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Use of serious games with older adults: systematic literature review

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The aim of this paper is to qualitatively synthesise literature on empirical research into video games and older adults. A total of 108 studies were analysed, with the participation of 15,902 individuals aged over 60. The framework of Search, Appraisal, Synthesis, and Analysis (SALSA) was used, with screening by three independent reviewers and phrase searching and combining search terms. The results indicate a majority of studies with a quantitative approach conducted in the European context in which a total of 125 scales were identified for the assessment of different geriatric aspects related to domains for the improvement of physical health and functional quality, improvement of cognitive, psychological and mental health, and improvement of physical and cognitive functions from a combined approach.

Introduction

In increasingly digitised social scenarios, certain groups are at a disadvantage. This is the case for the elderly. At the root of digital exclusion and the various digital divides are issues related to technical aspects and infrastructures, but above all a set of negative beliefs and stereotypes about older adults, which reinforce and amplify the effect of digital exclusion. Some studies suggest that the digital divide affecting this age group can be explained by internal motivational factors. For example, relative deprivation theory holds that relative disadvantage exists when people perceive themselves to be (unjustifiably) disadvantaged or different compared to others in a given situation. The negative stereotype of technological incapacity reinforces the subject's perception of the difficulty of using certain devices and the avoidance of situations in which they are necessary resulting in the underuse of technology, which contributes to maintaining the digital divide (Mariano et al., 2022). The case of video games exemplifies a type of resource traditionally associated with younger people and of little interest to older people.

However, available research suggests that video game-based technology can create opportunities for social connection, helping to alleviate social isolation and loneliness in this age group. For this reason, and in the framework of so-called positive technology, the use of video games (*serious games*) is one of the most current topics generating most interest among the gerontological scientific community, public leaders interested in developing active ageing and community health policies, as well as video game developers and the video game industry as a whole. Despite this interest, serious games are a relatively new field of study that could be described as the use of video games to help users achieve a specific objective through gaming (Barbosa et al., 2018). Game-based methods and concepts and gaming technology are thus

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combined with other ICTs and research areas and applied to a wide scope of domains of use ranging from training, simulation and education to sport and health, or any other relevant social or business topic (Barbosa et al., 2018). As a complement to traditional interventions, these digital games can help older adults boost their health by improving their physical condition and coordination skills, combined with greater motivation generated by the game experience and fun while practising. In any case, the purpose of serious games is much more than entertainment —which is still a factor—, seeking to achieve objectives that could be considered as educational and learning in the broadest sense.

As indicated, and despite interest in serious games as a gerontological resource, current knowledge available in this field is still incipient. After a first phase of study, specialised literature shows that most researchers have focused on understanding what type of digital games can be more interesting for older adults. Some studies have verified that most tend to play digital games known as casual (Gigante, 2009) and/or educational games. From this starting point, studies have focused on reviewing the effect this type of game could have as a support for cognitive training in gerontological therapy. The idea is to assess how to use video games to help maintain cognitive skills, increase self-esteem, improve coordination or reaction times or also to improve aspects such as spatial awareness, reasoning and mental rotation (McLaughlin et al., 2012). In a second phase, researchers are analysing to what extent the use of different types of casual, serious, social and educational games is related to the emotional and social well-being of older adults (Kaufman et al., 2019). Aspects such as cooperative and social play are viewed to contribute to improving social interaction and active participation, they also help maintain general cognitive function in older adults, improving social support, integration and social interaction. Finally, video games are also being analysed as mere entertainment, as an e-leisure resource. In this case, this type of resource is understood to also help improve mood, reducing sadness and depression (Nazry and Romano, 2017), helping to maintain social networks, and social and community ties in this age group. Despite the rough outline of these areas of interest and research studies, the relative youth of this research field means that there are many gaps and a lack of knowledge on basic aspects regarding the use of digital games for and by older adults, and this is well worth analysing. For this reason, we adopted a systematic review method to examine general literature available on serious games and adults over 60 years old in order to provide an overview of the state of gerontological research into this subject.

AIMS of review

Systematic review is a strategy to search for and select the best evidence published in certain bibliographical sources on a research topic, offering a series of theoretical and practical recommendations on the topic. In this case it was a review of studies published in the last 5 years on serious games and older adults in an attempt to clarify what knowledge is available on the matter. This SLR specifically attempts to clarify the following key questions:

1. What main objectives are proposed in studies on non-commercial serious games and older adults?
2. What are the main categories and types of video games and what have they been used for in the studies reviewed?
3. What are the main instruments and measurement scales used in studies on serious games and older adults? (screening)
4. What are the main results obtained after using serious games with older adults for socio-educational purposes? (with older adults aged 65 and above)

Method

Search strategy and study selection. Search, Appraisal, Synthesis and Analysis (SALSA) framework was implemented to guarantee the methodological precision of this research (Grant and Booth, 2009). The search process was carried out in August 2023. In this phase, firstly, Web of Science (WoS) and Scopus databases were selected to search for literature due to their impact factor and multidisciplinary nature. For the search, a term algorithm was established based on a series of keywords, some of which included the asterisk symbol ('*') as a truncation operator: (exergam* OR videogam* OR serious gam*) AND (elder* OR old* OR ageing). This algorithm was applied to field labels corresponding to Title, Abstract and Keywords. Secondly, a series of inclusion and exclusion criteria were established to assess literature based on two perspectives. The first focuses on filters applied during the search process, and the second on criteria to ascertain eligibility of the research studies. The criteria of both perspectives are shown in Table 1.

Thirdly, based on the research questions, a content matrix was designed as a documentation method and coding of information for the synthesis phase. It included the following coding variables: (a) author(s) «AUT», (b) year of publication «YP», (c) article title «AT», (d) research objective «RO», (c) research methodology «RM», (d) research instrument or test «RIT», (e) selected sample «SS», (f) geographical context «GC», (g) objective of the videogame «OVG», and (h) description of the videogame «DVG». Las variables «RM», «RIT», «SS», «GC» and «OVG» were coded for descriptive calculations (mean, standard deviation and frequency) using the statistical analysis package SPSSv.26 (Licence of *Anonymised*).

To categorise the research instruments or tests used in the studies, as well as the objectives of the video games, three categories were established: (a) physical domain, which covers

Table 1 Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Search filter criteria	
(a) Open-access and free publications	(a) Restricted-access publications
(b) Research published from January 2017 to July 2023.	(b) Research published outside the date range
(c) Research in English or Spanish	(c) Research in languages other than English or Spanish
(d) Researched published as articles in journals	(d) Research published as books, chapters, book reviews, conference papers, research protocols, theses
Eligibility criteria	
(a) Research describing the video game designed, implemented and/or assessed	(a) Research that does not describe the video game designed, implemented and/or assessed
(b) Research in which the video game is a study variable	(b) Research in which the video game is not a study variable
(c) Research in which the simple is comprised of older adults	(c) Research in which the simple is not comprised of older adults

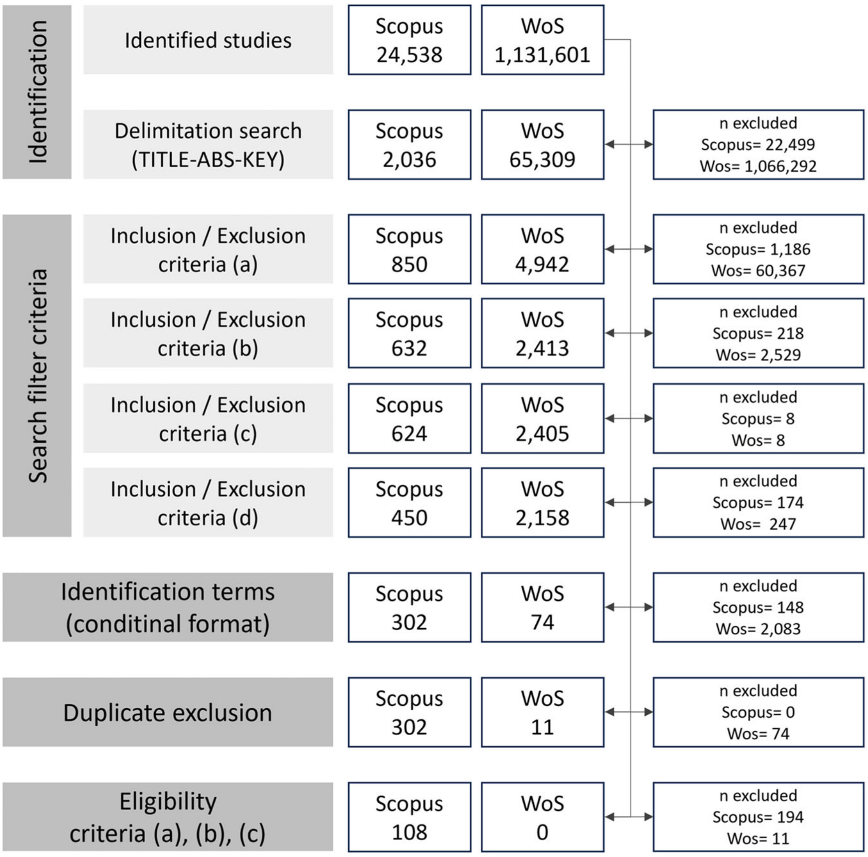

Fig. 1 Selection process of the studies. *n* number of identified studies.

aspects related to assessment, training and improvement of physical health and functional quality; (b) cognitive domain, encompasses aspects related to the assessment, training and improvement of cognitive, psychological and mental health; and (c) multi-modal domain, including aspects related to the assessment, training and improvement of physical and cognitive functions from a combined approach. A qualitative approach was also applied by means of narrative analysis for the variables «RO» and «DVG» And, fourthly, different objectives and video games presented in the studies selected were described and analysed for the final phase of the SLR, identifying which domains (general and specific) were targeted by each.

