



## Development of personalized exercogs for older adults care: A feasibility and single-arm study

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### ABSTRACT

**Introduction:** The prevalence of mild cognitive impairment and dementia is rapidly increasing worldwide, profoundly impacting older adults' quality of life and presenting significant challenges to healthcare systems. The heterogeneity of pathologies, the lack of customizable and available resources, and the scarcity of healthcare professionals are recurrent issues in aged care facilities. This study aimed to validate Exercogs®, a newly integrated portable exergaming platform designed to enhance cognitive function in older adults within elderly care facilities.

**Methodology:** We conducted two experiments: 1) a feasibility study with 12 healthcare professionals and 30 older adults to assess technology acceptance and usability, and 2) a single-arm pre-post study involving 204 seniors in aged care facilities to explore the potential multidimensional effects of the four Exercogs® (cognitive, affective, social, functional, and quality of life). The intervention was implemented over 12 weeks, with two weekly sessions.

**Results:** The intervention was well-received, with high-acceptance among older adults and healthcare professionals. Adherence was notably high (91.68%) with strong interest in continued use. Significant improvements were observed across multiple domains commonly impacted by aging, including cognition, mood, perceived loneliness, and quality of life, reflecting positive outcomes across all evaluated dimensions.

**Conclusion:** Preliminary results suggest that the Exercogs® is a promising tool to support healthcare professionals in aged care facilities. Future research should include a control group and randomized clinical trials to further validate these findings.

### Introduction

The increasing prevalence of mild cognitive impairment and dementia negatively impacts the quality of life of older adults and poses considerable challenges for healthcare systems (Jones et al., 2024). In response, societies are developing various support structures for older adults, such as nursing homes, daycare centers, and home care services (Alves et al., 2024; Gonçalves-Pereira et al., 2021).

In the Portuguese context, aged care facilities face significant challenges due to the lack of specialized care tailored to the heterogeneous needs of older adults, limited customizable resources, and shortage of healthcare professionals (Fonseca et al., 2021; Kueider et al., 2012).

Innovative, creative, and engaging interventions are urgently needed to address these issues (Saragih et al., 2023).

Technology-assisted interventions, have emerged as valuable tools for promoting health and well-being of elderly populations (Stara et al., 2022). Recreating traditional methods in a more engaging and stimulating way, such as using immersive environments, can improve interest and adherence (Alnajjar et al., 2019; Gallou-Guyot et al., 2020). Exergames (EGs) (Amjad et al., 2019) are particularly interesting because they integrate video games with physical activity in immersive environment, such as virtual reality (which transports the user to a simulated/virtual environment) and augmented reality (which integrates virtual objects into the real-world setting).

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This dual-task approach in immersive environments has demonstrated benefits across various domains, including cognition, physical activity, mood, socialization, and the quality of life of older adults (Margrett et al., 2022). Despite the positive outcomes reported in numerous studies (Amjad et al., 2019; Cardoso et al., 2019; Jahouh et al., 2021; Li et al., 2018; Zhao et al., 2020), it remains critical in the current landscape of health technologies to carefully consider the specific needs and characteristics of the target population (Mader et al., 2016).

Despite their benefits many existing exergame platforms developed for the masses, such as Nintendo Wii and PlayStation Move, were initially designed for younger populations and may not be well-suited for older adults (Ziegler et al., 2022) due to speed, excessive visual stimuli, and inadequate feedback (Waerstad & Omholt, 2013). A user-centered design approach is critical to ensure these technologies meet the needs and characteristics of the elderly population (Chien et al., 2024; Goodall et al., 2021).

Technologies that foster active aging and support healthcare professionals may be pivotal in addressing the needs of older adults attending aged-care facilities (Goodall et al., 2021). A notable example is the AHA (Augmented Human Assistance) project, which led to the creation of an augmented virtual reality platform that incorporates video games (primarily focused on physical activity) to improve the health of institutionalized seniors (Gouveia et al., 2019). This platform, named PEPE (Portable Exergaming Platform for Elderly), has shown benefits in promoting physical activity, social engagement, and the quality of life among Portuguese older adults without cognitive impairments (Cardoso et al., 2019; Gonçalves et al., 2021). Considering the diverse cognitive profiles in elderly support structures, developing new games mainly with cognitive objectives for platforms like PEPE is crucial. These games should be customizable to aid healthcare professionals in stimulating cognitive functions and enhancing the quality of life of seniors attending these facilities (Ferreira et al., 2022; Ziegler et al., 2022).

This study aims to validate Exercogs®, a new set of games designed primarily to stimulate cognitive function in older adults together with physical and social interaction components, all integrated in the PEPE augmented reality exergaming platform. We present the Exercogs® design, its main features, assess its feasibility, and examined its effects across cognitive, affective, social, functional, and quality of life domains.

## Methods

### Study design

This two-phase study was conducted from March 2021 to December 2023 in aged care facilities across Portugal. **Phase 1** focused on the user-centered design and development of four games (Exercogs®) in collaboration with healthcare professionals and older adults. **Phase 2** comprised two experiments: 2.1. an assessment of the feasibility and user experience of the intervention among older adults and healthcare professionals and 2.2. a single arm pre-post study that explored multi-dimensional effects of the Exercogs® in seniors with and without cognitive changes at aged care facilities.

### Phase 1

#### a) System setup & Exercogs®

The PEPE (Portable Exergaming Platform for Elderly) prototype represents an innovative approach to promoting physical and cognitive health in elderly individuals (Simão & Bernardino, 2017). Designed with a user-centered approach, PEPE integrates Exercogs® an augmented reality technology that displays four cognitive games on the floor (see Fig. 1). The floor display provides a more immersive experience and promotes social interaction by allowing participants to stand in a semicircle around the projected game area.



Fig. 1. Portable exergame platform for elderly (PEPE).

This intervention should be conducted in a semicircle around the game projection, promoting social interaction. This setup promotes a sense of community among users, mitigating social isolation commonly observed in aged care facilities. In addition, floor projection can reduce constraints associated with small screens by offering a larger visual workspace and a direct action–feedback correspondence. Moreover, it supports engagement among observing participants through passive stimulation and group involvement by following the tasks, mentally performing the exercises, and providing encouragement and positive feedback to the active player.

