults. Regular exercise, a balanced diet, mental stimulation, and nurturing social relationships are key recommendations for active aging, encompassing

practices that motivate, stimulate, and integrate older adults into society. However, societal attitudes toward aging present challenges. The term "ageism" refers to negative attitudes toward older individuals and those held by older adults toward younger generations. These attitudes and persistent issues like social isolation, particularly in Western societies, underscore the need for innovative solutions to promote active aging.

Incorporating information and communication technologies (ICT) into digital entertainment provides a unique opportunity to redesign entertainment systems for older adults, fostering their inclusion in digital culture and promoting active aging. By integrating digital tools and cognitive training applications, older adults can participate in activities that support cognitive, physical, and social engagement [5]. Recent research highlights the benefits of gamified cognitive interventions, particularly their ability to enhance memory, attention, processing speed, and executive functions—domains often affected by aging [3,4,7,8,13]. Cognitive training applications such as CogniFit, NeuroNation, and Elevate have been specifically tailored to address the cognitive needs of older populations, focusing on brain stimulation, dementia mitigation, and personalized mental training, respectively [8,9]. For instance, a meta-analysis by Nguyen et al. (2022) [9] on commercially available cognitive training programs reported small but significant improvements in cognitive domains for both healthy older adults and those with mild cognitive impairment (MCI). Programs like BrainHQ and CogniFit demonstrated near-transfer effects (improvements in trained tasks) but exhibited limited far-transfer effects (generalized improvements in untrained tasks). Similarly, Shah et al. (2017) [8] reviewed computerized cognitive training programs, reporting moderate efficacy in enhancing processing speed and memory but noting challenges in achieving sustained improvements across diverse cognitive tasks. These findings indicate that, while cognitive training programs can effectively target specific skills, translating these gains into everyday activities remains a critical challenge.

Immersive technologies, including virtual reality (VR), augmented reality (AR), and mixed reality (MR), provide promising avenues for engaging older adults in environments that support cognitive health and emotional well-being. These technologies create interactive, sensory-rich experiences that stimulate cognitive functions and offer therapeutic benefits. For example, VR has been successfully used in healthcare settings to manage pain and anxiety in older patients by immersing them in calming virtual environments that divert attention from physical discomfort [13].

Gamified cognitive training programs have also demonstrated advantages in their adaptability, accessibility, and capacity to engage users over time. Platforms like BrainHQ and Lumosity provide structured cognitive exercises that adjust to a user's performance, promoting sustained engagement and incremental improvements [8]. However, Nguyen et al. (2022) [9] noted that while these programs effectively target specific cognitive functions, the lack of far-transfer effects highlights the need for further exploration to achieve broader and longer-lasting impacts.

Inconsistencies in study quality, such as variability in design, sample size, and the inclusion of control groups, limit the current literature on cognitive training for older adults. As Tetlow and Edwards (2017) [13] observed, many studies rely on self-reported outcomes, which are susceptible to subjective bias and are often influenced by commercial funding, complicating the objective assessment of efficacy.

Compared to existing platforms like CogniFit, BrainHQ, Lumosity, Elevate, or NeuroNation, the Twist platform incorporates novel elements that enhance appeal and effectiveness. While traditional platforms focus on gamified cognitive exercises, Twist integrates immersive 360-degree virtual experiences, allowing users to participate in virtual tours of real-world locations. This immersive component stimulates memory recall and spatial awareness and provides emotional engagement, aspects often overlooked by conventional platforms. Furthermore, unlike these platforms, which prioritize individualized cognitive training, Twist emphasizes social connectivity by including social forums, ranking systems, and community-based challenges. These elements foster interaction, reduce loneliness, and enhance emotional well-being, addressing the social isolation that other platforms tend to

neglect. By combining gamification with immersive technologies and social connectivity, Twist represents an approach to active aging addressing the cognitive, social, and emotional needs of older adults within a single platform.

2.2. Gamification and Immersive Experiences

Recent research demonstrates that serious games and gamification have both enhancing and preventive effects on cognitive abilities in older adults [2]. However, gamification research has largely overlooked one of the fastest-growing demographic groups in recent years: older adults. Despite this oversight, studies have shown that older adults play and enjoy games as much as younger adults [2]. This research [2] has also concluded that digital games can provide various health benefits to older adults [2,3]. Furthermore, as future generations of older adults will have become more familiar with digital technologies and games from their childhood or youth, the digital divide between older and younger adults is expected to narrow significantly [4]. Consequently, it is imperative to investigate how older adults' interactions with digital games can positively impact aging.

Immersive ludic experiences present an innovative approach to promoting mental health and providing other benefits for older adults [7,14]. These experiences create environments that engage the senses, offering users a unique opportunity to disconnect from their usual surroundings and immerse themselves in sensory-rich spaces that evoke specific sensations. Immersive experiences can be developed using various technologies, including:

- Virtual Reality (VR): VR involves creating a lifelike digital universe, allowing users to replace their current environment with a virtual one and move freely within the digitally generated space.
- Augmented Reality (AR): AR overlays virtually created objects onto the physical world, integrating these elements seamlessly into the user's environment.
- Mixed Reality (MR): MR combines VR and AR to generate new spaces where real-world objects interact with 3D-generated virtual elements.
- 360° Images and Videos: This technology enables users to create and view immersive images that transport them visually to specific spaces, providing the sensation of being fully present in the depicted environment.

These immersive technologies are applied across diverse social and business sectors, including marketing, education, tourism, industry, leisure, and healthcare. In healthcare [14–16], immersive experiences play a significant role in palliative care by redirecting patients' focus to pleasant environments through projections or interactive games, stimulating emotions and engagement. Scientific studies have shown that these experiences can alleviate pain by stimulating the brain to block pain receptors.