As a result of applying the search filter criteria a total of 2608 articles were obtained (WoS $n = 2158$; Scopus $n = 450$). Due to the high number of pre-selected research, a search for key terms in the title and abstract was executed using conditional formats. In this way, 376 articles were identified (WoS $n = 74$; Scopus $n = 302$) containing the following terms in one of the two fields: 'exergam*', 'serious gam*', 'video gam*', 'video gam*', 'game", 'gaming'. Then, after excluding duplicate studies (generally from the WoS database), a total of 313 articles were identified (WoS $n = 11$; Scopus $n = 302$). Finally, after applying the eligibility criteria, 205 studies were excluded: 1 did not provide information on the age ranges of the sample; 14 focused on perceptions, usability, feasibility or improvements in the video game without providing information on benefits or impact on participants; 19 did not include older people in their sample; 20 did not provide descriptive or contextual information about the video game or did not study the video game as a video game per se; and 151 investigations did not analyse the video game as a study variable. These included literature reviews or research protocols. Finally, a total of 108 articles were selected for inclusion in the research (Fig. 1).

Results

Characteristics of the selected studies. The 108 articles selected were then read in depth. In summary, the main data on the matter subject to analysis appear in Table 2.

The following information was taken from each of these studies: author(s), year of publication, title, type of study, objectives presented in the article, geographical context, users or participants. Based on these data it is clear that a majority of these research studies were in the European context (51.38%), specifically in Belgium, Czech Republic, France, Germany, Hungary, Netherlands, Poland, Portugal, Spain, Switzerland and United Kingdom; meanwhile, the 20.18% of the studies analysed correspond to the Asian context (Singapore, Malaysia, Thailand, Japan) and 20.18% to the American context.

The set of studies analysed comprises a total of 15,902 participants. It is important to note that the majority of this sample corresponds to the study by Bonnechère et al. (2021), which included 12,000 people over the age of 60. On the other hand, Table 2 shows that the sample selected in most of the studies is limited to older people. However, four papers were identified that included participants with different age ranges. The research by Brauner and Ziefle (2022) included a sample of 128 participants, with a minimum age of 16 and a maximum age of 84 years. However, the study does not provide specific information on the age distribution of the participants. Chesham et al. (2019), Kaplan et al. (2018) and Qiu et al. (2023) conducted their studies on heterogeneous samples in terms of age. In the

Table 2 General characterization of the studies analysed.

Author/s (Publication Years)	Context	Type of Study Conducted	Sample
Adcock et al. (2020a)	Europe	Quantitative	31 participants/age group 65-90 years
Adcock et al. (2020b)	Europe	Mixed	19 participants/age group 65-91 years
Anguera et al. (2017)	United States	Quantitative	22 participants/age group 61-75 years
Ayed et al. (2018)	North Africa	Quantitative	2 participants/age group 72-78 years
Ballesteros et al. (2017)	Europe	Quantitative	55 participants/age group 60-73 years
Becker et al. (2020)	Europe	Quantitative	16 participants/age group +60 years
Belchior et al. (2019)	United States	Mixed	54 participants/age group 65-86 years
Beltran-Alacreu et al (2022)	Europe	Quantitative	18 participants/age group +65 years
Boj et al. (2018)	Europe	Quantitative	8 participants/age group 51-79 years
Bonnechère et al. (2021)	Europe	Mixed	12.000 participants/age group +60 years
Brachman et al. (2021)	Europe	Quantitative	13 participants/age group 65-80 years
Brauner and Ziefle (2022)	Europe	Quantitative	64 participants/age group 16-84 years 64 participants/age group 17-84 years
Bukhari et al. (2022)	Asia	Quantitative	24 participants/age group 60-75 years
Campo-Prieto et al. (2021)	Europe	Mixed	4 participants/age group 65-77 years
Campo-Prieto et al. (2022a)	Europe	Quantitative	12 participants/age group +90 years
Campo-Prieto et al. (2022b)	Europe	Quantitative	24 participants/age group +65 years
Chesham et al. (2019)	Europe	Quantitative	28 participants/age group 18-31 years 13 participants/age group 64-79 years 11 participants/age group 86-94 years
Chu et al. (2021)	Canada	Qualitative	13 participants/age group 66-97 years
Chua et al. (2019)	Asia	Mixed	60 participants/age group 67-79 years
Da Silva et al. (2021)	South America	Mixed	23 participants/age group +60 years
De Bruin et al. (2019)	Europe	Quantitative	20 participants/age group 71-87 years
De Queiroz et al. (2017)	South America	Quantitative	27 participants/age group 54-68 years
Dijkstra et al. (2018)	Europe	Quantitative	33 participants/age group 70-87 years
Drazich et al. (2023)	United States	Qualitative	14 participants/age group 63-96 years
Ellmers et al. (2018)	United States and United Kingdom	Mixed	26 participants/age group 69-87 years
Eun et al. (2022)	Asia	Quantitative	39 participants/age group 60-80 years
Farzin et al. (2018)	Asia	Quantitative	25 participants/age group 55-74 years
Ferreira et al. (2022)	Europe	Quantitative	28 participants/age group +60 years
Freed et al. (2021)	United States	Mixed	20 participants/age group 65-84 years
Gallou-Guyot et al. (2023)	Europe	Quantitative	39 participants/age group +65 years
Ghorbani et al. (2022)	Asia	Quantitative	37 participants/age group +50 years
Gielis et al. (2021)	Europe	Quantitative	46 participants/age group 64-76 years
Guimarães et al. (2018)	South America	Quantitative	27 participants/age group 56-65 year
Gunst et al. (2022)	Europe	Quantitative	32 participants/age group +70 years
Hernandez-Martínez et al. (2022)	South America	Quantiative	25 participants/age group 60-89 years
Høeg et al. (2023)	Europe	Mixed	10 participants/age group 64-91 years
Hou et al. (2022)	Asia	Quantitative	48 participants/age group +50 years
Hou et al. (2023)	Asia	Quantitative	128 participants/age group 60-80 years
Jahouh et al. (2021)	Europe	Quantitative	80 participants/age group 74-93 years
Janhunen et al. (2022)	Europe	Quantitative	7 participants/age group +60 years
Janhunen et al. (2023)	Europe	Quantitative	50 participants/age group 60-75 years
Jirayucharoensak et al. (2019)	Asia	Quantitative	119 participants/age group 67-81 years
Kamińska et al. (2018)	Europe	Quantitative	23 participants/age group 67-84 years
Kamnardsiri et al. (2021)	Asia	Mixed	5 participants/age group 65-79 years
Kaplan et al. (2018)	Asia	Quantitative	14 participants/age group 69-76 years 15 participants/age group 24-30 years
Kleschnitzki et al. (2022)	Europe	Quantitative	56 participants/age group 62-96 years
Lee (2023)	Asia	Quantitative	55 participants/age group +75 years
Li et al. (2020)	Asia	Mixed	20 participants/age group 65-87 years
Li et al. (2021)	Asia	Mixed	23 participants/age group 64-84 years
Liepa et al. (2022)	Europe	Quantitative	44 participants/age group 60-85 years
Liu et al. (2022)	Asia	Quantitative	50 participants/age group +65 years
Maixnerová et al. (2017)	Europe	Quantitative	28 participants/age group 73-89 years
Maranesi et al. (2022)	Europe	Quantitative	30 participants/age group +65 years
Martins et al. (2020)	Europe	Quantitative	34 participants/age group 76-93 years
Mascarenhas et al. (2023)	South America	Quantitative	50 participants/age group 60-79 years
Merriman et al. (2022)	Europe	Quantitative	56 participants/age group 65-84 years
Money et al. (2019)	Europe	Mixed	15 participants/age group 50-80 years
Moret et al. (2022)	Europe	Quantitative	38 participants/age group +65 years
Mugueta-Aguinaga and Garcia-Zapirain (2017)	Europe	Quantitative	39 participants/age group 74-93 years
Mugueta-Aguinaga and Garcia-Zapirain (2019)	Europe	Quantitative	40 participants/age group +65 years
Müller et al. (2023)	Europe	Quantitative	28 participants/age group +70 years
Nath et al. (2023)	United States	Quantitative	33 participants/age group +50 years
Neumann et al. (2018)	Europe	Quantitative	33 participants/age group 53-93 years
Nonino et al. (2018)	South America	Quantitative	24 participants/age group 63-78 years
Oliveira et al. (2021)	South America	Quantitative	14 participants/age group 71-92 years
Ordnung et al. (2017)	Europe	Quantitative	29 participants/age group 63-77 years
Padala et al. (2017)	United States	Quantitative	30 participants/age group 60-74 years
Pereira et al. (2019)	Europe	Quantitative	39 participants/age group 56-91 years
Perrot et al. (2019)	Europe	Qualitative	36 participants/age group 60-71 years
Phirom et al. (2020)	Asia	Quantitative	40 participants/age group 66-74 years
Qiu et al. (2023)	Asia	Mixed	18 participants/age group 55-70 years 18 participants/age group 17-35 years
Radhakrishnan et al. (2020)	United States	Mixed	10 participants/age group 55-84 years

Table 2 (continued)