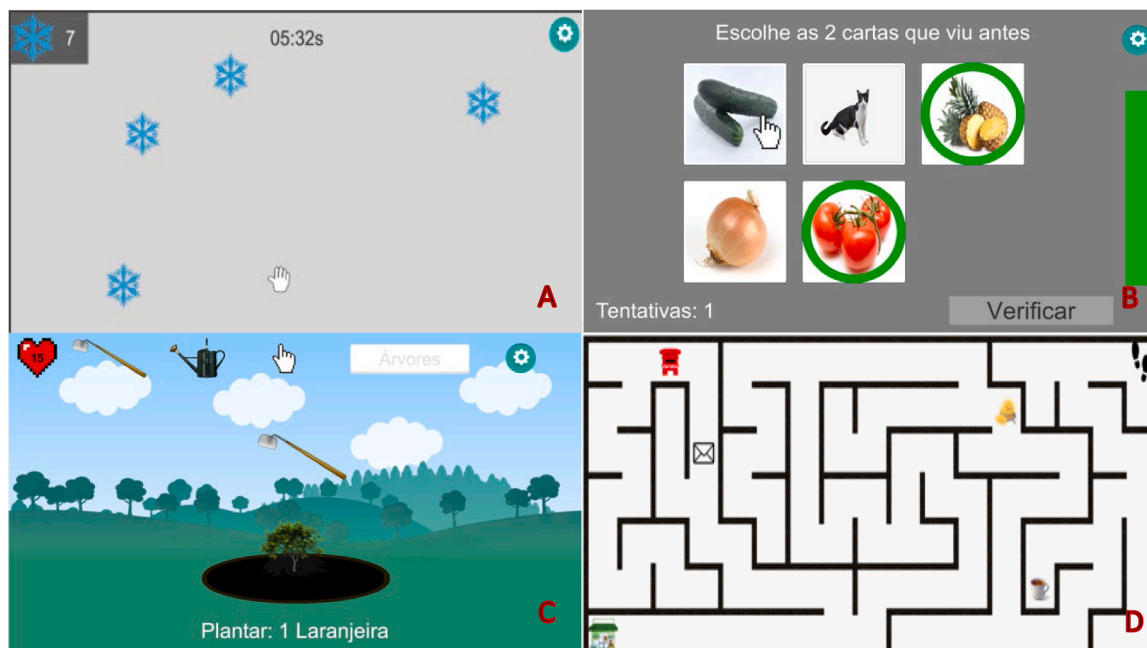
Users interact with these exergames by moving their bodies, which are detected by the Kinect V2 camera placed in front of them. This technology's dimensions allow easy transportation in a standard city car trunk, enabling the system to be deployed quickly across multiple aged care facilities. The system is easy to set up.

The design of the four games, known as Exercogs®, was based on a co-development process with healthcare professionals and academic researchers. We tried to include as many elderly individuals as possible by creating customizable games to accommodate cognitive changes (games with various difficulty levels) and physical limitations (such as being in a wheelchair). Each game features individual calibration, enabling the person to stand, sit and use whichever arm they feel most comfortable with.

In multiple meetings, we identified physical movements and cognitive exercises that could benefit older adults. We designed four Exercogs®, to enhance upper limb functionality, balance, and gait as physical attributes, and attention, memory, and executive functions as cognitive features.

The first game, "Pop It," (Fig. 2A) involves moving visual stimuli that participants must intercept using hand movements. It is designed to enhance visual attention, information processing speed, and executive functions, mainly inhibitory control, by incorporating visual stimuli that participants are required to avoid intercepting. The game features customizable settings, such as the speed of stimulus movement, the maximum number of stimuli presented, the duration of the game, and an impulse inhibition mode. Additionally, it offers the option to adapt the theme of the stimuli according to the seasons, promoting reality orientation.

The second game, "Memorize Me" (Fig. 2B), challenges participants



Note. A) Pop-it Game; B) Memorize me game; C) Agricultural Activity game; D) Maze game

Fig. 2. Exercogs® implemented in the intervention.

Note. A) Pop-it game; B) Memorize me game; C) Agricultural activity game; D) Maze game.

to memorize images, stimulating visual attention, information retention and recognition, and working memory. In this game, participants must first memorize images presented for a predetermined time. Then, using hand movements, they must identify the memorized images from several options, some of which serve as distractors. The game allows for adjusting various parameters, including memorization time, categories of images used (e.g., fruits, tools, animals, etc.), the number of images to memorize, distractor images, response time, and the number of attempts.

The third game, titled "Agricultural Activity" (Fig. 2C), simulates farming tasks such as planting one to three trees and harvesting their fruits. It primarily targets executive functions—including action planning, inhibitory control, and working memory—as well as procedural memory and visual attention. To complete the exercise, players must follow a specific sequence of tasks using arm and hand movements: 1) Select the appropriate tool to dig a hole in the ground; 2) Retrieve the seed or fruit specified by the game; 3) Plant the seed in the previously dug hole; 4) Choose the correct tool to refill the hole; 5) Select the appropriate tool for watering; 6) Harvest the fruits and place them in the designated basket (with an optional inhibition mode to avoid rotten fruits). This game also includes a two-player mode (collaboration mode), where players work together to collect as many fruits as possible. In this mode, the exercise starts with planting trees and getting ready for harvesting.

The final game, titled "Maze" (Fig. 2D), challenges participants to trace a correct path using their arm and hand, guiding an object (shoes) to the endpoint of the maze (grocery store). This activity stimulates visual attention, executive functions (action planning), and visuospatial and perceptual abilities. In advanced levels, optional tasks can be added along the way: a) Collecting Money: The player must first "collect" the money before proceeding to the end of the maze (grocery store); b) Coffee Cup: Picking up the coffee cup grants extra points. This is optional; the player is not required to "collect" it to complete the maze; c) Mailing a Letter: The player can only complete the maze by first picking up the envelope, placing it in the mailbox, and finally heading to the end of the maze (the grocery store).

This technology, offering various difficulty levels and configuration

options, enables the creation of a personalized profile for each participant. Additionally, it provides real-time information on the senior's progress, functioning as a tool for monitoring and performance progression. Moreover, beyond stimulating physical and cognitive components, the games are conducted in groups within a specially designed environment to encourage interaction among users during exergame participation, thereby promoting socialization. Additionally, participants can gain benefits both actively by performing the tasks and passively by observing the performance of other participants.