Numerous commercial web applications and platforms have been developed to offer immersive experiences tailored to distinct purposes and audiences [17,18]. For instance, JigSpace uses 3D elements to enable users to explore, create, and share knowledge interactively. Employing augmented reality offers insights into how objects function, enhancing visualization-based learning. Another example is Orbulus, which facilitates virtual travel and exploration by allowing users to visit various locations through virtual reality. Designed for accessibility, Orbulus eliminates the need for additional accessories to control the experience, making virtual reality more approachable. Similarly, Unimersiv focuses on educational VR, regularly publishing immersive content on space, history, and science, aiming to accelerate learning through engaging VR experiences. Lastly, Pokémon GO, a mobile game, integrates augmented reality with geolocation, encouraging players to search for, capture, and collect Pokémon. Beyond collection, it incorporates competitive elements, allowing players to battle for gym control and earn rewards. These platforms demonstrate the versatility of immersive technologies in education, entertainment, and exploration.

The following section proposes a gamified and immersive technological solution to promote active aging, developed as part of the PEGAMEX-ACTIVE research project [19].

3. Gamified Platform for Active Aging

3.1. Technological Characteristics

This work aims to develop a gamified application to promote active aging through the design of engaging gamified experiences, with a primary focus on older adults as the target audience. To achieve this goal, the following implementation requirements have been established [19]:

- Service: The application must provide personalized services tailored to each user.
- Responsive Design: It must adapt seamlessly to any device.
- User Experience (UX) Design: The UX design should cater specifically to the needs of older adults.
- Experiences: The experiences offered must actively promote the principles of active aging.
- Gamification: Game design elements must be incorporated into the application.
- Security: The application must ensure secure connections and data privacy.
- Scalability: It must handle an increasing number of users efficiently.
- Availability: The application should be accessible to users at all times.

Based on these requirements, several technologies and tools have been selected for the development of the application:

- Ionic Framework: an open-source user interface toolkit for building high-quality mobile and desktop applications using web technologies (HTML, CSS, and JavaScript). It integrates seamlessly with popular frameworks such as Angular, React, and Vue, ensuring a clean and functional design across all devices and platforms. Ionic enhances developer productivity and reduces development costs. The Ionic CLI tool, a command-line interface that simplifies many common development tasks, was employed for this project.
- Angular: an open-source framework developed by Google for building single-page applications (SPAs). Following a Model–View–Controller (MVC) pattern, Angular supports modular, scalable development using TypeScript, enabling robust project structures. This project utilized Ionic technology in conjunction with Angular, resulting in a more structured and efficient development process.
- Google Firebase: a cloud platform for web and mobile app development, supporting multiple platforms (iOS, Android, and web). In this project, the following Firebase functionalities were employed:
- Firestore Database: a flexible and scalable database that synchronizes data between client applications using real-time listener objects.
- Firebase Authentication: provides backend services, SDKs, and UI libraries for user authentication via passwords, phone numbers, or identity providers like Google, Facebook, and Twitter, enabling rapid user registration and login.
- Cloud Storage: offers secure, cost-effective storage for media files required by the application, with seamless file upload and download operations.
- Firebase Hosting: a production-level web content hosting service that provides secure and fast hosting for the application. The final product was deployed efficiently using Firebase Hosting.
- Bootstrap: a free, open-source framework for designing responsive websites and web applications. It includes templates for typography, forms, buttons, navigation menus, and other design elements based on HTML, CSS, and JavaScript extensions.
- H5P: a free and open-source platform for creating interactive content in HTML5, used to design the project's interactive experiences.
- Google Street View: A tool within Google Maps that provides panoramic views of locations through 360-degree photographs, enhancing the application's immersive experiences.

A public repository hosting the application's source code has been created on GitHub [20], making it accessible online [21].

To access the application, users must register. Upon launching the platform, a welcome screen provides options to log in or register. The interface is designed to be simple and

intuitive, accommodating the needs of older adults. Once logged in, users are directed to the main screen, where available activities are displayed.

3.2. Gameful Experiences

The application Twist enables users to engage in various activities, earning points and achieving victories based on their performance in the experiences offered. As users accumulate points, they advance in rankings, level up, and unlock achievements, encouraging sustained activity on the platform. Additionally, a forum feature allows users to connect, fostering a sense of community.

The platform offers two main types of experiences:

- Games: These quiz-style activities address various topics, providing immediate feedback on users' answers. Designed to stimulate cognitive function, promote positivity, and entertain, these games contribute to users' mental well-being. Upon completion, users earn points and victories if they score the highest.
- Challenges: These immersive experiences feature 360-degree virtual tours, providing information about visited locations and concluding with a brief questionnaire to enhance attention, memory, and concentration. These challenges aim to create sensory-rich experiences that transport users to different environments, engagingly stimulating cognitive function.