Author/s (Publication Years)	Context	Type of Study Conducted	Sample
Ramnath et al. (2021)	South Africa	Quantitative	45 participants/age group 66-78 years
Randriambelonoro et al. (2023)	Europe	Quantitative	57 participants/age group 67-97 years
Rebêlo et al. (2021a)	South America	Quantitative	5 participants/age group 60-74 years
Rebêlo et al. (2021b)	South America	Quantitative	4 participants/age group 61-77 years
Ren et al. (2022)	Europe	Quantitative	24 participants/age group +60 years
Ruggiero et al. (2023)	United States	Mixed	71 participants/age group +50 years
Sadeghi et al. (2017)	Asia	Quantitative	30 participants/age group 66-80 years
Shah et al. (2022)	Europe	Mixed	14 participants/age group +60 years
Sápi et al. (2021)	Europe	Quantitative	14 participants/age group 64-75 years
Segal et al. (2022)	United States	Quantitative	19 participants/age group 58-74 years
Soancatl Aguilar et al. (2018)	Europe	Quantitative	10 participants/age group 72-88 years
Souders et al.(2017)	United States	Quantitative	60 participants/age group 66-79 years
Stamm et al. (2022)	Europe	Quantitative	22 participants/age group +65 years
Stanmore et al. (2019)	Europe	Quantitative	106 participants/age group +55 years
Swanenburg et al. (2018)	Europe	Quantitative	10 participants/age group 65-82 years
Swinnen et al. (2021a)	Europe	Quantitative	45 participants/age group 70-91 years
Swinnen et al. (2021b)	Europe	Mixed	22 participants/age group 70-95 years
Tabak et al. (2020)	Europe	Mixed	20 participants/age group 70-72 years
Talaei-Khoei and Daniel (2018)	United States	Qualitative	21 participants/age group 65-87 years
Triandafilou et al. (2018)	United States	Quantitative	15 participants/age group 33-81 years
Valenzuela et al. (2018)	Australia	Qualitative	24 participants/age group 73-89 years
Van der Kooij et al. (2019)	Europe	Quantitative	24 participants/age group 68-83 years
Vorwerg-Gall et al. (2023)	Europe	Quantitative	22 participants/age group +65 years
Vozzi et al. (2022)	Europe	Mixed	32 participants/age group 65-80 years
Willaert et al. (2020)	Europe	Quantitative	16 participants/age group 66-72 years
Wong et al. (2022)	Asia	Quantitative	40 participants/age group +60 years
Wu et al. (2023)	Asia	Quantitative	24 participants/age group +65 years
Yang et al. (2020)	Asia	Quantitative	20 participants/age group 62-77 years
Yoon et al. (2019)	United States	Mixed	230 participants/age group 64-92 years
Yu et al. (2019)	United States	Quantitative	80 participants/age group 62-98 years
Yuan et al. (2020)	Asia	Quantitative	24 participants/age group 57-75 years
Zadro et al. (2019)	Australia	Quantitative	60 participants/age group 62-74 years
Zahn et al. (2022)	Europe	Qualitative	10 participants/age group 76-93 years
Zając-Lamparska et al. (2019)	Europe	Quantitative	99 participants/age group 60-89 years
Zangirolami-Raimundo et al. (2019)	South America	Quantitative	83 participants/age group +65 years
Zhao et al. (2022)	Asia	Quantitative	55 participants/age group +60 years

first research, three groups were established: 28 subjects aged 18–31 years, 13 subjects aged 64–79 years and 11 subjects aged 86–94 years. In the second study, the sample included a group of 15 participants aged between 24 and 30 and a second group of 14 subjects aged between 69 and 76. Finally, in the third study, the sample was divided into two age ranges, 17–35 years and 55–70 years, with a total of 18 participants in each group. Chesham et al. (2019), Kaplan et al. (2018) and Qiu et al. (2023) conducted their studies on heterogeneous samples in terms of age. In the first research, three groups were established: 28 subjects aged 18–31 years, 13 subjects aged 64–79 years and 11 subjects aged 86–94 years. In the second study, the sample included a group of 15 participants aged between 24 and 30 and a second group of 14 subjects aged between 69 and 76. Finally, in the third study, the sample was divided into two age ranges, 17–35 years and 55–70 years, with a total of 18 participants in each group. Regarding the minimum and maximum ages included in the samples, as well as the ranges corresponding to this age group, in 22.07% of the studies, the minimum age corresponds to 65 years, while in 18.60% of the investigations, the minimum age of the sample is 60 years. On the other hand, in 7.44% of the studies, there were participants with a maximum age of 80 and 74 years, both of them coinciding in percentage.

In relation to the number of publications per year, Fig. 2 shows that from 2017 to 2021 the publication of research in this line shows a gradual increase, with a slight decrease in 2021. In 2022, the number of publications increased considerably, representing more than 25% of the research analysed. As for the year 2023, the number of published works is lower, corresponding to 10.20% of the selected studies. However, it is important to bear in mind that the publications of the latter year are limited to the first half of the year. In terms of the productivity of the main authors responsible for the papers, there is no clear leadership in this line of research.

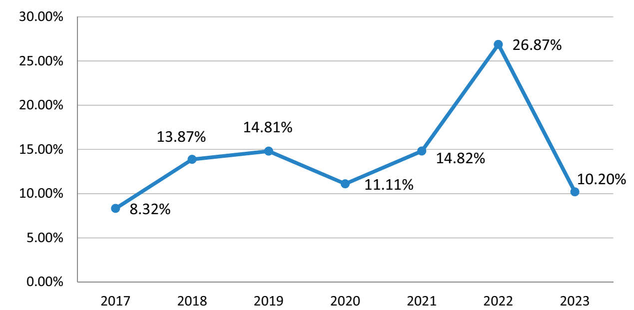

Fig. 2 Number of publications per year (2017–2023).

What are the main objectives set out in studies on non-commercial and major serious games? In this section we review only non-commercial video games. In this group, 47.17% are related to the improvement or evaluation of the physical domain (exergames), 30.19% to multi-modal training and 22.64 per cent are associated with cognitive training.

This section only reviews non-commercial video games. In this group, 47.17% are related to improving or assessing the physical domain (exergames), 30.19% to multi-modal training, and 22.64% to cognitive training.

Objective 1: improving physical health, functional quality and quality of life. Physical domain video games are designed for training, improving and assessing different motor and coordination skills; they are the so-called exergames. This type of video game encourages moving the body while using interactive environments with immersive experiences that simulate different feelings of presence. Most exergames included in this domain focus on coordination skills such as combination, balance and space-time perception. (Ayed et al., 2018) research the feasibility and effectiveness of exergame prototypes designed for training posture control and balance rehabilitation in older adults. These prototypes, called 'Reach Game', 'Hit-it' and 'Watch-Out', required users to complete coordinated upper and lower limb movements, trunk movements and lateral displacements to achieve the goals set in the games. Similarly, Janhunen et al., (2022) also present ten exergames custom-designed for older users who needed rehabilitation for post-operative knee replacement. Each exercise included a story explaining the goal of the game and the participants' body movements, tracked by the Kinect sensor, which acted as a game controller and was translated to the screen to move the avatar. The exercises were performed according to each participant's mobility limitations. From there, in the research by Janhunen et al., (2023), they present a programme of 11 personalised post-operative knee replacement surgery games that engage patients in self-directed, personalised therapeutic exercises at home for physical function and pain reduction in older adults following knee replacement surgery. Meanwhile, Brachman et al., (2021) assess the efficacy of the balance exercise training programme in improving users' posture control, as well as static and dynamic balance. The seven exergames used were based on virtual reality immersive environments in which players practised static postures, dynamic weight changes, balancing on one leg, leaning in different directions and trunk rotations. Exergame software meant that the difficulty of these movements could be adapted to the individual abilities of each participant.

Continuing with exergames linked with balance and posture control, on one hand, (Soancatl Aguilar et al., 2018) conducted a study to research how an ice-skating exergame affects dynamic posture control and balance. To achieve this, the software offers two game modes: one for movement coordination and the other for player resistance. On the other hand, Ellmers et al. (2018), conducted a study to assess the potential of gamified interventions with video games in reducing discrepancies between perceived balance skills and real skills in older adults. The researchers present a game, 'Pong', which is an adaptation of a traditional game. Using a commercial balance platform (Wii Balance Board) and in a virtual reality environment, players must control paddle displacement by maintaining balance. By moving their centre of gravity forward, players moved the paddle upwards, while by moving backwards the paddle moved down. Also using virtual reality, Bukhari et al. (2022) develop training games that allow participants to interact with a virtual environment to perform different exercise games (target shooting, football head-butts, table tilting, tight rope tension and snowboard slalom) to improve balance, gaze stability and gait performance. Similarly, Yuan et al. (2020) present a research study to assess the efficiency of gamified interventions with interactive video games on balance in older adults, in this case patients suffering from Parkinson's with minor to moderate symptoms. This software comprises two tasks: in one, players must take steps in multiple directions guided by illustrated instructions indicating where they must step. This assesses the user's ability to change their weight, their dynamic and static balance. The other task is to take guided steps towards an objective, assessing coordination skills of orientation and balance.

Dijkstra et al. (2018), Martins et al. (2020), Neumann et al. (2018) and Vorwerg-Gall et al. (2023) present a study that focuses on the efficiency of exergames in improving balance and also their effect on improving resistance and muscle strength, taking into account the state of the participant's musculoskeletal system and even the improvement of blood pressure. Dijkstra et al. (2018) is to assess whether exergames are an effective method for favouring the autonomy and independence of older adults. For this they used 'Fox Hunting Game', where the goal is to find the fox avatar three times. The user's graphic interface is a virtual world with three settings—a street, a museum and a zoo— that the player can move around by walking. The player must indicate which direction their avatar should go by moving their arms. All these movements are recorded and viewed using a motion sensor. The software also allows the user to increase their score by playing mini-games included in the programme. These mini-games are related with reach and grip, balance and squats. As a result, this exergame can train and improve the coordination skills of combination, balance and space-time perception. Finally, there are two game modes (individual and multi-player) making it a social activity.