Group dynamics were considered crucial from the very beginning of the design of Exercogs®. In fact, there is extensive literature in cognitive stimulation that highlights the importance of group dynamics. Furthermore, conducting activities in group, allows for a more balanced management of the participants physical effort, alternating active exercise periods with calmer periods that allow for some physical rest while maintaining cognitive and social involvement. Also, potentially, this approach is a more scalable intervention, since it requires fewer human resources and is easier to implement than individual approaches in the real context of these institutions.

#### Phase 2

In this phase, two experiments were conducted: 2.1) a feasibility study to evaluate the acceptability and user experience of the technology among both seniors and healthcare professionals; 2.2) a single-arm pre-post testing study to explore the potential effects of the four Exercogs® in multidimensions (cognitive, affective, social, functional, quality of life) among seniors attending elderly day care facilities.

#### Participants

Twenty-three aged care facilities in Portugal were formally contacted and agreed to participate. A convenience sampling method was used at each of the participating organizations.

Inclusion criteria for older adults considered:

- 1) age  $\geq$  65 years,
- 2) attendance at an aged care facility at least twice a week,
- 3) willingness to participate.

Exclusion criteria considered severe physical disabilities preventing participation. No exclusions were made based on cognitive status, ensuring a diverse representation of cognitive abilities in real-world care settings. This inclusive approach allowed a more comprehensive evaluation of the Exercogs® acceptance and effects across various cognitive profiles. Note that cognitive diagnostic assessment of elderly individuals is often absent in real-world care settings despite evident cognitive impairments.

For healthcare professionals, eligibility required prior knowledge of the PEPE platform and direct involvement in older adult care.

Study Groups:

1) Feasibility study: the sample consisted of 12 healthcare professionals and 30 older adults. Among the healthcare professionals, 4 were psychologists, 4 were psychomotor therapists, and 4 were health assistants. Regarding the contact hours with seniors, 25% worked 4 to 6 h daily, while 75% worked more than 6 h daily. As for the older adults, 9 were men, and 21 were women, aged between 68 and 89 years, with an average age of 76.7 (SD=5.9). 90% had an educational level of less than four years, and 46.7% were widowed.

2) Single-Arm Pre-Post Study: 204 participants attended the 12-week cognitive sessions using the Exercogs®. Participants ages ranged from 65 to 96 years (M = 78.9, SD 8.1) categorized into:

- Dementia Group (DG): 52 participants met the diagnostic criteria for dementia (DG) as assessed by a neurologist,
- Cognitive Impairment Group (CIG): 104 presented cognitive impairment (CIG),
- No Significant Cognitive Impairment Group (NCIG): 48 had no significant cognitive impairment (NCIG).

Most participants were female (80.9%). Table 1 summarizes socio-demographic data and characteristics of older adults before the intervention.

We used a naturalistic approach, in which the intervention groups reflected the real composition of the participants in the institutions. In practice, participants attended the sessions according to their regular participation in the institution. Therefore, participants were not allocated to the groups based on their cognitive status. The classification of the participants to the categories DG, CIG, and NCIG was defined after, only for analytical purposes, in order to examine how the intervention results in the populations that are in fact typically found in these institutions. Classification was based on prior clinical diagnoses in the case

**Table 1**  
Sociodemographic data and characteristics of older adults before the intervention.

Variables		DG (N = 52)	CIG (N = 104)	NCIG (N = 48)	Total Sample (N = 204)
Sex	Female	41 (78.8%)	87 (83.7%)	37 (77.1%)	165 (80.9%)
	Male	11 (21.2%)	17 (16.3%)	11 (22.9%)	39 (19.1%)
Age	—	65–85	65–96	65–92	65–96
Min–Max	—	79.96 ± 8.27	79.84 ± 8.41	76.12 ± 6.39	78.99 ± 8.07
M ± DP	—	5,39	5,19	±21.50	
Education	≤ 4 years	24 (46.2%)	69 (66.4%)	26 (54.1%)	119 (58.3%)
	> 4 years	28 (53.8%)	35 (33.6%)	22 (45.9%)	85 (41.7%)
MMSE	—	4–28	4–26	23–30	4–30
Min–Max	—	16.17 ± 5,39	17.62 ± 5,19	26.63 ± 21.50	19.37 ± 6.22
M ± DP	—				
Barthel	—	10–100	20–100	20–100	10–100
	Index	72.31 ± 25.73	87.31 ± 19.74	96.25 ± 12.78	85.59 ± 21.82
Min–Max	—				
M ± DP	—				

Note. Values are presented as mean (standard deviation) and minimum and maximum values or as percentages.

of DG and on cognitive assessment conducted within the study in the case of CIG and NCIG, according to the Portuguese norms of MMSE adjusted to age and education.

Outcome measures

We collected demographic and outcome data. Demographic data was collected at baseline (T0), and outcome data was collected at both baseline (T0) and the week after the intervention's completion (T1). A neuropsychologist, not involved in the intervention, conducted the assessment data face-to-face at both T0 and T1.

The instruments were administered in individual sessions, within a structure setting without distractions. The examiner read each item in its entirety, adopting a measured pace and language appropriate to the participant's educational level and cognitive profile.

Standardized support for comprehension was provided, including vocabulary clarification and exclusively linguistic rephrasing, when necessary, while maintaining the conceptual content. Whenever hesitation was observed, items were repeated without additional content or response cues. Administration proceeded at an individualized pace, with possible breaks. These procedures were designed to ensure comprehension of the items, safeguarding the interpretative validity of the results.