The application offers six games and challenges: Enigma, Tandem, Triviland, Matquiz, Strolling the Streets, and Strolling the Clouds. We present the developed games and challenges as follows:

- Enigma: focuses on improving verbal skills, maintaining cognitive alertness, and reducing the risk of cognitive decline by leveraging the brain's language capabilities. This activity combines word games with puzzles. Three of the five questions presented involve crosswords, requiring users to fill in blanks with letters that align horizontally and vertically to form words. The remaining two questions are puzzles promoting memory, patience, relaxation, and stress relief. Users drag words onto images displayed on the screen, completing the puzzles interactively (Figure 1).
- Tandem: One of the most well-known games for exercising memory is the matching game, also known as "memotest." Tandem is a card-matching game where the user flips two cards simultaneously. If the images on the cards match, they remain face-up; if not, they are turned back over, and the user tries again. The objective is to remember the location of the images to match them successfully. The cards feature images of famous landscapes from the Canary Islands, adding an educational and nostalgic dimension. Users who recognize these places engage their ability to evoke memories and personal experiences, enhancing both cognitive stimulation and motivation (Figure 2).
- Triviland: a general culture quiz combining true-or-false, multiple-choice, and puzzles. One of the puzzles focuses on popular proverbs from Spain, which is particularly effective as these sayings are widely recognized among older adults. This activity helps users recall familiar proverbs, stimulating and enhancing their memory (Figure 3).
- Matquiz: Mathematical games are excellent for stimulating the mind, exercising memory, and enhancing the intellectual activity of older adults, contributing to the prevention of cognitive decline. For this reason, Matquiz is designed as a mathematical game that combines simple arithmetic questions with mathematical puzzles (Figure 4).
- Strolling the streets: Immersive experiences significantly enhance cognitive stimulation. Strolling the Streets is one of the challenges featured in the application. This interactive virtual tour uses 360-degree images of the city of San Cristóbal de La Laguna on the island of Tenerife. As users progress through the tour, they encounter points with information and interesting facts about the locations they visit. At the end of the activity, a quiz on the tour's information is conducted to determine the user's score for the challenge. This experience helps improve attention, memory, and concentration. Additionally, if users recognize the places they visit, their motivation

increases, as seen in the Tandem game, making the experience more engaging and enjoyable (Figure 5).

- Strolling the clouds: Similar to the previous challenge, this is an interactive virtual tour created with 360º images of Teide National Park on the island of Tenerife. As users progress through the tour, they encounter points with information and interesting facts about the locations they visit. At the end of the activity, a quiz based on the tour information is conducted to determine the user's score for the challenge (Figure 6).

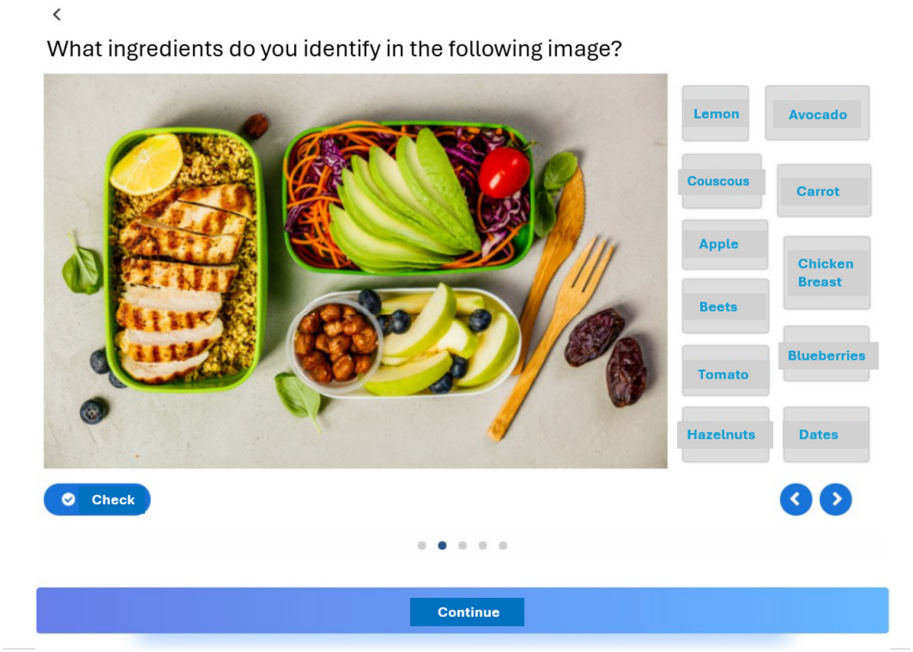

Figure 1. Example of the game Enigma.

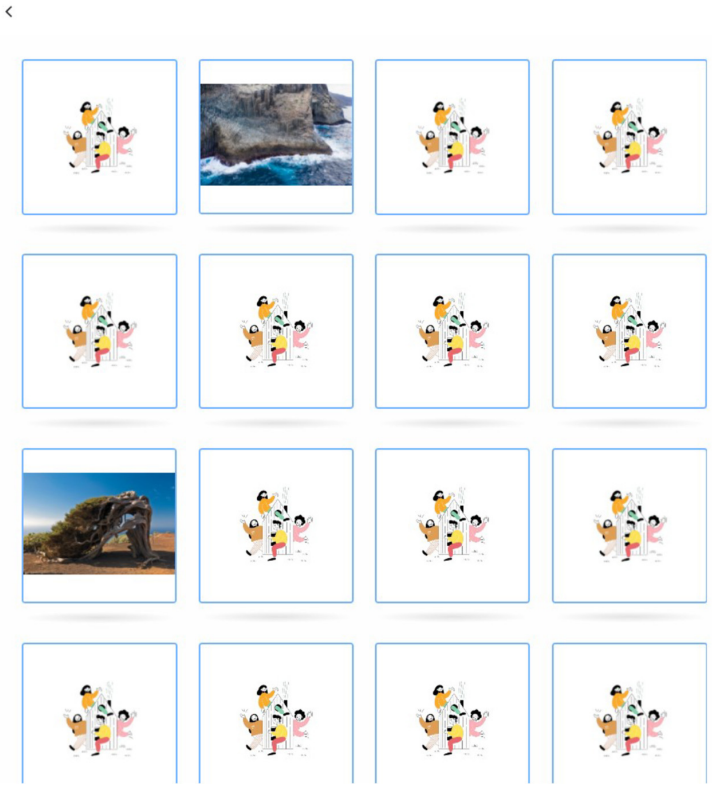

Figure 2. Example of the game Tandem.