Martins et al. (2020) assess the effect of a virtual training programme for balance and muscle strength in older adults. The programme is based on the traditional Otago Exercise Programme. In the study, the researchers assessed the results of three mini-games in the 'm-OTAGO' exergames that trained the coordination skills of combination, balance and reaction by completing exercises to bend the knees and move from sitting to standing on two feet, exercises to strengthen the hip and knees, and exercises to lift the calves and toes. These movements are shown in the graphic interface with a penguin avatar in different environments where the player must avoid obstacles and overcome different challenges. Neumann et al. (2018) assess how a virtual training programme called 'WeTakeCare-System' affects certain body functions, as well as performance and quality of life in older adults. This exergame has three games: 'Sound Movement', 'Treasure Hunt' and 'Sudoku'. In this case, the activities are used to maintain and improve body functions such as balance, resistance and mobility, focusing on upper and lower limb mobility, preventing risk of falls, balance, resistance and muscle strength.

Alongside them, Vorwerg-Gall et al. (2023) focus their research on studying virtual reality exercise training games specifically for older people with hypertension. In this way, through a home-based physical exercise programme for older people with hypertension, they manage not only to improve their general physical health but also to contribute to the reduction of blood pressure.

Finally, regarding exergames designed to improve balance and other motor skills, Mugueta-Aguinaga and Garcia-Zapirain (2019) conduct a study to validate the exergame 'FRED'. In a subsequent research study, one of the objectives posed by these authors is to assess the efficiency of this exergame in reducing fragility in older adults, improving their independence and quality of life (Mugueta-Aguinaga and Garcia-Zapirain, 2019). This video game comprises a sequence of three settings, all with one or more steps in a simplified wine production process. Player movements are detected and recorded with a motion sensor, assessing movement functionality. Depending on what setting the player is in, they must perform lateral body movements, squats, stand on two feet, lift their arms and legs alternately, arm flexion-extension and abduction-adduction, rotate their shoulders, and more. As a result, this exergame encourages players to practice coordination skills of orientation, combination, balance and space-time perception.

A person's functional and physical quality is another element in maintaining and improving their quality of life. For this reason, Boj et al. (2018) present an application called 'HybridPLAY', which aims to encourage outdoor activity and training. This system transforms outdoor fitness equipment in a digital game interface with a motion detector that links the equipment to a mobile device. The software includes a series of mini-games and the movements detected are transformed into actions such as jumping, running, turning or striking, depending on the mini-game. It is an individual or collaborative exergame, adding a social component to activity and training. Tabak et al. (2020) carried out a study with the aim of describing the design of a training application to encourage physical activity in daily life and assess older adults' experiences when using the 'ActivityCoach' app. The game presented and included in the app mentioned is 'WordFit'; it consists of placing words from a starting to an end point. The game's graphic interface has a board with several tiles with rocks along the route that must be demolished with hammers in order to place the word. Hammers are won when the player meets certain step goals. The objective of the study proposed by Da Silva et al. (2021) is to design and develop an exergame to promote health and physical activity, and to encourage participants to follow and enjoy the exercises. This exergame, called 'Boliche virtual', was designed in collaboration with a group of older adults and includes a multi-player component in order to foster socialisation while participants train. Along these lines, Ruggiero et al. (2023), designed a health education exergame adapted for adults over 50 years of age with the aim of ensuring the maintenance and improvement of quality of life by complementing didactic education on healthy eating/nutrition with physical activity exercises. The objectives of the health-related game are to provide knowledge, increase motivation, incorporate movement and encourage behaviour change related to healthy eating and physical activity.

Preventing falls and motor rehabilitation are also two aspects that improve functional quality. The first is addressed in a study by Money et al. (2019) and Ren et al. (2022). These authors propose three research objectives: to describe a serious game called 'Falls Sensei'; to assess game usability from the perspective of older adults; and to explore user perceptions on the use of this exergame and to what extent risky behaviours are modified. The exergame takes place in an augmented reality environment with a graphic interface that shows different spaces in a home. Each space is a game level and has between five and nine dangers of falling. As the player moves through each space they must identify the dangers. Ren et al. (2022) present Envolv, a specific exercise programme to work on fall prevention and balance for older adults. Designed as a feasible strategy to provide therapeutic exercise, it is based on a motion capture system combined with balance training exercise software. As for the second aspect—motor rehabilitation—, the objective of the study by Pereira et al. (2019) is to assess the efficiency of exergame-based motor rehabilitation training, and also to understand how commitment and social participation affect training. The game has three modes: competitive, coactive and collaborative. The aim is to move the arms to trap balls that fall from the top of the screen. Randriambelonoro et al. (2023) also designed a gamified multi-functional rehabilitation equipment system called ActivLife to improve the functional capabilities of older adults through physical activation, rehabilitation, mobility, bedside assistance and mental stimulation.

Other examples of arm training exergames are presented in studies by Triandafilou et al. (2018) and Kaplan et al. (2018). The objective of the first is to review the feasibility of the 'VERGE' system as a physical exercise resource for people who have suffered strokes, including older adults. This system features an augmented reality environment where avatars interact with virtual objects. Meanwhile a study by Kaplan et al. (2018) present an exergame in which users must control an aeroplane using arm movements in order to pass through rings along the route. Both exergames offer multi-player modes for social interaction. Third, Stamm et al. (2022) focus on designing a virtual reality game called ViRST VR in which, through interactive tasks on a farm (e.g., rowing, lighting light bulbs, or sorting vegetables), they conduct training sessions to specifically improve pain intensity and severity of chronic pain, functional abilities, and fear avoidance beliefs (kinesiophobia).

Objective 2: improving cognitive, psychological and mental health. One example of this type of serious game is featured in the study by Anguera et al. (2017). One of the research objectives proposed is to explore how an intervention on the 'Project EVO' platform impacts cognitive control, mood and cognitive symptoms of depression in older adults. This platform consists of guiding a character through different environments while overcoming a series of challenges. The player must therefore combine neuropsychological processes of visuomotor and perceptive discrimination. The serious game gets harder as the user progresses through the different environments or levels, adapting to the player's responses and skills. Another example is the paper by Belchior et al. (2019), who seeks to compare cognitive improvements caused by the video game 'Crazy Taxi' on one hand, and the 'InSight' cognitive training system on the other. Crazy Taxi is an immersive driving game in an urban setting. It consists of picking up passengers and taking them to their destination to earn as much money as possible (a higher score requires greater speed and complexity). The game includes complementary settings ('Crazy Boxes') to practice different tasks. In line with cognitive training, there are several research studies that present video games that allow the assessment of cognitive aptitude, processing speed and reaction time. Hou et al. (2022) developed three cognitive computer games: 1) Cognitive Game based on Nostalgia Theory; 2) Whack-a-Mole; 3) Hit-the-Ball. The first one focused on improving memory, attention, executive function and language, while the other two focused on reaction time and processing speed. In turn, Eun et al. (2022) study a series of cognitive mini-games for computers, smartphones, tablets, and other portable devices designed with artificial intelligence that facilitate older users to feel entertained and immersed in cognitive play voluntarily and to benefit from cognitive training. Ghorbani et al. (2022) use augmented reality to develop a video game that not only provides cognitive training but also simultaneously examines the mental state of players to slow down the progression of potential cognitive problems and increase the quality of life of the individual. The augmented reality serious game consists of a simulation of everyday life situations with five tasks that are defined to assess different cognitive functions, such as pattern separation and completion, visuospatial and episodic memory, decision-making ability, concentration and overall processing speed by measuring response time.

It is designed to train and improve visual attention and cognitive processing speed. In line with performance and visual capacity, Chesham et al. (2017) present a serious game puzzle called 'TMM3 Puzzle Game'. This software is part of study that aims to develop a visual search and pairing task with a video game to them assess the feasibility of the task designed. Based on this objective, the goal of this serious game is to practice, improve and assess visual search capacity in older adults with or without cognitive deterioration in a fun, adaptive and attractive format. 'TMM3 Puzzle Game' is designed as a jigsaw board filled randomly with tiles (geometric shapes) in different colours. Each player must match a pattern with a horizontal or vertical sequence of three identical tiles. The matched tiles disappear from the board which is then filled up. Meanwhile, a study by Farzin et al. (2018) assesses the efficiency of prospective memory training among older adults using 'Virtual Week Board Game'. This software has a board graphic interface. Each board corresponds to a day of the week and includes different tests. To move forward each day, the user must throw a die, taking decisions and remembering to do some daily activities as they progress. Each virtual day includes eight to ten tasks that include regular (very common), irregular (less common) and timed activities. All activities aim to exercise prospective memory, thus practising and improving older adults' ability to exercise how they carry out this type of task in the future. Along a similar line, Yu et al. (2019) assess the efficiency of a software for long-term memory in older adults, in this case people with symptoms of dementia. This serious game is called 'Memory Matters' and is a traditional pairing game. Images include objects, food, places, clothing and historical events from the 1930s to the 1960s. It therefore aims to help users recover autobiographical memories. After matching each pair there is a section called 'Did you know? which is designed to foster memory, reflection and reminiscence. This software also includes a mode to view the images without playing and an option for the user to add personal and family photos. Two modes 'solo mode' or 'social/group mode', are also available in this serious game for collaborative game experiences. And, precisely in this more social line, is Myosotis FoodPlanet, a video game designed by Zahn et al. (2022) to promote positive social interactions between players of different generations while playing. Specifically, it is an iPad game that involves two players jointly preparing a Swiss cheese fondue by dragging floating ingredients into a pot. By using a traditional Swiss dish, Myosotis FoodPlanet provides a positive entertaining activity that facilitates intergenerational communication and allows players to find new and exciting access to the memories of older people.