The outcome variables included cognitive, mood, social, functional, quality of life, and feasibility dimensions:

- **Cognitive function** was assessed using Addenbrooke's Cognitive Examination – Revised (ACE-R), a cognitive screening tool that evaluates five cognitive domains: attention and orientation, memory, verbal fluency, language, and visuospatial abilities. The instrument offers versatility by providing a comprehensive assessment of cognition through the summation of scores from the five domains (with a maximum score of 100) and a more segmented analysis, evaluating each domain independently. Higher scores indicate higher cognitive function. Additionally, we can obtain MMSE scores (30 points) with some of the administered items (Firmino et al., 2018).
- **Mood** was assessed with The Geriatric Depression Scale (GDS-15). It is a widely recognized and validated screening tool for depressive symptoms in older adults. This self-report questionnaire consists of 15 items with dichotomous responses ("yes" or "no"). A score higher than 5 points may indicate the presence of depressive symptoms (Matos et al., 2019).
- **Social dimension** was assessed using the UCLA-loneliness Scale and the Satisfaction with Social Support Scale (SSSS). The UCLA-16 (Portuguese version) is a questionnaire designed to assess individuals' subjective feelings of loneliness and social isolation. This scale consists of 16 items with a 4-point Likert-type response scale (1. "never" to 4. "often"). Scores above 32 indicate negative feelings of loneliness, while lower scores reflect greater social satisfaction (less loneliness) (Pocinho & Dias, 2010). The Satisfaction with Social Support Scale (SSSS) assesses individuals' perception and satisfaction with their existing social support. It comprises 15 items rated on a 5-point Likert scale ("strongly agree" to "strongly disagree"), yielding a total score between 15–75, where a higher score corresponds to better social support (Pais-Ribeiro, 2011).
- **Functional assessment** used The Barthel Scale, a questionnaire designed to measure a person's ability to complete activities of daily living. Scores range from 0 to 100, with scores <25 indicating total dependence, 26–50 indicating severe dependence, 51–75 indicating moderate dependence, 76–99 indicating mild dependence, and 100 indicating independence (APMGF, 2023).
- **Quality-of-Life** was assessed with The World Health Organization Quality of Life (WHOQOL-BREF), a 26-item instrument using a 5-point Likert scale. The first two questions address general quality of life and health satisfaction, while the remaining 24 items are

grouped into four domains: physical health, psychological health, social relationships, and environment. Higher scores in each domain indicate a better quality of life (Serra et al., 2006).

- Feasibility of the intervention with the Exercogs® in aged care facilities in Portugal, was assessed through 1) adherence, 2) satisfaction and motivation, and 3) usability.

1) **Adherence** was measured by the attendance protocol to record the number of training sessions performed. According to criteria established in the literature, an attendance rate exceeding 75% indicates good adherence (Horne et al., 2019; Orgeta et al., 2019). This percentage reflects the participant's motivation and commitment and the intervention's effectiveness in maintaining seniors' interest and active participation. The present study systematically conducted attendance records at the beginning of each intervention session with the PEPE platform.

2) **Satisfaction and motivation** were assessed by a self-report questionnaire developed by the researchers of this study at the end of the intervention. We used three questions: 1) "I am satisfied with the decision to play with the PEPE platform"; 2) "The games played with the PEPE platform are motivating"; 3) "If given the opportunity, I would like to continue playing with the PEPE in the future". The selection of these questions (using a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree"), according to the literature, allows to obtain critical indicators of acceptance and long-term sustainability of the intervention (Alturas, 2019).

3) Usability of the newly developed Exercogs® integrated into the PEPE platform was assessed by administering the a) System Usability Scale (SUS) to the older adult participating in the intervention, and the b) Usefulness, Satisfaction, and Ease of Use (USE) questionnaire to the healthcare professionals after the intervention period. a) SUS is a validated and reliable tool for evaluating usability. It consists of a 10-item questionnaire (using 5-point Likert scales numbered from 1 ("Strongly disagree") to 5 ("Strongly agree")). The final SUS score is calculated based on the provided answers, resulting in a score ranging from 0 to 100 (Bangor et al., 2008). According to Brooke (1986) and corroborated by Martins et al. (2015), a score higher than 76.67% indicates good usability, suggesting that users found the system easy and intuitive to use. b) USE questionnaire aims to evaluate users' perceptions of a particular product or system. This self-report questionnaire is composed of 30 items and examines four dimensions of usability: usefulness, ease of use, ease of learning, and satisfaction. Participants rate each item on a 7-point Likert scale (1 = "Strongly Disagree"; 7 = "Strongly Agree") with an "N/A" option. In the end, participants may freely indicate the negative and positive aspects of Exercogs® as a cognitive stimulation tool in interventions with seniors in elderly care facilities. In the literature, the scoring method for the USE questionnaire involves separately averaging the scores of the items within each of the four dimensions.

### Procedure

This study was approved by the Ethics Committee of a Health unit (12-01-2021), with registration number 1/2021EI. Before the study, participants received and signed the consent form.

1) For the feasibility study, we administered the sociodemographic questionnaire to seniors and healthcare professionals (at T0) and the feasibility assessments to the elderly. The older adults underwent cognitive stimulation sessions twice a week for eight weeks, each lasting approximately 60 min. Attendance was recorded, and in the final session (session 16), seniors responded to the SUS questionnaire and the researcher's questionnaire in addition to the intervention. Additionally, at T1, the USE questionnaire was administered to healthcare professionals.

All selected professionals were first introduced to the Exercogs® system during a formal presentation session, in which they were able to interact freely with the system and to explore its functionalities. The twelve professionals involved were from three different institutions, and

a total of sixteen sessions were implemented in each institution. During the equipment usage phase, the professionals were invited to participate at least in the initial sessions. A neuropsychologist member of the research team was always present to support and facilitate the sessions, and the sessions were under her responsibility.

2) For the single-arm pre-post-testing study, we administered a sociodemographic questionnaire (at T0) to the elderly participants, along with the following outcome assessments (at both T0 and T1): ACE-R, GDS-15, UCLA-16, SSSS, The Barthel Scale, and WHOQOL-bref. The intervention sessions occurred twice weekly over twelve weeks (24 sessions), each lasting approximately 60 min.

### Intervention

The 4 Exercogs® (Fig. 2) intervention involved groups of 5 to 8 older adults and was conducted by either a neuropsychologist or a psycho-motor therapist at aged care facilities. They were held in activity or social rooms with enough space to create a semicircle around the game projection on the floor, allowing for social interaction (Fig. 3). Each session occurred twice a week and lasted approximately 60 min. Participants benefited from personalized profiles for each game, enabling adjustments to difficulty levels based on their cognitive abilities and limitations. All sessions followed a structured format: 1) introduction (welcoming and temporal orientation), 2) main activity (selecting and playing one or two Exercogs®), and 3) conclusion (thanking participants, session feedback, and farewells).