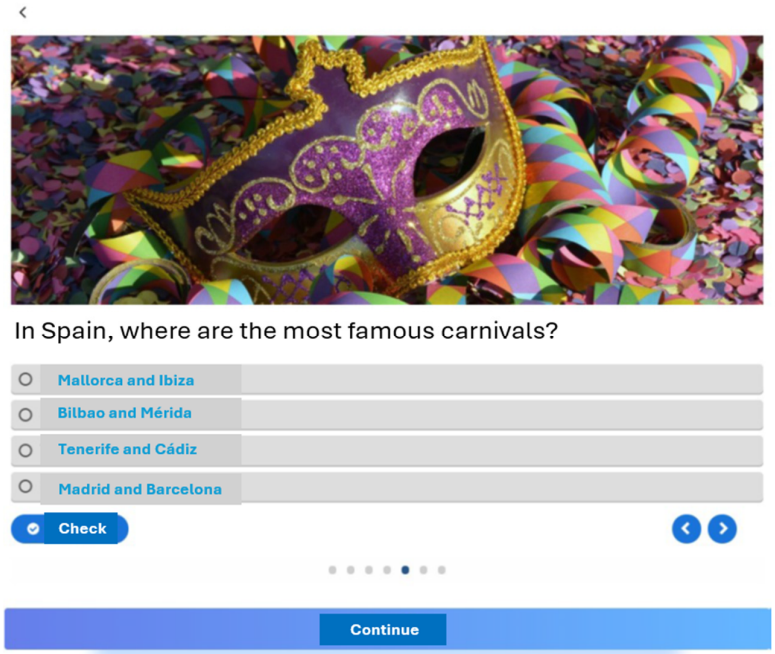

Figure 3. Example of the game Triviland.

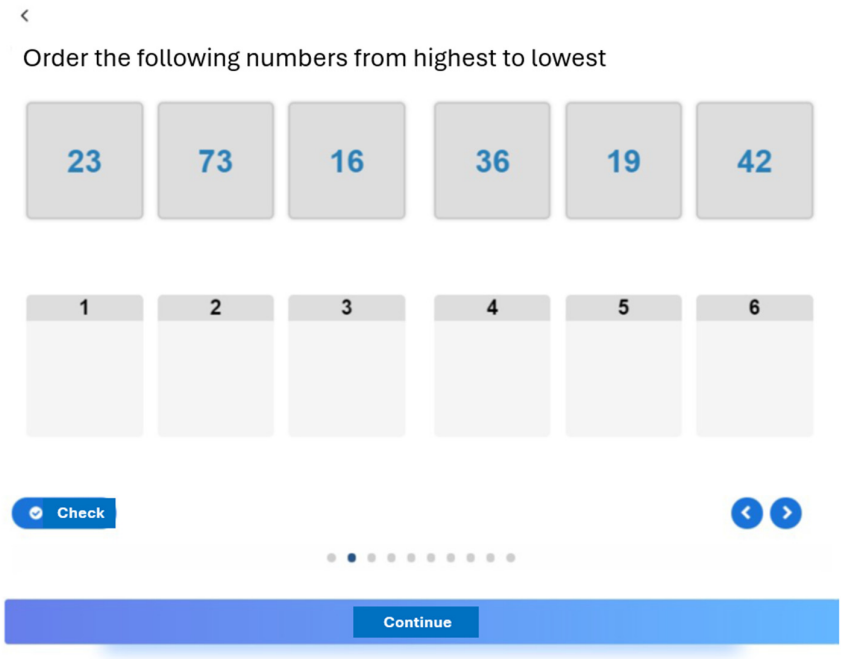

Figure 4. Example of the game Matquiz.

3.3. Gamification System Overview

The Twist platform incorporates a comprehensive gamification system built around three core elements: mechanics, dynamics, and components [22,23]. Mechanics are the fundamental building blocks of the game that make user progress visible and measurable. They serve as the foundation for creating engaging game dynamics. Dynamics elements drive user motivation and are critical to shaping the overall game experience, ensuring sustained engagement. Components include the tools and resources used to design activities, defining the game's aesthetics and visual appeal. Using these elements, and integrating

Points, Badges, and Leaderboards (PBL), a proven gamification strategy, the platform provides the features described in Table 1.

