Journal of Biomedical Informatics 98 (2019) 103287

Contents lists available at ScienceDirect

Journal of Biomedical Informatics

journal homepage: www.elsevier.com/locate/yjbin

Game-based interventions for neuropsychological assessment, training and rehabilitation: Which game-elements to use? A systematic review

Filipa Ferreira-Brito[a,*], Mónica Fialho[a], Ana Virgolino[a], Inês Neves[a], Ana Cristina Miranda[a,b], Nuno Sousa-Santos[a,c], Cátia Caneiras[a,d], Luís Carriço[e,f], Ana Verdelho[a,g,h], Osvaldo Santos[a]

[a] Instituto de Saúde Ambiental (ISAMB), Faculdade de Medicina, Universidade de Lisboa, Av. Prof. Egas Moniz, Ed. Egas Moniz, Piso 0, Ala C, 1649-028 Lisboa, Portugal
[b] USF AlbaSaude, ACeS de Sintra, Administração Regional de Saúde de Lisboa e Vale do Tejo, Bairro da Tabaqueira 30, 2635-101 Rio de Mouro, Portugal
[c] Escola Superior de Saúde de Leiria, Instituto Politécnico de Leiria, Campus 2 – Morro do Lena, Alto do Vieiro – Apartado 4137, 2411-901 Leiria, Portugal
[d] Healthcare Department, Nippon Gases Portugal, Rua Real Fábrica de Atanados, n°. 1, 2600-242 Vila Franca de Xira, Portugal
[e] LASIGE, Faculdade de Ciências, Universidade de Lisboa, Portugal
[f] Departamento de Informática, Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal
[g] Instituto de Medicina Molecular (iMM), Faculdade de Medicina, Universidade de Lisboa, Av. Prof. Egas Moniz, Ed. Egas Moniz, 1649-028 Lisboa, Portugal
[h] Departamento de Neurociências, Hospital de Santa Maria-Centro Hospitalar Lisboa Norte, Faculdade de Medicina, Universidade de Lisboa, Av. Prof. Egas Moniz, Ed. Egas Moniz, 1649-028 Lisboa, Portugal

ARTICLE INFO

Keywords:
Video games
Serious games
Cognitive functions
Attention
Working memory
Inhibitory control

ABSTRACT

Game-based interventions (GBI) have been used to promote health-related outcomes, including cognitive functions. Criteria for game-elements (GE) selection are insufficiently characterized in terms of their adequacy to patients' clinical conditions or targeted cognitive outcomes. This study aimed to identify GE applied in GBI for cognitive assessment, training or rehabilitation. A systematic review of literature was conducted. Papers involving video games were included if: (1) presenting empirical and original data; (2) using video games for cognitive intervention; and (3) considering attention, working memory or inhibitory control as outcomes of interest. Ninety-one papers were included. A significant difference between the number of GE reported in the assessed papers and those composing video games was found ($p < .001$). The two most frequently used GE were: score system (79.2% of the interventions using video games; for assessment, 43.8%; for training, 93.5%; and for rehabilitation, 83.3%) and narrative context (79.2% of interventions; for assessment, 93.8%; for training, 73.9% and for rehabilitation, 66.7%). Usability assessment was significantly associated with six of the seven GE analyzed (*p-values between* $p \leq 0.001$ and $p. = 027$). The use of GE that act as extrinsic motivation promotors (*e.g.,* numeric feedback system) may jeopardize patients' long-term adherence to interventions, mainly if associated with progressive difficulty-increase of gaming experience. Lack of precise description of GE and absence of a theoretical framework supporting GE selection are important limitations of the available clinical literature.

1. Introduction

Game-based interventions (GBI) are built on the assumption that specific human skills and behaviors can be more easily promoted when the required training is conducted within a playful and entertaining context, such as the ones entailed by video games [1]. Gamification processes [2], serious games [3] and applied games [4] are, currently, relevant and innovative approaches in the study of human behavior change through the use of video games.

Game-based interventions have been used in clinical contexts to promote adherence and cognitive capacity among both healthy and clinical populations. Directly inspired on traditional games, game-elements (GE) can be defined as a set of video games components which include patterns, objects, principles, models or methods [2,5]. Points, levels of difficulty, badges, storyline and plot, progression based on success or failure to achieve the game's goals and multiplayer component are just a few examples of GE typically present in video games.