The games, projected in augmented reality, were visible to all participants, allowing collective monitoring of performance. The dynamic followed a rotational model, alternating between individual task execution and collaborative activities. During individual segments, all the participants remained actively engaged through verbal encouragement, performance validation, anticipation of responses and brief discussion of the completed tasks.

In the collaborative games, conducted in dyads, interpersonal communication, strategic negotiation and mutual support were promoted, reinforcing the relational component of the intervention.

The facilitator ensured equitable participation, fostering shared attention, common goals, and the active involvement of all group members, thereby ensuring that each session, in addition to cognitive stimulation and exercise, constituted a socially participatory and cognitively stimulating group experience.

### Data analysis

Data were analyzed using the IBM SPSS Statistics version 28. Initially, descriptive analysis of the sociodemographic data was performed to characterize the sample. Feasibility variables were assessed using percentages, measures of central tendency (mean and median), and measures of dispersion (range and standard deviation).

To explore the potential effects of the technology across the various dimensions, we first conducted an exploratory data analysis to confirm the assumptions of normality (using the Kolmogorov-Smirnov test) and homogeneity of variances (using the Levene test), allowing us to select the most suitable statistical tests. We employed the paired sample *t*-test to compare pre and post-test results within each of the three groups and the one-way ANOVA to compare the mean progression of results among the groups for the variables ACE-R, GDS-15, SSSS, UCLA-16, BARTHEL, and WHOQOL\_General.

The statistically significant level was set at  $p \leq 0.05$ . We also analysed the effect size using Cohen's *d* (values  $> 0.2$  indicate a small effect;  $> 0.5$  indicate a medium effect, and  $> 0.8$  indicate a large effect) (Cohen, 1988).



Fig. 3. Implementation of the intervention in an aged care facility.

**Results**

*Feasibility outcomes*

*Adherence, satisfaction & motivation*

The older adults’ adherence to the Exercogs® intervention through the PEPE platform was calculated as a percentage of their attendance across the 16 sessions conducted. The results demonstrated high adherence (91.68%, with an average attendance of 15 out of 16 sessions).

Participants did not reside on site and attended the sessions as out-patients. Activities usually took place within the facilities, most often in common rooms where individuals were already present. Participants were aware that sessions were scheduled twice per week and typically recognized that the activity was about to begin when the equipment and members of the research team arrived. Participants without mobility limitations who wished to take part would approach the equipment. For participants with reduced mobility, staff could assist them in reaching the location where the activity was taking place, if requested. No specific

instructions were given to facility staff to remind participants about the sessions

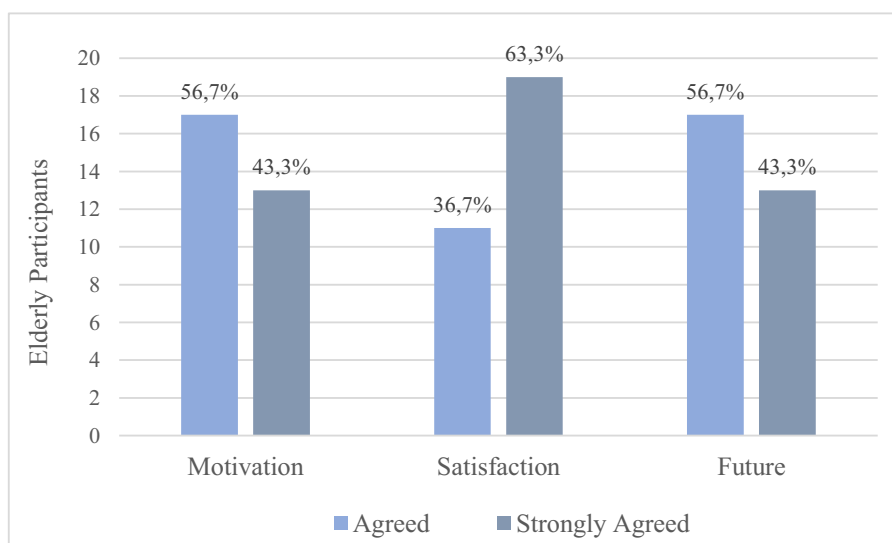
All participants completed the intervention program without any unexpected adverse events. Some participants did not attend all scheduled sessions due to fatigue, headaches, events outside the aged care facility, or unexpected weather conditions (such as heavy rain).

Regarding the elderly feedback on the intervention (Graph 1), they found the PEPE Exercogs® motivating (17 (56.7%) agreed and 13 (43.3%) strongly agreed) and were satisfied with the decision to participate in the intervention (11 (36.7%) agreed and 19 (63.3%) strongly agreed).

Additionally, they showed a willingness to engage with PEPE again in the future (17 (56.7%) agree, and 13 (43.3%) strongly agree).

*Usability*

To assess the Exercogs® usability through the PEPE platform, we applied the SUS questionnaire (administered to the older adults) and the USE questionnaire (administered to healthcare professionals). Table 2 presents the SUS and USE scores measured post-intervention.



Graph 1. Participants' feedback.

**Table 2**  
Usability outcome (SUS and USE questionnaires).

Participants	Instrument	N	Mean (SD)	Median (Min-Max)
Seniors	SUS	30	82.6 (7.2)	82.5 (70 - 95)
	Healthcare Professionals		5.9 (0.7)	—
Healthcare Professionals	USE – Total Score	12	5.5 (0.7)	5.4 (4.5 – 6.5)
	USE – (Usefulness)		5.8 (0.9)	6.0 (4.2 – 6.9)
	USE – (Ease of Use)		6.3 (0.8)	6.5 (4.3 – 7.0)
	USE – (Satisfaction)		5.9 (0.6)	6.0 (4.9 – 6.7)

*Nota.* SUS=System Usability Scale; USE=Usefulness, Satisfaction, and Ease of use.

The average score of the SUS questionnaire ( $M = 82.6$ ;  $SD=7.2$ ) exceeded 76.7 (considered an adequate cutoff point according to the literature), indicating that the technology application is suitable for the target population.

In the USE questionnaire, across all dimensions, an average score equal to or higher than 5 on a maximum 7-point scale was observed, indicating a good level of Exercogs® usability in healthcare professionals’ perceptions.