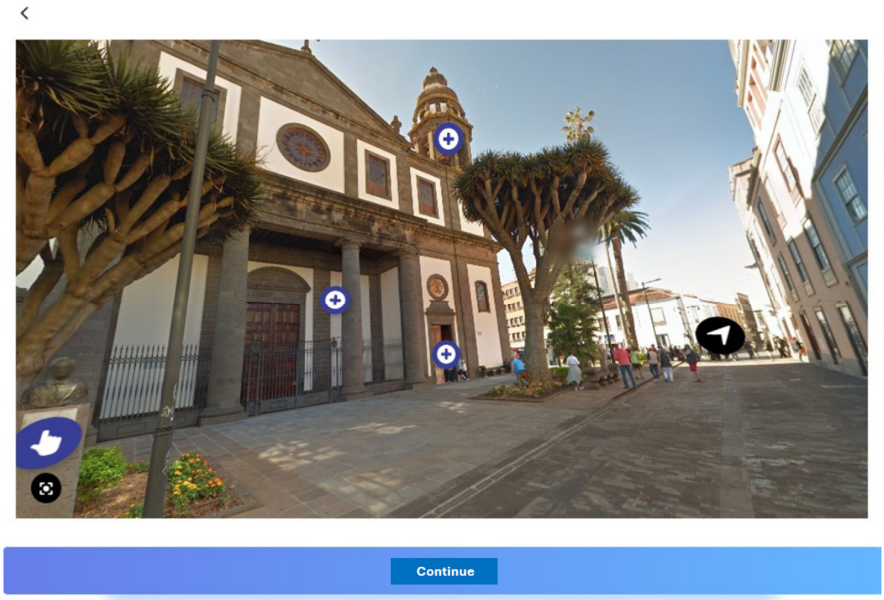

Figure 5. Example of the challenge "Strolling the streets".

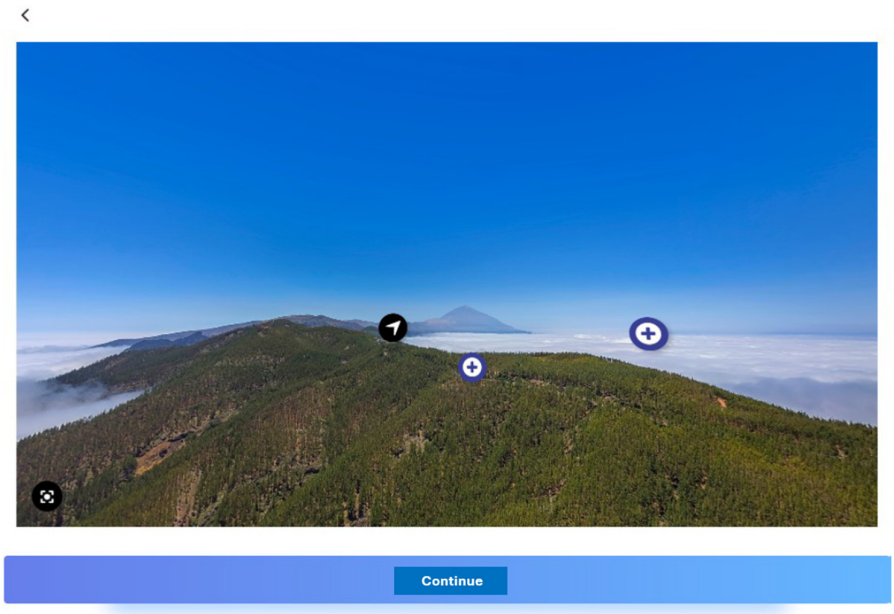

Figure 6. Example of the challenge "Strolling the clouds".

Regarding targeted cognitive domains and assessment, the platform targets three key cognitive domains:

- Memory: Games like Enigma and Tandem are designed to improve recall and working memory. Brief assessments conducted before and after gameplay measure accuracy and response times to evaluate memory enhancement.
- Attention: Games such as Triviland and Strolling the Streets train sustained focus and attention to detail through time-limited tasks and observational challenges.
- Digital Skills: Guided tasks at the start of each session build digital literacy, from basic navigation to more complex interactions such as forum participation and profile customization.

Table 1. Gamification elements implemented in Twist.

Gamification Element	Description
Scoring System	Users earn points by completing games. Each game assigns scores based on the total number of activities and correct answers achieved in a single attempt. These scores are stored in the user's profile. Additionally, achieving the highest score in a game adds a "win" to the user's profile. As users accumulate points, they advance through levels and unlock achievements, fostering continuous engagement.
Level Scaling	The platform features a progressive leveling system. Each level has a specific point threshold that users must meet or exceed to advance. Levels are represented by unique badges displayed as avatars on users' profiles, providing a visual indicator of progress and adding status within the platform.
Unlocking Achievements	Users can unlock achievements as they accumulate points. Achievements are visually represented as badges on the user's profile, offering additional motivation. The platform currently includes the following achievements: • First Time: Awarded upon the user's first login, providing immediate feedback to boost motivation. • Beginner: Unlocked after completing the first game, encouraging continued play. • Brave: Granted upon reaching Level 5, equivalent to earning 200 points. • Top 1: Earned by the user who achieves the highest score on the leaderboard. • Professional: Awarded upon reaching Level 10, requiring a total of 5000 points and signifying mastery of the platform.
Ranking	The leaderboard displays user scores in descending order, highlighting the top performers. The highest-ranking user unlocks the "Top 1" achievement. This ranking system promotes healthy competition, motivating users to improve their scores and climb the leaderboard.
Progressive Difficulty in Games	Each game and challenge on the platform is designed with a progressive difficulty structure to build user confidence and skills: • Enigma: Combines word puzzles and crosswords to improve language and memory skills. The game begins with straightforward crossword questions and progresses to more complex puzzle-based tasks. • Tandem: A memory card-matching game where the number of cards and potential matches increases with each round, enhancing memory recall and concentration. • Triviland: A general knowledge quiz incorporating true/false questions, multiple-choice questions, and puzzles. The game starts with simple questions and gradually introduces more challenging ones. • Matquiz: Focuses on arithmetic and mathematical puzzles, beginning with basic calculations and advancing to complex problem-solving tasks.
Immersive Challenges with Gradual Engagement	Strolling the Streets and Strolling the Clouds: These challenges involve interactive 360° virtual tours of famous landmarks. Early stages focus on passive observation, while later stages introduce detailed quizzes, encouraging memory recall, attention to detail, and cognitive processing.
Continuous Feedback and Score Tracking	Immediate feedback after each interaction allows users to know whether their answers are correct. This system supports error correction and reinforces learning. Scores are updated in real time, and users can replay games to improve their performance or proceed to new challenges.