Other examples of serious games in the cognitive domain are 'Mind Frontiers' y 'GRADYS Game', both types of software are designed to train different neuropsychological processes and skills. In the first case, the serious game is presented by Souders et al. (2017) who assessed the efficiency of in acquiring and transferring cognitive skills using different gamified tasks. The software is designed to cover three games to exercise inductive reasoning, planning, spatial reasoning skills, cognitive processing speed, switching tasks and working memory. Zając-Lamparska et al. (2019) conduct a study to assess the effects of virtual reality cognitive training in older adults with and without minor dementia. 'GRADYS Game' is a virtual reality-based serious game presented by the authors that comprises four modules inspired by daily activities. The overall goal of this game is to exercise attention, memory, language and visuospatial processing.

Objective 3: improving health from a multi-modal approach. A review of the literature selected identified a series of video games designed to improve physical and cognitive functions from a multi-modal or combined approach, aiming to achieve physical-cognitive interaction between participants. These studies include research by Becker et al. (2020) whose proposed objective is to present and assess the 'PDDanceCity' system as a resource for measuring the functional performance of older adults using physical activity. The system is based on a map of city in the form of a labyrinth. To reach the finish line, players have to complete two-dimensional movements. It is designed to allow users to pass through different settings or points of interest (e.g., museum, monument or cafe) along the way. 'PDDanceCity' offers rehabilitation for dual tasks by training the visuospatial function, balance and movement coordination. Meanwhile, the study objective of Chua et al. (2019) is, on one hand, to review the feasibility and use of virtual reality to detect cognitive deterioration in older adults and, on the other, to assess the system's capacity to distinguish cognitively intact participants from others with cognitive deterioration. They present the video game 'RE@CH', which replicates everyday tasks. This exergame develops seven key activities: (a) open a window with a key and the correct code; (b) make a telephone call by retrieving a predefined 8-digit number; (c) identify famous people, food adverts and a 4-digit lottery number in a newspaper; (d) classify household objects into categories; (e) choose suitable clothing for a specific event; (f) withdraw money from a cash machine; and (g) buy food at a shop. This video game trains motor control, attention, memory, completing dual tasks and executive functions.

In their study, the objective of Li et al. (2020) is to design a virtual reality-based movement video game to improve various cognitive and physical skills in older adults. 'Whac-A-Mole' is a video game with an immersive virtual reality environment simulating a farm. Motion sensors record and replicate limb movements in the game. Players are required to move both arms and legs to feed the animals that appear on the graphic interface, guided by instructions provided by the system. This exercise aims to train static and dynamic posture control, gross and fine motor coordination, as well as neuropsychological processes such as attention, response inhibition and execution of dual tasks. Also relying on virtual reality, Liepa et al. (2022), present Falling diamonds, a video game developed to improve stability and physical and cognitive fitness, which allows elderly people to train physically and cognitively to avoid falls and thus improve their quality of life. Zangirolami-Raimundo et al. (2019) use the video game 'MoviLetrando' to compare the performance of physically active and sedentary older adults. The aim is to capture pre-established symbols and it takes into account both the player's number of hits (captures) and speed. The faster the participant can capture the symbol requested, the more symbols will be displayed and, therefore, the higher the final score. Levels and phases evolve according to player performance. Symbols include numbers, vowels, consonants and numerical series, which can be defined individually or as a combination. The stimulus used to display the symbols can be visual, audio or both. With this training exercise, the user practices coordination skills such as reaction and cognitive processes like attention, information processing speed, working memory and response inhibition.

More focused on rehabilitation, there are also examples of video games that combine physical and cognitive training to allow the elderly to improve their condition. These are the cases of video games such as Active Airliness by Beltran-Alacreu et al. (2022), I Am Dolphin by Drazich et al. (2023) and SilverFit BV 3D by Müller et al. (2023). The former consists of a Windows-based application that allows the player to control a virtual aircraft to reach targets by means of head movements. At the end of the exercise, the application stores the achieved and unachieved goals and the trajectory of the plane so that the elderly can improve their rehabilitation through physical and cognitive exercise. The second video game was initially designed to reduce upper limb impairment after stroke but is being applied to older adults without a history of stroke because it can also improve players' overall cognitive, emotional and physical health. The game is about helping Bandit, a dolphin, to eat fish, jump and avoid being eaten by sharks using a Kinect-based motion sensor remote control. The third game is a television screen-based exercise system recommended for balance training in the physical rehabilitation of older adults, which allows for a puzzle game, a tilt game and a step game called the fox. In this research, they study the impact of this type of exercise game on the cognitive health of the elderly, demonstrating that it inherently increases cognitive activity.

A study by Adcock et al. (2020a) aims to determine the usability of a multi-component exergame and explore its effects on physical and cognitive functions, and cortical activity. In a subsequent study (Adcock et al., 2020b) aim to assess the effects that multi-modal training using the 'Active@Home' exergame has on physical and cognitive functions. This video game simulates a trip around different European countries; as the user follows the route, they complete different activities and exercises inspired by tai-chi, dance and cognitive games. The result is an exergame that can train coordination skills such as coordination, reaction, balance and rhythm, as well as cognitive skills like selective and divided attention, response control, cognitive flexibility and working memory. To ensure challenge and progress, the game has various difficulty levels with more complex and faster movements. Each level of difficulty is associated with a city. The order is predefined and it is advisable to play all the levels in a city before moving to the next and, before moving on, users should train in the level for two sessions.

Alongside this research, Qiu et al. (2023) study an intergenerational balance training system that allows older and younger people to play together, encouraging social interaction between generations and promoting physical, mental and emotional well-being in older adults. The video game is called Social Balance Ball and allows using three different modes to test the player's level of social presence as a determinant of the player's experience: (1) virtual player, (2) mediated human player (i.e. participants played online) and (3) co-located human player (i.e. participants played face-to-face).

Finally, five exergame systems grouping different video games were identified. These include a study by Jirayucharoensak et al. (2019) whose proposed objective was to review whether a game-based neuro-feedback training system can improve neurocognitive performance in healthy older adults and others with minor cognitive deterioration. The games included in this system ('Dogsperat', 'Penguin', 'Both hands draw', 'Recall Mem' y 'Math') are designed to train coordination skills such as combination and balance, and neuropsychological processes like memory, executive functions and learning. Meanwhile, (Chu et al., 2021) design and develop a cognitive and physical training exergame system for use by older adult's resident in long-term care homes. 'MouvMat' aims to train coordination skills such as combination, reaction and rhythm, as well as cognitive skills like attention, memory, executive function and response inhibition using the games 'Simons Says', 'Memory Pairs', 'Scrabble', 'Don't Let the Music Stop' y 'Tic-Tac-Toe'. Finally, 'SureStep' is presented in a study by Valenzuela et al. (2018) who propose the objective of exploring experience and use of this system by older adults to reduce the risk of falling. It therefore aims to improve walking, balance, posture control, and also cognitive processes such as working memory, visuospatial skills, completing dual tasks, response inhibition and attention. Fourth, Ferreira et al. (2022) develop Portable Exergame Platform for Elderly, an augmented reality exergame designed to play four games (Exerpong, Grape stomping, Rabelos and Toboggan) that mobilise physical and mental resources simultaneously to improve reaction times, cognitive flexibility, or verbal fluency in the elderly. Finally, Brauner and Ziefle (2022) address general physical or cognitive fitness using two different game prototypes to study the similarities and differences between different types of serious games for health care in active and assisted living settings. The first game, Fitness Farm, addresses general fitness, agility, endurance and body control, while the second game, Cook it Right, is designed to promote executive functioning.

What are the main categories or typology of video games and what have they been used for in the studies reviewed? The 49.07% of the video games analysed were categorised as non-commercial, while 50% were commercial products for recreational purposes (for example, Nintendo Company Ltd o Xbox Network) or designed by companies specialised in other fields (for example, Dividat, Motek o VITAAL Exergame). The remaining 0.93% corresponds to studies that do not specify the name of the video game or its categorisation (Commercial or Non-Commercial), although there is a description.

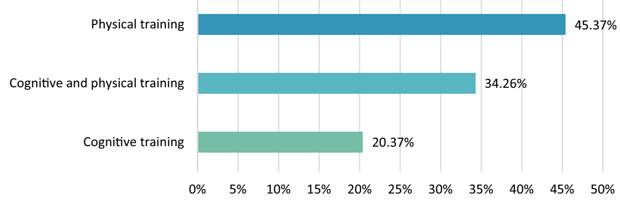

Fig. 3 Aim and purpose of the video game.

By observing the general domains for which the video game is used, we can see that they are mostly related to physical capacities (45.37%), followed by video games for the multi-modal domain (Cognitive and Physical) (34.26%), and to a lesser extent video games (serious games) designed exclusively to improve the cognitive, psychological and mental health of older adults (20.37%) (Fig. 3).

The following table (Table 3) includes a summary of the different video games analysed in the studies selected.

What are the main measurement instruments and scales (screening) used in studies on serious games? One of the aspects of interest in this paper is related to the type of instrument used in the studies reviewed in order to evaluate different aspects related to the use of video games. On the one hand, it is of interest to know to what extent the use of video games can be related to the training or improvement of certain cognitive, physical or social elements and, on the other, to establish how these aspects have been measured by researchers. Table 4 shows the relationship between the domain analysed in the studies and the assessment or diagnostic instrument used to obtain the data.