At the end of the USE questionnaire, healthcare professionals were encouraged to identify positive and negative aspects of Exercogs® intervention through the PEPE platform. Across all participants, 11 different positive aspects and three negative aspects were mentioned, indicating that this technology elicits more positive than negative impressions. Positive aspects highlighted by participants included ease of use, the ability to adjust difficulty levels for each user’s cognitive abilities, the intuitive interface, and the opportunity for group intervention. The three negative aspects mentioned were the cost of the system, sporadic motion detection failures, and the limited number of Exercogs®.

**Multidimensional variables outcomes**

In this section, we present the most significant results obtained.

**Cognitive dimension**

As measured by the ACE-R test scores, cognitive functions showed significant differences between the pre-and post-tests across the three groups: the dementia group ( $t(51) = -6.7$ ;  $p \leq 0.001$ ,  $d = 1.37$ ), the cognitive impairment group ( $t(103) = 19.3$ ;  $p \leq 0.001$ ,  $d = 2.72$ ), and the no significant cognitive impairment group ( $t(47) = -8.2$ ;  $p \leq 0.001$ ,  $d = 2.07$ ). All participants demonstrated better cognitive performance in the second assessment ( $M = 53,87$ ;  $M = 69,75$ ;  $M = 86,54$ ) compared to the

**Table 3**  
Multidimensional variables outcomes for each group in pre- and post-test.

Variables	DG (n = 52)			CIG (n = 104)			NCIG (n = 48)		
	Pre-test M ± DP	Post-test M ± DP	p,d	Pre-test M ± DP	Post-test M ± DP	p,d	Pre-test M ± DP	Post-test M ± DP	p,d
ACE-R	44,50±16,18	53,87±19,19	$p < 0001$ , $d = 1,37$	51,73±18,27	69,75±16,63	$p < 0001$ , $d = 2,72$	76,79±14,11	86,54± 8,97	$p < 0001$ , $d = 2,07$
MMSE	16,17± 5,39	19,08± 6,01	$p < 0001$ , $d = 1,03$	17,62± 5,19	23,69± 4,71	$p < 0001$ , $d = 2,33$	26,63±2,15	28,23± 2,01	$p < 0001$ , $d = 1,03$
GDS-15	6,92± 3,85	4,54± 3,64	$p < 0001$ , $d = 1,04$	5,66± 3,42	3,92± 3,36	$p < 0001$ , $d = 0,77$	4,79± 3,14	3,79± 2,97	$p = 0031$ , $d = 0,45$
SSSS	50,52±11,37	53,96±11,00	$p 0022$ , $d = 0,46$	53,07±11,19	59,28±10,76	$p < 0001$ , $d = 0,63$	51,71±10,70	57,48± 8,29	$p < 0001$ , $d = 0,79$
UCLA-16	34,37±10,67	29,56±10,02	$p < 0001$ , $d = 0,67$	31,74±10,48	25,38± 8,93	$p < 0001$ , $d = 0,86$	31,08±10,17	27,79± 8,20	$p = 0018$ , $d = 0,51$
Barthel	72,31±25,79	75,58±25,33	$p 0089$ , $d = 0,34$	87,31±19,74	90,53±18,21	$p 0008$ , $d = 0,37$	96,25±12,78	96,88±10,19	$p = 0508$ , $d = 0,15$
WHOQOL-BREF	5,77± 1,75	7,25± 1,62	$p < 0001$ , $d = 1,28$	6,48±1,47	7,63±1,24	$p < 0001$ , $d = 1,12$	6,56± 1,43	7,44± 1,43	$p < 0001$ , $d = 0,79$

Note. Dementia Group (DG); Cognitive Impairment Group (CIG) No Significant Cognitive Impairment Group (NCIG);  $p \leq 0.05$  statistic significant level;  $d$  = effect size.

first ( $M = 44,50$ ;  $M = 51,73$ ;  $M = 76,79$ ) after the exergames intervention, with a large effect size (see Table 3).

Analyzing the MMSE scores across the two assessments, an increase of 2.91 points was observed in the dementia group, 6.07 points in the cognitive impairment group, and 1.6 points in the no significant cognitive impairment group. These results indicate that the intervention positively affected the cognitive performance of the older adults.

A one-way ANOVA was conducted to evaluate which of the three groups benefited most from the exergames intervention in cognitive function. The analysis revealed statistically significant differences between the groups ( $p < 0.001$ ), with the cognitive impairment group showing a significantly greater improvement in outcomes ( $M = 18.02$ ;  $SD = 9.51$ ) compared to the dementia group ( $M = 9.37$ ;  $SD = 10.08$ ) and the no significant cognitive impairment group ( $M = 9.75$ ;  $SD = 8.29$ ).

**Mood dimension**

According to the GDS-15 scale scores, significant differences in mood levels were observed between the pre-and post-tests across the three groups: the dementia group ( $t(51) = 5.29$ ;  $p \leq 0.001$ ,  $d = 1.04$ ), the cognitive impairment group ( $t(103) = 5.52$ ;  $p \leq 0.001$ ,  $d = 0.77$ ), and the no significant cognitive impairment group ( $t(47) = 2.22$ ;  $p = 0.031$ ,  $d = 0.45$ ).

Table 3 illustrates the reduction of depressive symptoms after the exergames intervention. The dementia group experienced a decrease of 2.38 points (mean dropped from 6.92 to 4.54), with a large effect size ( $d = 1.04$ ). In the cognitive impairment group, a decrease of 1.74 points was observed (mean reduced from 5.66 to 3.92), with a large effect size ( $d = 0.77$ ). Finally, in the no significant cognitive impairment group, a reduction of 1 point was observed (mean fell from 4.79 to 3.79), corresponding to a medium effect size ( $d = 0.45$ ). A one-way ANOVA was also conducted, but no statistically significant differences were observed between the groups ( $p = 0.099$ ).

**Social dimension**

The SSSS scale scores revealed statistically significant differences in the perception of satisfaction with social support between the pre-and post-tests across the three groups: the dementia group ( $t(51) = -2.37$ ;  $p = 0.022$ ,  $d = 0.46$ ), the cognitive impairment group ( $t(103) = -4.55$ ;  $p \leq 0.001$ ,  $d = 0.63$ ), and the no significant cognitive impairment group ( $t(47) = -3.82$ ;  $p \leq 0.001$ ,  $d = 0.79$ ).