The platform also includes some accessibility features for individuals with varying abilities. It incorporates features in the user interface, such as a clean design, large buttons, high-contrast text, and recognizable icons, reducing cognitive load and aiding users with visual impairments or cognitive challenges.

4. Pilot Study

The research and volunteers' participation strictly adhered to the principles outlined in the Declaration of Helsinki. All participants provided informed consent at all times, and the utmost respect for their rights and well-being was maintained throughout the study. The protocol is structured into four sessions, each with three phases: objectives, content, materials, and evaluation instruments. Activities include using technology such as tablets and mobile phones and are evaluated through questionnaires on technology acceptance, playability, and satisfaction. The sessions incorporate motivational techniques like participatory design and gamification elements, promoting the inclusion of transversal

aspects such as gender and value-based design. At the end of each session, data are collected and analyzed to assess technology acceptance and playability in order to identify potential improvements and their future utility.

4.1. Method

A pilot study evaluated the player experience and technological acceptance of older adults interacting with a gamified platform. This pilot assessed how gamification can enhance user engagement, stimulate cognitive abilities, and increase familiarity with digital tools. The pilot study also explored participants' motivation and satisfaction levels, particularly their experiences with the platform's games and challenges. A mixed-method approach was employed for data collection and analysis. Qualitative data were gathered using a field diary to document observations made during the workshop. Additionally, video recording of all sessions enhanced the observational data. Quantitative data were collected via administrated questionnaires: the Player Experience (PX) and the Technological Acceptance questionnaires (TAM).

4.2. Participants

The study involved 12 older adults (11 females, 1 male) aged between 55 and 75, all enrolled at the Popular University in Gran Canaria, Spain. This institution allows individuals aged 50 or over to access educational programs to promote lifelong learning. Participants' prior experience with technology varied, though all were regular users of digital devices for communication and entertainment purposes. Detailed demographic information is presented in Table 2, and a snapshot of the workshop can be seen in Figure 7.

Table 2. Demographic data of participants by age and gender.

Age	Participants	Gender
55	1	Female
58	1	Female
60	3	Female
64	1	Female
65	1	Female
67	1	Male
68	2	Female
70	1	Female
75	1	Female

Figure 7. Moment in the workshop carried out with older adults.

4.3. Instruments

A mixed-method approach was used to collect data using the following instruments:

1. Player Experience (PX) questionnaire: This instrument assessed participants' engagement, enjoyment, and satisfaction with the gamified activities. The questions covered various aspects of gameplay, such as ease of use, challenge level, and the perceived value of rewards.
2. Technology Acceptance Model (TAM) questionnaire: This tool measured participants' attitudes toward using digital technologies and their willingness to continue engaging with these tools in the future. It also evaluated their confidence and comfort in adopting new technologies like virtual reality.
3. Field Observations and Video Documentation: The researchers maintained a field diary to capture qualitative data based on their session observations. Additionally, video recordings provided deeper insights into participants' behavior and interactions with the platform.

The Player Experience (PX) questionnaire is a validated tool widely used to assess user engagement, enjoyment, and perceived challenges in gaming contexts. It evaluates key elements such as immersion, enjoyment, and ease of learning. Sample items include statements such as "I felt a sense of accomplishment while playing" (engagement) and "The game was easy to understand" (ease of use). This tool has demonstrated strong internal consistency in previous studies [24].

The Technology Acceptance Model (TAM) questionnaire, developed by Davis et al. (1989) (cited in Bolaños et al., 2021), measures perceived usefulness, ease of use, and behavioral intention to use technology. Its validity and reliability are well-established across diverse demographics. Sample items include "I believe using the platform would enhance my cognitive abilities" (perceived usefulness) and "I find the platform easy to use" (ease of use) [25,26]. Insights from PX and TAM results directly informed platform improvements, such as adjusting game difficulty progression and enhancing user engagement.

4.4. Procedure

The session was divided into three phases:

1. Introduction and Orientation: Participants were introduced to the platform and given a brief tutorial on navigating the activities.
2. Game Interaction: Participants played games individually or in pairs, depending on their preference. The games ranged from puzzles to virtual tours designed to improve memory, attention, and digital skills.
3. Reflection and Assessment: The session concluded with a group discussion, during which participants reflected on their experiences. Following this, they completed two questionnaires (PX and TAM) to provide feedback on the platform's usability and their experience.

4.5. Results

Regarding the results related to the player experience, all participants (100%) agreed that the game rules were clear and the objectives were well-defined. They felt that the rewards offered by the platform provided appropriate recognition for their achievements. When asked about the overall enjoyment and fun of the experience, 50% "always" agreed that the game was enjoyable, while the remaining 50% agreed "almost always." Most (84%) reported that the games were easy to learn, while 100% found the interface intuitive and accessible. They appreciated the coherence of the game's narrative, noting that it contributed to an enjoyable and believable experience. A total of 66.7% of participants believed the game's challenges were balanced to prevent frustration. However, 50% thought that the game's difficulty could be adjusted for users with less gaming experience, with some participants indicating that new challenges appeared too quickly. Concerning the TAM, 92% of participants reported that involvement in creating and using technological tools