As can be seen (Fig. 4), most instruments (52%) seek to measure or assess cognitive, psychological or mental domains; 36.8% of the instruments and/or tests aim to specifically assess physical domains (e.g., balance, posture control, muscle strength, limb movement, etc.). Finally, instruments to simultaneously assess cognitive and physical domains are used less in the studies selected, accounting for 11.2% of the instruments used.

In the case of instruments and tests implemented to measure aspects related to the cognitive, psychological and mental domains, they were grouped into five subcategories: (a) Neuropsychological Assessment, (b) Emotional and Social Health, (c) Cognitive Impairment, (d) Mental Disorder, y (e) Quality of Life. Most instruments assess neuropsychological aspects such as attention; visual, working and verbal semantic memory; visuospatial skills; executive functions; reaction time; and response control, among others, accounting for 66.15% of all tests used. The second group of tests in subcategory Emotional and Social Health, account for 13.85% of the instruments used in the studies selected. These tests aim to assess aspects related to emotional, perceptive, experiential and social components that influence different areas of life of older adults and that have an impact on well-being and quality of life. 9.23 per cent of the instruments were assigned to the Mental Disorder category, which includes those instruments intended to assess the status of disorders such as depression in older people. Subcategory four (Cognitive Impairment) accounts for 7.69% of the instruments used. This type of test aims to assess the cognitive status of people with neurodegenerative diseases such as dementia or Alzheimer's. Finally, to a much lesser extent, 3.08% of the instruments used in the studies were intended to measure quality of life in older adults (Table 5).

From a general perspective, Table 5 presents the instruments or tests that were implemented in 2 or more investigations. In this table, the most frequently used test is the Timed Up-and-Go,

Table 3 Video games data.

Product Name	Author/s (Publication Years)	Product Type	General Objective Product
Active@Home	Adcock et al. (2020a)	Non-commercial	Cognitive training and physical training
Active@Home	Adcock et al. (2020b)	Non-commercial	Cognitive training and physical training
Reach game, Hit-It and Watch-Out	Ayed et al. (2018)	Non-commercial	Physical training
Lumosity.	Ballesteros et al. (2017)	Commercial	Cognitive training
PDDanceCity	Becker et al. (2020)	Non-commercial	Cognitive training and physical training
Crazy Taxi	Belchior et al. (2019)	Non-commercial	Cognitive training
Active Airliness	Beltran-Alacreu et al. (2022)	Non-commercial	Cognitive training and physical training
HybridPLAY	Boj et al. (2018)	Non-commercial	Physical training
Cognitive mobile games provided by Peak Brain Trainig	Bonnechère et al (2021)	Commercial	Cognitive training
Fitness Farm; Cook it Right	Brauner and Ziefle (2022)	Non-commercial	Cognitive training and physical training
Training exergame	Bukhari et al. (2022)	Non-commercial	Physical training
Box Virtual Reality and NVIDIA Virtual Reality Fun House.	Campo-Prieto et al. (2022a)	Commercial	Physical training
Immersive virtual reality exercise game	Campo-Prieto et al. (2022b)	Commercial	Physical training
Box VR	Campo-Prieto et al. (2022a, 2022b)	Commercial	Cognitive training and physical training
TMM3 pluzze game	Chesham et al. (2019)	Non-commercial	Cognitive training
MouvMat	Chu et al. (2021)	Non-commercial	Cognitive training and physical training
RE@CH	Chua et al. (2019)	Non-commercial	Cognitive training and physical training
Boliche Virtual	da Silva et al. (2021)	Non-commercial	Physical training
Dividat – Dividat Senso Smart Platform (Simple, Targets, Split, Simon, Flexi A + B, Stations, Tetris)	de Bruin et al. (2019)	Commercial -System used in specific or rehabilitation centres-	Physical training
Kinect - Xbox 360 (Kinect Sports Ultimate)	De Queiroz et al. (2017)	Commercial	Physical training
Fox Hunting Game	Dijkstra et al. (2018)	Non-commercial	Physical training
I Am Dolphin	Drazich et al. (2023)	Non-commercial	Cognitive training and physical training
Pong	Ellmers et al. (2018)	Non-commercial	Physical training
Cognitive training mini-games with artificial intelligence	Eun et al. (2022)	Non-commercial	Cognitive training
Virtual Week Board Game	Farzin et al. (2018)	Non-commercial	Cognitive training
Portable Exergame Platform for Elderly	Ferreira et al. (2022)	Non-commercial	Cognitive training and physical training
Kinect - Xbox One (Just Dance y Kinect Sports Rivals)	Freed et al. (2021)	Commercial	Physical training
Fall prevention training exergame	Gallou-Guyot et al. (2023)	Commercial	Cognitive training and physical training
Serious game-based on augmented reality	Ghorbani et al. (2022)	Non-commercial	Cognitive training
Klondike Solitaire	Gielis et al. (2021)	Commercial	Cognitive training
Kinect - Xbox 360 (Kinect Sports Ultimate Collection)	Guimarães et al. (2018)	Commercial	Cognitive training and physical training
Training exergames - Xbox 360 Kinect Sport	Gunst et al. (2022)	Commercial	Cognitive training
Active training exergame	Hernandez-Martínez et al. (2022)	Commercial	Physical training
Virtual reality-based group exercise therapy with cycloergometers.	Høeg et al. (2023)	Commercial	Cognitive training and physical training
Cognitive training Game based on Nostalgia Theory; Whack-a-Mole; Hit-the-Ball	Hou et al. (2022)	Non-commercial	Cognitive training
Four Nintendo Wii sports games (tennis, bowling, baseball and golf).	Hou et al. (2023)	Commercial	Cognitive training and physical training
Wii Fit	Jahouh et al. (2021)	Commercial	Cognitive training and physical training
10 Customised Exergames	Janhunen et al. (2022)	Non-commercial	Physical training
Programme of 11 customised post-operative TKR exergames	Janhunen et al. (2023)	Non-commercial	Physical training
Neurofeedback training system (Dogsperat, Penguin, Both hands draw, Recall Mem, Math)	Jirayucharoensak et al. (2019)	Non-commercial	Cognitive training and physical training
Kinect - Xbox 360 (Kinect Sports Ultimate Collection)	Kamińska et al. (2018)	Commercial	Physical training
Interactive physical-cognitive training game-based training system (Fruits Hunter, Where am I?, Whack a Mole, Sky Falls, Crossing Poison River)	Kamnardsiri et al. (2021)	Non-commercial	Cognitive training and physical training
MemoreBo	Kleschnitzki et al. (2022)	Commercial	Cognitive training and physical training
Ring Fit Adventure (Nintendo Switch)	Lee (2023)	Commercial	Physical training
Whac-A-Mole	Li et al. (2020)	Non-commercial	Cognitive training and physical training
Kinect - Xbox 360 and Wii (Kinect Sports Ultimate Collection and Wii Sports)	Li et al. (2021)	Commercial	Physical training
Falling diamonds	Liepa et al. (2022)	Non-commercial	Cognitive training and physical training
EXER-TC	Liu et al. (2022)	Commercial	Cognitive training and physical training
Wii Fit	Maixnerová et al. (2017)	Commercial	Physical training
Tymo®	Maranesi et al. (2022)	Commercial	Cognitive training and physical training
m-OTAGO ('Modified' Otago)	Martins et al. (2020)	Non-commercial	Physical training
Kinect Sports Rivas - Xbox Kinect One -	Mascarenhas et al. (2023)	Commercial	Physical training

Table 3 (continued)