All participants demonstrated an increase in satisfaction with social support in the second assessment ( $M = 53.93$ ;  $M = 59.28$ ;  $M = 57.48$ ) compared to the first ( $M = 50.52$ ;  $M = 53.07$ ;  $M = 51.71$ ) after the exergames intervention with a medium to large effect size (see Table 3).

A one-way ANOVA was also conducted, but no statistically

significant differences were observed between the groups ( $p = 0.494$ ).

According to the UCLA-16 scale scores, significant differences in subjective feelings of loneliness and social isolation were observed between the pre-and post-tests across the three groups: the dementia group ( $t(51)=3.39$ ;  $p \leq 0.001$ ,  $d = 0.67$ ), the cognitive impairment group ( $t(103)=6.17$ ;  $p \leq 0.001$ ,  $d = 0.86$ ), and the no significant cognitive impairment group ( $t(47)=2.45$ ;  $p = 0.018$ ,  $d = 0.51$ ).

Table 3 illustrates the reduction in feelings of loneliness and social isolation after the exergames intervention. The dementia group showed a decrease of 4.81 points (mean dropped from 34.37 to 29.56); the cognitive impairment group exhibited a reduction of 6.36 points (mean declined from 31.74 to 25.38); and the no significant cognitive impairment group experienced a decrease of 3.29 points (mean dropped from 31.08 to 27.79).

These findings suggest that the intervention positively impacted the social dimension of older adults.

A one-way ANOVA was also conducted, but no statistically significant differences were observed between the groups ( $p = 0.213$ ).

#### Functional dimension

The Barthel scale scores demonstrated no statistically significant differences between the pre-and post-tests in the dementia group ( $t(51)=-1.73$ ;  $p = 0.089$ ,  $d = 0.34$ ) and the no significant cognitive impairment group ( $t(47)=-0.67$ ;  $p = 0.508$ ,  $d = 0.15$ ).

In the cognitive impairment group, statistically significant differences were observed between the pre-and post-tests ( $t(103)=-2.69$ ;  $p = 0.008$ ,  $d = 0.37$ ). Functionality scores improved, increasing from 87.31 to 90.53, with a medium effect size.

A one-way ANOVA was also conducted, but no statistically significant differences were observed between the groups ( $p = 0.393$ ).

#### Quality of life dimension

According to the WHOQOL-BREF scale scores, significant differences in the perception of quality of life were observed between the pre-and post-tests across the three groups: the dementia group ( $t(51)=-6.52$ ;  $p \leq 0.001$ ,  $d = 1.28$ ), the cognitive impairment group ( $t(103)=-7.97$ ;  $p \leq 0.001$ ,  $d = 1.12$ ), and the no significant cognitive impairment group ( $t(47)=-3.84$ ;  $p \leq 0.001$ ,  $d = 0.79$ ).

All participants demonstrated an increase in the perception of quality of life in the second assessment ( $M = 7.25$ ;  $M = 7.63$ ;  $M = 7.44$ ) compared to the first ( $M = 5.77$ ;  $M = 6.48$ ;  $M = 6.56$ ) after the exergames intervention (see Table 3).

A one-way ANOVA was also conducted, but no statistically significant differences were observed between the groups ( $p = 0.144$ ).

## Discussion

This study validated a newly integrated portable exergaming platform designed for older adults. We assessed the feasibility and explored the technology's effects across several dimensions (cognitive, affective, social, functional, and quality of life). In general, the newly developed Exercogs® are highly acceptable by older adults and healthcare professionals, with positive influences on all studied cognitive dimensions.

#### Feasibility of the exergame training

The adherence rate of 91.68% is very high and aligns with previous studies that evaluated seniors' adherence to exergame interventions (Adcock et al., 2020; Altorfer et al., 2021; Kwan et al., 2021). However, it is important to acknowledge that, as in most studies, the intervention in this research was closely supervised by a healthcare professional (specifically, a psychologist), which may have positively impacted the adherence rate by fostering a therapeutic alliance (Moore et al., 2020). This elevated adherence rate may also be attributed to the strong motivational potential of these innovative technologies and the enjoyment that participants experienced while engaging with the exergames

(Gallou-Guyot et al., 2020; Zhao et al., 2020). Many older adults enjoy playing exergames (Adcock et al., 2020; Altorfer et al., 2021), which was also the case in this study in which high motivation and enjoyment levels were perceived during the training sessions. Furthermore, these participants showed a willingness to continue with cognitive stimulation sessions. In response to the question regarding their desire to keep using the exergames in the future, 43.7% indicated "strongly agree" and 56.7% of seniors indicated "agree", highlighting the appeal of this tool for the elderly population.

It is worth emphasizing that the absence of adverse events during the study indicates that exergames are safe for healthy older adults and for those with physical and cognitive limitations.

The newly developed Exercogs® demonstrated acceptable usability, as reflected in the questionnaire ratings. The System Usability Scale (SUS) scores exceeded the established cutoff point of 76.7, and the average scores on the Usability Scale for End Users (USE) were equal to or above 5 on a 7-point scale. These findings suggest that seniors and healthcare professionals perceived the tool's applicability positively, highlighting its potential as a feasible and user-friendly intervention capable of reaching all older adults by personalizing the profile for each participant.

However, healthcare professionals pointed out some negative aspects, such as the cost of the system, issues with the motion detector (including system blocking), and the limited number of available Exercogs®.

These findings are consistent with previous research showing that exergames are generally well-received and usable by older adults (Altorfer et al., 2021; Freed et al., 2021; Paulino et al., 2019).

#### Exploration of potential effects of the exergame training

Our study showed significant improvement in cognitive function following the exergames intervention. These findings align with previous studies that have used exergames as a tool to stimulate cognitive functions in older adults (Liao et al., 2020; Zhao et al., 2020; Zhong et al., 2021). However, the improvements observed in the MMSE scores (2.91 points in the dementia group, 6.07 points in the cognitive impairment group, and 1.6 points in the no significant cognitive impairment group) were high, exceeding what is typically for interventions (see Woods et al., 2023 for people with dementia). One possible explanation is that the initial assessment (pre-test) may not have fully reflected the participants' true cognitive capacities due to contextual factors stemming from the COVID-19 pandemic. These factors likely included reduced cognitive stimulation, social isolation, and mood alterations, which may have negatively impacted the initial assessment of cognitive performance (Kassam & McMillan, 2023; Martín-Erice et al., 2024). This hypothesis can be supported by evidence showing that prolonged periods of isolation and lack of engagement can negatively impact cognitive and emotional functioning in older adults (Sepúlveda-Loyola et al., 2020; Simonetti et al., 2020). Moreover, the unexpectedly high improvement observed in the dementia group might have resulted from the intervention being conducted in mixed groups, where individuals with dementia participated alongside others with different profiles and fewer impairments, without separating participants based on their conditions. This inclusive setup may have enabled individuals with dementia to benefit from observation, imitation, and the development of support networks, which possibly contributed to their improved cognitive performance.