boosted their motivation to continue using them. In addition, 66.7% expressed a desire to develop their technological skills further, and 100% of participants agreed that new technologies can enhance communication and interaction, reflecting a positive attitude toward technology as a social tool. Confidence in using more advanced tools, such as virtual reality (VR) glasses, was lower, with only 58.3% feeling confident using them, while 91.7% admitted they were yet to become proficient with VR. Despite these challenges, 100% of participants felt that participating in the workshops improved their perspective on technology, and all agreed that learning to use new tools positively impacted their self-esteem. Regarding motivation and engagement, 66.7% of participants consistently reported increased motivation throughout the gamified activities. Every participant expressed positive feelings during the session, emphasizing the games' social interaction and collaborative aspects. Participants highlighted that integrating familiar cultural references, such as local landmarks and traditional sayings, enhanced their emotional connection to the activities, stimulating cognitive engagement and memory recall. Qualitative observations were made, and as the session progressed, it was evident that participants were gaining confidence in using the digital devices provided. Initially hesitant, they became more adept at navigating the platform, indicating that the gamified approach effectively promoted digital literacy. Some participants needed help with specific game mechanics, such as timing or the speed of new challenges. Despite these issues, no one exhibited disinterest or disengagement. On the contrary, participants showed resilience, actively seeking solutions and collaborating with peers to overcome these challenges. Collaborative games fostered a strong sense of community, which participants particularly valued. Several individuals noted that the social aspect of the experience was as enjoyable as the cognitive challenges themselves. The game-specific performance of participants across the different games on the Twist platform demonstrated varying levels of cognitive engagement and completion times. For Enigma, a word game combining crosswords and puzzles, participants typically required 10–12 min to complete the activity, reflecting the cognitive effort involved in verbal recall and problem-solving. The memory-matching game Tandem was the quickest to complete, averaging 7–9 min, as its straightforward mechanics were familiar to most participants. In contrast, Triviland, a quiz blending true/false questions, multiple-choice questions, and puzzles, took approximately 8–10 min, requiring a moderate level of cognitive engagement. The most time-intensive game, Matquiz, involved mathematical puzzles that demanded focused concentration and problem-solving, with participants spending an average of 12–15 min on this activity.

In terms of perceived difficulty, participants identified Matquiz as the most challenging due to its emphasis on arithmetic and logic. Tandem, with its simple matching mechanics, was regarded as the easiest, requiring minimal cognitive processing. Both Enigma and Triviland were seen as moderately challenging, offering engaging tasks without overwhelming users.

Completion rates further highlighted participant engagement. All participants completed Tandem and Triviland, reflecting their accessible and intuitive design. Enigma showed a slightly lower completion rate of 83.3%, with some participants encountering minor challenges in the puzzle components. Matquiz had the lowest completion rate at 66.7%, as the mathematical tasks proved demanding for some participants. Despite these challenges, the majority expressed interest in revisiting the game, indicating that the difficulty level, while high, did not deter motivation.

The platform also captured both quantitative and qualitative data on cognitive performance and engagement. Each game tracked metrics such as completion time, accuracy, and score improvement across sessions. For example, Enigma assessed verbal recall through word selection accuracy, while Tandem measured memory recall based on the speed and accuracy of card matching. These metrics provided valuable insights into the participants' cognitive progress.

The adaptive difficulty feature dynamically adjusted the complexity of the games based on user performance. For instance, in Tandem, participants who quickly and accu-

rately matched cards faced increasingly complex tasks, such as additional cards or shorter time limits. This approach ensured sustained engagement by maintaining an optimal level of challenge tailored to individual abilities.

5. Discussion

This study highlights both the potential and challenges of using the Twist platform to support cognitive engagement and social interaction among older adults. The findings of this pilot study suggest that gamification can be an effective tool for promoting cognitive stimulation, digital literacy, and social engagement among older adults. The platform's game mechanics, clear objectives, and appropriate rewards motivated participants to engage with the activities. By including familiar cultural elements, such as local landscapes and traditional sayings, participants further enhanced their connection to the platform and increased memory recall. After conducting questionnaires with the participants in the research, we obtained information regarding users' familiarity with technology and games. All respondents, most of whom are daily users, use technology to connect to the Internet and communicate with others. Additionally, many use digital devices for entertainment activities such as listening to music, reading news, and watching videos. Digital communication is also important in their lives, using tools like video conferencing, instant messaging, and email. Participants feel competent in using technology. They believe they can recognize shapes and sounds on digital devices and manipulate them with their hands. Several participants indicated that they play games with technology. Some of them play several times a week or even every day. When asked about the importance of games in their lives, some mentioned that they spend time playing during the week and enjoy games that require thinking and test their memory. Game preferences vary among those who prefer to play alone, in groups, competitively, or in activities that challenge their cognitive skills.

The findings also align with a growing body of literature emphasizing the benefits of gamified and immersive technologies for aging populations. For instance, research highlights that digital interventions, including gamified platforms, can support cognitive stimulation, emotional well-being, and social connectivity among older adults [7,27]. The immersive features of Twist, such as 360-degree virtual tours, enhance user engagement by providing sensory-rich experiences, a benefit consistent with findings from immersive VR studies [28,29].

One notable limitation of this study is the predominance of female participants, potentially skewing the findings. Prior research has shown significant gender differences in gaming preferences, with males more likely to engage in competitive features such as leaderboards. At the same time, females often prefer collaborative and narrative-driven game elements [30]. Also, males tend to engage more extensively with console-based gaming and prioritize competitive features such as leaderboards. Females are more likely to favor games like board and card games and may exhibit varied preferences for console gaming [31]. This gendered bias may explain the observed preferences for specific features of Twist. Addressing these biases in future studies is critical to ensure that the platform accommodates diverse user groups effectively.