Product Name	Author/s (Publication Years)	Product Type	General Objective Product
CityQuest	Merriman et al. (2022)	Commercial	Cognitive training
Falls Sensei	Money et al. (2019)	Non-commercial	Physical training
Dr. Kawashima's Body and Brain Exercises	Moret et al. (2022)	Commercial	Cognitive training
FRED	Mugueta-Aguinaga and Garcia-Zapirain (2017)	Non-commercial	Physical training
FRED	Mugueta-Aguinaga and Garcia-Zapirain (2019)	Non-commercial	Physical training
SilverFit BV 3D	Müller et al. (2023)	Non-commercial	Cognitive training and physical training
iPACES Memory Lane - iPad Air 2	Nath et al. (2023)	Commercial	Cognitive training and physical training
WeTakeCare System (Sound Movement, Treasure Hunt, Sudoku)	Neumann et al. (2018)	Non-commercial	Physical training
Wii Sports	Nonino et al. (2018)	Commercial	Physical training
Kinect - Xbox 360 (Summer Stars 2012)	Ordnung et al. (2017)	Commercial	Cognitive training and physical training
Wii Fit	Padala et al. (2017)	Commercial	Physical training
Nintendo (Kawashima Brain Training, Súper Mario Bros)	Perrot et al. (2019)	Commercial	Cognitive training
Interactive physical-cognitive training game-based training system (Fruits Hunter, Where am I?, Whack a Mole, Sky Falls, Crossing Poison River)	Phirom et al. (2020)	Non-commercial	Cognitive training and physical training
Social Balance Ball	Qiu et al. (2023)	Non-Commercial	Cognitive training and physical training
Heart Mountain.	Radhakrishnan et al. (2020)	Commercial	Cognitive training and physical training
Kinect - Xbox 360 (Kinect Sports Ultimate Collection)	Ramnath et al. (2021)	Commercial	Cognitive training and physical training
ActivLife	Randriambelonoro et al. (2023)	Non-commercial	Physical training
Wii Fit Plus	Rebêlo et al. (2021a)	Commercial	Physical training
Wii Sports Resorts	Rebêlo et al. (2021b)	Commercial	Physical training
Envolv	Ren et al. (2022)	Non-commercial	Physical training
Adapted health education exergame for adults over 50 years of age	Ruggiero et al. (2023)	Non-commercial	Physical training
Kinect - Xbox 360 (Kinect Sports Ultimate Collection)	Sadeghi et al. (2017)	Commercial	Physical training
Virtual reality-based social exrercise game	Shah et al. (2022)	Commercial	Physical training
Kinect - Xbox 360 (Kinect Sports Ultimate Collection)	Sápi et al. (2021)	Commercial	Physical training
Portable interactive balance training system	Segal et al. (2022)	Commercial	Physical training
Mind Frontiers (Ante Up, Irrigator, Pen 'Em Up, Riding Shotgun, Safe Cracker, Sentry Duty, Supply Run)	Souders et al. (2017)	Non-commercial	Cognitive training
ViRST VR	Stamm et al. (2022)	Non-commercial	Physical training
MIRA Exergames (Airplane, Animals, Atlantis, Basketball, Catch, Colour Clouds, Firefly, Follow, Grab, Izzy the Bee, Jugger, Memory Scape, Move, Piano, Powerhouse Bid, Seasons)	Stanmore et al. (2019)	Commercial -System used in specific or rehabilitation centres-	Physical training
Dividat – Dividat Senso Smart Platform (Simple, Targets, Flexi A + B)	Swanenburg et al. (2018)	Commercial -System used in specific or rehabilitation centres-	Cognitive training and physical training
Dividat – Dividat Senso Smart Platform (Simple, Targets, Birds)	Swinnen et al. (2021a)	Commercial -System used in specific or rehabilitation centres-	Cognitive training and physical training
VITAAL Exergame (Outdoor, Library, Mommy Chicken, Healthy Food, Shopping List)	Swinnen et al. (2021b)	Commercial -System used in specific or rehabilitation centres-	Cognitive training and physical training
ActivityCoach	Tabak et al. (2020)	Non-commercial	Physical training
Kinect - Xbox 360 (Dr. Kawashima Body and Brain Exercises)	Talaei-Khoei and Daniel (2018)	Commercial	Cognitive training
VERGE System (Ball Bump, Foof Fight, Trajectory Trace Exercise)	Triandafilou et al. (2018)	Non-commercial	Physical training
SureStep (StepMania, Stepper, Trail-stepping, Tetris)	Valenzuela et al. (2018)	Non-commercial	Cognitive training and physical training
SilverFit BV – Garden Hose Game; Motek – Microbes (Avoid Obstacles, Acceleration-Deceleration, Hit Targets	Van der Kooij et al. (2019)	Commercial -Designed by companies-.	Physical training
Virtual reality training exergames for older people with hypertension	Vorwerg-Gall et al. (2023)	Non-Commercial	Physical training
DOREMI y METADIETA®	Vozzi et al. (2022)	Commercial	Physical training
Motek – Virbal Exergame Training Package (Wasps, Slingshot, Garage, Fishing)	Willaert et al. (2020)	Commercial -Designed by companies-.	Physical training
Cleverbrain	Wong et al. (2022)	Non-commercial	Cognitive training
Alchemist's Treasure	Wu et al. (2023)	Commercial	Cognitive training and physical training
Kinect - Xbox 360 (Your Shape: Fitness Evolved II)	Yang et al. (2020)	Commercial	Physical training
BrainHQ – Posit Science (Double Decision, Freeze Frame, Target Tracker); The Rise of Nations Gold Edition; Desktop Crossword, Britannica Sudoku Unlimited, Britannica Word	Yoon et al. (2019)	Commercial -Designed by companies-.	Cognitive training
Memory Matters.	Yu et al. (2019)	Non-commercial	Cognitive training
Interactive Video Game-Based.	Yuan et al. (2020)	Non-commercial	Physical training
Wii Fit U	Zadro et al. (2019)	Commercial	Physical training
Mysosotis FoodPlanet	Zahn et al. (2022)	Non-commercial	Cognitive training
GRADYS Game	Zając-Lamparska et al. (2019)	Non-commercial	Cognitive training
MoviLetrando	Zangirolami-Raimundo et al. (2019)	Non-commercial	Cognitive training and physical training
Training exergames - Nintendo Switch	Zhao et al. (2022)	Commercial	Cognitive training

Table 4 Categorisation of the assessment instruments used in the selected investigations.

COGNITIVE/MENTAL	Instruments Domain
	1) Addenbrooke's Cognitive Examination III
	2) Alzheimer's Disease and Related Dementia Mood Scale
	3) Attention assessment test D-CAT
	4) Attention assessment test SAT
	5) Attention Network Test
	6) Beck Depression Inventory
	7) Benton Visual Retention Test
	8) Borg Rating of Perceived Exertion Boston Naming Test
	9) Cambridge Neuropsychological Test Automated Battery
	10) Cantril Scale
	11) Cognitive Failure Questionnaire
	12) Cognitive screening assessment test
	13) CogState Battery
	14) Colour Trails Test
	15) D2 Test of Attention
	16) Dementia Apathy Interview and Rating
	17) Digit span backward (DSB) memory tests
	18) Digit span forward (DSF) memory test
	19) Falls Efficacy Scale International
	20) Floor Maze Test
	21) Game Experience Questionnaire
	22) Geriatric Anxiety Scale
	23) Geriatric Depression Scale
	24) German version of the efficacy scale-international questionnaire
	25) Goldberg Anxiety and Depression Inventory
	26) Hamilton Depression Rating Scale
	27) Iconographical Falls Efficacy Scale
	28) Intrinsic Motivation Inventory
	29) Maastricht Social Participation Profile
	30) Melbourne Edge Test
	31) Mini-Examination Cognitive of Lobo
	32) Mini-Mental State Examination
	33) Mini-Mental Status Test
	34) Modified Clinical Test for Sensory Integration of Balance
	35) Modified Falls Efficacy Scale
	36) Montreal Cognitive Assessment
	37) Neuropsychiatric Inventory Questionnaire
	38) Patient Health Questionnaire-9
	39) Personal Profile Analysis
	40) Physical Activity Enjoyment Scale
	41) Player Experience of Need Satisfaction
	42) Prospective and Retrospective Memory Questionnaire
	43) Raven's Advanced Progressive Matrices
	44) Rey Auditory Verbal Learning Test
	45) Rey-Osterrieth Complex Figure
	46) Ruler Drop Test
	47) Santa Barbara Sense of Direction Scale
	48) Simple Reaction Time
	49) Symbol Digit Modalities test
	50) Spanish version of the Mini-Mental the Folstein Scale
	51) Stroop Colour–Word test
	52) Test Attentional Performance
	53) Test of Variables of Attention
	54) The Congruent Correct–Incongruent Incorrect metric
	55) The Cornell Scale for Depression in Dementia
	56) The Dementia Quality of Life Instrument
	57) The Positive and Negative Affect Schedule
	58) The Spatial Recall Test
	59) Trail Making Test
	60) Verbal fluency test
	61) Victoria Stroop Test
	62) Visual Analogue Scale
	63) Wechsler Adults Intelligence Scale
	64) Wechsler Memory Scale-Revised
	65) Yesavage Scale for Geriatric Depression
Physical/Functional Quality	Instruments Domain
	1) 2-Minute Step Test
	2) 30 Second Sit to Stand Test
	3) 3-Minute Step Test
	4) 4 Stage Balance Test 'Modified'
	5) 6-Minute Walk Test*
	6) Chronic Pain Grade Questionnaire
	7) Cumulative Illness Rating Scale-Geriatric
	8) Barthel Index
	9) Beier's SET scale
	10) Berg Balance Scale
	11) Body mass index/BMI
	12) Borg Rating of Perceived Exertion
	13) Dynamic Gait Index
	14) Extended Timed Get-Up-and-Go
	15) Five-times sit-to-stand test
	16) Functional ambulation categories
	1) Functional Gait Assessment
	2) Functional Reach Test
	3) Hannover Functional Ability Questionnaire
	4) Health Survey SF-12
	5) International Physical Activity Questionnaire
	6) Jebsen-Taylor Hand Function Test
	7) Korean Geriatric Depression Scale
	8) Korean Mini-Mental State Examination
	9) Maximum Step Length
	10) Morton Mobility Index
	11) Multi-Directional Reach Test
	12) Western Ontario and McMaster Universities Osteoarthritis index
	13) N-back Test
	14) Numeric Rating Scale
	15) Patient Specific Functional Scale
	16) Physical performance test
	1) Roland-Morris Disability Questionnaire
	2) Schuler's scale
	3) Senior Fitness Test
	4) Short Physical Performance Battery
	5) Simulator Sickness Questionnaire
	6) Spanish version of Simulator Sickness Questionnaire
	7) TAMPA Scale for Kinesiophobia
	8) Tandem-Stance Test
	9) Timed Up-and-Go
	10) Tinetti Test/Performance-Oriented Mobility Assessment
	11) The Chinese version of California Verbal Learning Test
	12) The Chinese version of the Stroop Colour and Word Test
	13) The Community Balance and Mobility Scale
	14) The Motivation Scale for Physical Activity for Health Purposes
Multimodal (cognitive and physical)	Instruments Domain
	1) 36-Item Short Form Survery
	2) Assessment Staging
	3) European Quality of Life-5 Dimensions
	4) Global Deterioration Scale/Functional
	5) Groningen Activity Restriction Scale
	6) Inclusion of Other in the Self (IOS) Scale
	7) Instrumental Activities of Daily Living Scale
	8) Korean Activity of Daily Living
	9) NASA Task Load Index
	10) Neck Disability Index
	11) Networked Minds Social Presence Inventor
	12) One-Leg Standing Balance Test
	13) Self-Efficacy for Exercise
	14) Tandem Walk Test

which was used in 11 investigations to assess skills related to the physical domain, specifically mobility and balance. The second most applied test is the Montreal Cognitive Assessment - MoCA ($n = 9$), aimed at assessing cognitive skills such as memory, attention, language, visuospatial ability, calculation, abstraction and executive function. As for less frequent instruments or tests, there are tests focused on both the cognitive domain (e.g., Beck's Depression Inventory, Falls Efficacy Scale-International, Neuropsychiatric Inventory Questionnaire, among others) and the