Furthermore, this technology enables the creation of a personalized profile for each participant, minimizing potential difficulties and enhancing the overall experience for individuals with dementia.

We also observed that the group with cognitive impairments benefited the most from the intervention with exergames. This finding can be attributed to several factors. Individuals in this group, being in cognitive decline but not being demented, have a greater

potential for improvement compared to those performing within the average range for their age and educational level. In contrast, individuals in the dementia group have a significantly reduced capacity for cognitive improvement due to the progressive nature of neurodegenerative diseases, which typically result in a continuous decline over time, leaving limited room for measurable gains (Chan et al., 2024). Therefore, the group with cognitive impairments possesses more significant potential to enhance their cognitive abilities. This improvement is particularly possible due to brain plasticity, even in advanced ages, allowing for cognitive improvement in response to the intervention. Exergames, combining physical activity and cognitive engagement, may be beneficial in enhancing cognitive resilience to degenerative brain processes (Jardim et al., 2021; Mundada & Dadgal, 2022). The intervention not only served as a cognitive stimulus but also provided a structured and socially engaging activity, which might have mitigated some of the pandemic's effects.

By being an activity conducted in a group setting, the intervention promoted social connections, encouraging interaction and engagement among participants. Moreover, it is important to emphasize that although most activities were performed independently, all seniors actively benefited from the intervention, even in a passive way. By observing the cognitive tasks, participants remained focused on the activity, mentally engaging with it, stimulating their attention, and motivating those actively participating. Even without direct participation, this continuous involvement created an inclusive environment where passive observation may have yielded significant cognitive and social benefits.

This dual benefit of cognitive stimulation and social engagement is further supported by additional findings from the study, which highlight improvements in emotional well-being, reduced isolation, and enhanced overall quality of life following the exergames intervention.

A significant reduction in depressive symptoms was observed across all groups. In the dementia group, depressive symptoms decreased by 2.38 points; the cognitive impairment group exhibited a reduction of 1.74 points; and the no significant cognitive impairment group experienced a decrease of 1 point. These results suggest that the intervention not only targeted cognitive performance but also addressed emotional challenges, potentially alleviating symptoms of depression that were exacerbated by the social isolation and stress associated with the COVID-19 pandemic.

In addition to its emotional benefits, the Exercogs® intervention positively influenced social dimensions, as evidenced by increased participants' satisfaction with social support and reduced feelings of loneliness and social isolation after the Exercogs® intervention. These improvements contributed to increased participants' perceptions of quality of life in the second assessment ( $M = 7.25$ ;  $M = 7.63$ ;  $M = 7.44$ ) compared to the first ( $M = 5.77$ ;  $M = 6.48$ ;  $M = 6.56$ ).

These findings align with prior research suggesting that interventions combining cognitive stimulation with social engagement can synergistically affect mental health and quality of life in older populations (Cardoso et al., 2019; Liao et al., 2020; Zhao et al., 2020). For these dimensions, no differences were observed among the three groups, suggesting that stimulation with Exercogs® benefits all older adults equally.

Regarding the functionality dimension, no improvements were observed in the group with dementia and the group without cognitive impairments. In the group with dementia, this outcome was expected, as functional difficulties are characteristic of the diagnosis and tend to be more resistant to intervention (Cloutier et al., 2020). In the group without cognitive impairments, their high baseline level of independence (mean value 96.25) likely left little room for further improvement, suggesting a potential ceiling effect. In contrast, the group with cognitive impairments showed a statistically significant improvement, highlighting the positive impact of Exercogs® on this population. These

older adults demonstrated enhanced functionality with appropriate external support, which may contribute to greater independence.

This study has several limitations that limit the interpretation of the results. Since the study did not include a control group, it is not possible to determine to what extent the observed improvements can be attributed specifically to the intervention rather than to other factors such as social interaction, engagement with the research team, or participation in structured group activities.

The study also adopted a naturalistic approach in which participants were not allocated to intervention groups based on cognitive status. Although this approach increases ecological validity and reflects the real-world context in which such interventions are intended to be delivered, and is a deliberate choice of the researchers, it also resulted in a heterogeneous sample with different cognitive profiles which may have influenced the magnitude and variability of the observed effects. Since it was conducted under real-world conditions in multiple institutions, several contextual factors could not be fully controlled. While we believe this approach improves the ecological validity and practical relevance of the findings, it should nevertheless be recognized that may also introduce additional variability.

Future studies should address these limitations, particularly the absence of a control group, implementing a randomized controlled trial with appropriate comparator to more clearly isolate the effects of the intervention

## Conclusion

The findings demonstrated that this innovative and creative intervention was highly acceptable and well-received among older adults and healthcare professionals. This indicates that integrating this tool into elderly support structures is feasible. By offering a personalized approach, this technology enables the inclusion of all older adults, regardless of age, cognitive profile, or physical condition, allowing them to participate in the same cognitive stimulation sessions. Furthermore, it supports healthcare professionals by simplifying their work processes and making more efficient use of their time. This adaptability was highly valued by the health professionals involved.

Additionally, significant improvements were observed in various domains commonly affected by the aging process, including cognition, mood, perceived loneliness, and perceived quality of life among older adults.

The results indicate that Exercogs® have the potential to be integrated into preventive, therapeutic, and cognitive rehabilitation programs, regardless of an individual's condition.

However, the outcomes should be interpreted cautiously due to the absence of a control group and the non-normative context in which the interventions were conducted (after the COVID-19 pandemic).

Nevertheless, the preliminary results of the Exercogs® application suggest a significant potential of this technology as a valuable and complementary tool for healthcare professionals to support seniors in aged care facilities. These findings represent a significant step forward, offering a foundation for refining the approach and conducting future randomized clinical trials to validate and expand upon these promising results.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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