The study highlights the Twist platform's distinct advantages over traditional cognitive training tools, such as CogniFit or NeuroNation, by integrating immersive elements alongside gamified mechanics like points, badges, and levels. These features provide dual cognitive and emotional stimulation benefits, enhancing the overall user experience. This approach aligns with the findings of Bonnechère et al. (2020) [17] and Alnajjar et al. (2019) [32], who noted the value of gamification in mitigating cognitive decline through engaging and interactive formats. Furthermore, the inclusion of social features, such as forums and ranking systems, addresses isolation—a critical issue among older adults [33]. This social dimension, often missing in traditional platforms, fosters meaningful interaction and community building, as supported by research into virtual reality's role in promoting social engagement [34].

Despite these promising outcomes, the study's short duration and small sample size limit the generalizability of the findings. The pilot study's single 60 min session offered only a snapshot of user engagement, leaving the long-term effects of Twist on cognitive health, social well-being, and digital literacy unexplored. Previous research has highlighted the importance of longitudinal studies in assessing the sustained impact of cognitive interventions [16,35]. Additionally, the issue of limited far-transfer effects—where improvements achieved in platform tasks fail to generalize to real-world cognitive challenges—remains a concern [7,36]. This highlights the need for future iterations of Twist to incorporate real-world tasks that bridge the gap between platform-based cognitive exercises and everyday life.

Accessibility emerged as another challenge in the study. While Twist was designed with an intuitive interface, integrating advanced tools such as virtual reality glasses posed initial barriers for older users, consistent with findings from Drazich (2023) [18] and Thapa et al. (2020) [28]. Older adults often require additional time and training to adapt to these technologies, which can initially impact engagement and satisfaction. Ensuring that immersive features remain accessible to users with varying levels of technological familiarity is essential for the platform's inclusivity and effectiveness.

Future research should focus on expanding the participant pool to include a more diverse demographic, encompassing different genders, cognitive abilities, and physical health profiles. Such diversity will allow for a more comprehensive evaluation of the platform's accessibility and effectiveness across various user groups [37]. Moreover, longitudinal studies will provide critical insights into the platform's ability to support sustained cognitive stimulation, improve digital literacy, and foster social connections over time. By incorporating control groups and evaluating both qualitative and quantitative outcomes, future studies can better assess the unique benefits of Twist compared to traditional cognitive training methods [14,32].

To enhance the transferability of cognitive gains, the platform should integrate tasks simulating everyday scenarios, such as managing schedules, navigating environments, or solving practical problems. This approach aligns with recommendations from Wang et al. (2016) [36] and Sokolov et al. (2020) [7] on designing interventions that promote real-world applicability. Additionally, accessibility improvements, such as simplified interfaces and adaptive difficulty levels, will ensure that Twist accommodates users with varying cognitive and physical capabilities [18,30].

We think that the Twist platform can offer significant potential as an innovative tool for active aging. By addressing its current limitations and building on the insights gained from this pilot study, future iterations can contribute meaningfully to older adults' cognitive and social well-being.

6. Conclusions

This pilot study provides preliminary evidence supporting the potential of gamified platforms, such as Twist, in enhancing cognitive engagement, digital literacy, and technological acceptance among older adults. By integrating gamified elements with immersive experiences, Twist offers a novel approach to promoting active aging, addressing this population's critical needs for cognitive stimulation, motivation, and social interaction. The findings suggest that gamified interventions effectively foster positive attitudes toward technology and enhance self-perceived cognitive abilities. Participants reported high satisfaction with the platform, particularly appreciating the intuitive design, clear objectives, and rewarding game mechanics. The platform also demonstrated its potential to improve digital skills, as participants engaged in interactive activities that facilitated learning and enjoyment. Despite these promising outcomes, challenges related to difficulty balance and the pace of introducing new challenges highlight areas for refinement. A key strength of the platform lies in its ability to bridge cognitive engagement with social interaction. Features such as forums and leaderboards encouraged community-building, addressing issues of isolation often faced by older adults. This aligns with existing research emphasizing integrating social dimensions into cognitive training tools to enhance overall well-being.

However, the study also revealed limitations in accessibility, particularly concerning the use of advanced technologies such as virtual reality glasses. These challenges underscore the need for simplified interfaces and robust training modules to ensure inclusivity for users with varying levels of technological familiarity.

The small sample size and short study duration represent significant limitations, restricting the generalizability of the findings. The predominance of female participants may also have influenced the observed engagement patterns, reflecting gendered biases in gaming preferences. Additionally, the single 60 min session provided insights into short-term engagement but did not allow for an evaluation of the platform's sustained impact on cognitive health, social connections, or digital skills.

Future research should address these limitations by conducting longitudinal studies with larger and more diverse participant samples. Including control groups will help to assess the benefits of Twist compared to traditional cognitive training tools. Expanding the platform's features to include cooperative games, customizable user experiences, and real-world cognitive tasks will further enhance its applicability and user engagement. Moreover, incorporating user-generated content and achievements tied to time spent or accomplishments within the platform could provide additional motivation and enrichment.

While Twist remains a prototype, this pilot study demonstrates its potential as an innovative tool for active aging. The platform's integration of gamified and immersive elements provides a foundation for fostering cognitive engagement and social interaction. However, further refinement and comprehensive evaluation are necessary to validate its long-term effectiveness. As a step toward leveraging gamification and immersive technologies, Twist highlights the promise of digital interventions in supporting aging populations' cognitive and emotional well-being. This research contributes to the growing evidence base on the role of gamification in promoting active and inclusive aging, offering valuable directions for future studies and platform development.

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