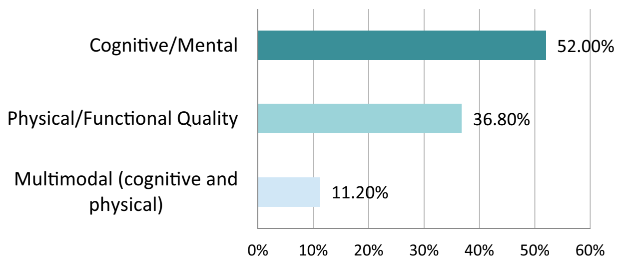

Fig. 4 Domains of the assessment instruments used in the selected investigations.

Table 5 Most common instrument.

Instrument/Test	Frequency
Timed Up-and-Go test	11
Montreal Cognitive Assessment (MoCA)	9
30 Second Sit to Stand Test or 30 Second Chair Stand Test (30CST)	6
Berg Balance Scale's	6
Trail Making Test	6
Game Experience Questionnaire	5
Mini-Mental State Examination	5
Short Physical Performance Battery	5
Stroop task	5
Borg Rating of Perceived Exertion	4
Intrinsic Motivation Inventory	4
Simulator Sickness Questionnaire	4
6-Minute Walk Test (6MWT)	3
Geriatric Depression Scale	3
International Physical Activity Questionnaire	3
N-back Test	3
One-Leg Standing Balance Test	3
Tinetti Test	3
Barthel index (BI)	2
Beck's Depression Inventory	2
Dynamic Gait Index	2
Falls Efficacy Scale-International	2
Modified Falls Efficacy Scale	2
Neuropsychiatric Inventory Questionnaire	2
Phisycal Activity Enjoyment Scale	2
Senior Fitness Test	2
Short physical performance battery (SPPB)	2

physical domain (e.g., Barthel Index, Senior Fitness Test or Short Physical Performance Battery). These instruments or tests are implemented in at least 2 of the selected studies.

What are the main results obtained after the socio-educational use of digital games with older adults aged 65 and above?

Benefits in the cognitive domain. The results obtained in the studies reviewed show that the serious games presented are a potentially effective intervention for the overall improvement of the cognitive domain (Anguera et al., 2017; Zając-Lamparska et al., 2019), highlighting specific benefits in relation to: mood in older adults (Anguera et al., 2017; Farzin et al., 2018; Yu et al., 2019); cognitive processing speed (Belchior et al., 2019; Zając-Lamparska et al., 2019); memory (Farzin et al., 2018; Yu et al., 2019); independence and functional capacity (Farzin et al., 2018) and improving cognitive memory through social interaction (Yu et al., 2019).

Benefits in the physical domain. The studies reviewed yield results that endorse the use of video games to maintain and improve physical condition and general quality of life (Neumann et al., 2018), as well as motor rehabilitation processes (Pereira et al., 2019; Triandafilou et al., 2018;). Specifically to improve physical skills related to: static and dynamic balance (Ayed et al., 2018; Brachman et al., 2021; Ellmers et al., 2018; Martins et al., 2020; Yuan et al., 2020); posture control (Ayed et al., 2018; Ellmers et al., 2018; Soancatl Aguilar et al., 2018; Yuan et al., 2020); fall prevention (Martins et al., 2020; Money et al., 2019; Yuan et al., 2020); functional capacity (Martins et al., 2020; Mugueta-Aguinaga and Garcia-Zapirain 2017, 2019; da Silva et al., 2021) and social interaction through physical training (Boj et al., 2018; Pereira et al., 2019; da Silva et al., 2021).

Benefits in the multi-modal domain. Based on the effects of the digital games highlighted in some of the studies analysed, we can conclude that they are an option to encourage simultaneous physical-cognitive training (Adcock et al., 2020a), with positive effects such as maintaining and improving higher cognitive functions (Adcock et al., 2020a, 2020b; Li et al., 2020), as well as specific cognitive functions associated with preventing falls (Valenzuela et al., 2018) by improving balance and posture control (Chu et al., 2021; Li et al., 2020; Valenzuela et al., 2018). Other benefits of these studies obtained by implementing serious games are shown in the improvement of attention (Jirayucharoensak et al., 2019), working memory (Adcock et al., 2020a; Jirayucharoensak et al., 2019; Li et al., 2020); executive control and function (Adcock et al., 2020a; Jirayucharoensak et al., 2019); visuospatial skills (Jirayucharoensak et al., 2019; Valenzuela et al., 2018); decision-making skills and response inhibition (Adcock et al., 2020a; Jirayucharoensak et al., 2019).

Discussion and conclusion

In this systematic review we delimit and analyse, from a multi-disciplinary perspective, research lines related to the use of video games to improve the physical and mental health and, by extension, quality of life of adults aged over 60. Reviewing the studies selected enables us to extract some overall conclusions for the initial questions proposed. Studies in this field have mostly been reviewed from quantitative methodological approaches involving direct participation by older adults, and mainly in European countries. Specifically, and according to the questions posed, the objectives proposed in most studies with video games are related to training and improving physical health and functional quality in older adults. More than half aim to improve the physical health of older adults, training skills such as balance, posture control, muscle strength and walking. Secondly, cognitive health is also addressed from a perspective of training cognitive processes such as memory, attention, response inhibition and executive functions, among others. And finally, we have also identified video games that jointly train both physical and cognitive domains. Indirect to these domains (physical and cognitive), video games also provide benefits for maintaining and improve the social health of older adults as an aggregate value of serious games. However, and despite identifying some video games (see Boj et al., 2018; Dijkstra et al., 2018; Kaplan et al., 2018; Qiu et al., (2023); Pereira et al., 2019; Triandafilou et al., 2018; Yu et al., 2019; da Silva et al., 2021; Zahn et al., 2022) designed in multi-player format to encourage social interaction among users, this does not appear to be a clear use for this type of resource in specialised research on the subject to date. Even so, some examples of studies (Faraji and Metz 2021; Lin et al., 2022; Pageau et al., 2022) highlight the idea that social isolation in older adults is a risk factor that significantly reduces their quality of life, so they support the use of video games as a tool for encouraging group activities, integration and social interaction, as well as maintaining a social identity role (Cacciata et al., 2019; Di Lorito et al., 2021). In particular, the ability of these video games to significantly foster positive intergenerational social interaction between young and old people, and their consequent improvement in long-term psychological well-being, comes to the fore. Thus, previous research in which serious is specifically designed as an intergenerational game (Qiu et al., 2023; Zahn et al., 2022) stresses the importance of analysing the social dimension of the exergame and recommends that future empirical studies directly compare different game forms to discover the effects of intergenerational interactions. According (Vázquez et al., 2018) social health is thus an emerging domain that is gaining greater weight in the design of video games for older adults and this line of research must be expanded. Moreover, very few studies clearly have older adults participating in the process of designing this type of product (one example is the study presented by Da Silva et al. (2021) which involves a group of older adults in the process of designing and assessing the video game). Some authors emphasise the importance of co-creation as it can favour the participation of older adults, obtaining more effective and useful products adapted to their needs (Martín-García et al. 2021) or their empowerment (King et al. 2020). Regarding the second research question on type of digital games, similar numbers of video games have commercial and recreational purposes, and educational and social purposes in the broadest sense. As for the third question, we identified a total of 125 geriatric assessment tests used in the studies selected. Finally, the lack of clear evidence based on the data analysed in the review leads to the conclusion that we cannot extract definitive findings on the benefits obtained in using socio-educational digital games, and much less results that can verify their effectiveness compared to other resources or interventions with older adults. We can conclude that this article presents significant contributions that support the interest in the use of serious games in the framework of the so-called positive technology, especially given its potential not only in the video game industry but also in active ageing and community health policies.

Limitations and future lines of research. Results of the systematic review have enabled us to identify and delimit certain aspects of serious games for older adults that can help improve their knowledge and use for social or educational purposes. However, our study is limited by variability in the sample age of the selected research, heterogeneity of the studies analysed, and that the sample size of most studies can been deemed relatively small. Despite considering that a good number of studies have been reviewed, the results obtained still seem very incipient, highlighting the need to strengthen this line of research through various channels. For example, the need to explore new methods that help gain a more in-depth understanding of the usefulness and effectiveness of serious games for use in socio-educational interventions with older adults. This could include controlled experimental tests and it would also be interesting to incorporate more studies with a qualitative approach in their research design. The studies must explore new analysis channels, also examining the roles older adults play in handling this type of technological resource, and their participation in technical and pedagogical design. All with the aim of evaluating whether the use of video games (serious games) helps to improve well-being and quality of life from a comprehensive perspective, covering physical, cognitive and social domains, and providing spaces and experiences for active ageing.

Data availability

All data generated or analysed during this study are included in this published article.

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All authors actively participated in all stages of the preparation of the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Additional information

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