The use of GE to promote learning and motivation finds support on traditional psychological theories [6]. According to the Self-Determination Theory [7], intrinsic-motivated behavior (or at least more

* Corresponding author.
E-mail addresses: filipa.brito@campus.ul.pt (F. Ferreira-Brito), mfialho@medicina.ulisboa.pt (M. Fialho), avirgolino@medicina.ulisboa.pt (A. Virgolino), inestdneves@gmail.com (I. Neves), ana.miranda@arslvt.min-saude.pt (A.C. Miranda), nunoneto@campus.ul.pt (N. Sousa-Santos), ccaneiras@gmail.com (C. Caneiras), lmcarrico@fc.ul.pt (L. Carriço), averdelho@medicina.ulisboa.pt (A. Verdelho), osantos@medicina.ulisboa.pt (O. Santos).

https://doi.org/10.1016/j.jbi.2019.103287
Received 22 January 2019; Received in revised form 19 August 2019; Accepted 7 September 2019
Available online 10 September 2019
1532-0464/

autonomous motivated behavior) is developed when the person achieves a sense of competence towards the activity and when it is allied with an internal perceived locus of control of the task. In video games, some GE, such as positive feedback messages, can promote a sense of competence while playing the game. Also, internal perceived locus of control is promoted with tooltips or help buttons that show to the player what he or she did wrong and how to correct the action [7].

Another possible example is the implementation of tutorials and other on-boarding tools to introduce game mechanics that are initially beyond the newbie's capacity. The acquisition and development of new skills, supported by such "external" help or by a more experienced agent, finds theoretical support in Vygotsky's concept of zone of proximal development [8], as well as in the concept of scaffolding proposed by Wood and colleagues [9]. Within these two conceptual views, learning and problem solving are depicted as constructive processes that can be fostered if guided by more capable peers. This is also the case in Massively Multiplayer Online Games, where interaction and collaboration with more skilled players are not only available but highly sought through participation in both in- and out-game activities, such as raids, parties, chats and discussion forums.

The study of the impact of video games on human cognition and behavior has been heavily focused on the downsides of such playing. Notwithstanding, existing results are conflicting. On one side, excessive exposure to video games, especially to those with violent content [10], has been associated with increased aggressiveness (at behavioral, cognitive or emotional levels), and decreased prosocial behavior, empathy, and sensitiveness to aggression [11]. On the other side, there are studies were these results were not replicated [12]. A recent study proposed that the increase of aggressive behavior associated with playing video games is mainly the result of a priming effect (which increases accessibility to aggressive/violent thoughts) and, so, the effects are short-lived, occurring only immediately after video game exposure (no more than 15 min) [12]. Przybylski and Weinstein [13], on the other hand, propose that the aggressiveness that might be associated with video games may be better explained by background-factors present in specific cohorts (*e.g.,* technology use and material deprivation). Additionally, the authors highlighted the high methodological flexibility present in aggression behavior and violent gaming measures that contributes to selective reporting of results [13].

The scientific community has recently been also interested on the beneficial impact that video games may have in human behavior. For instance, in a recent meta-analysis about the efficacy of serious games to reduce cognitive decline among psychiatric patients, a moderate effect size of this ludic-therapeutic approach was found ($g = 0.79$ (95% CI 0.36 – 1.21); $p < 0.05$) [14]. In another systematic review of literature, where the impact of video games was compared to other computer-based interventions, Kueider and colleagues concluded that video games constitute an effective intervention for global cognition stimulation ($d = 0.69$), with relevant results also on reaction time ($d = 0.77$), processing speed ($d = 0.72$), executive function ($d = 0.25$), and attention ($d = 0.21$) [15]. Anguera et al. [16] showed a significant reduction in multitasking cognitive cost in a group of older adults after playing NeuroRacer – a 3D multitasking training video game designed to improve cognitive control – when compared to an active control (single-task training) and to a non-contact group. Furthermore, improvements identified in Anguera's experiment persisted after six months without boosting sessions, with benefits being transferred to other cognitive domains than those directly targeted by the video game (*i.e.,* sustained attention and working memory).

Nonetheless, important methodological shortcomings (*e.g.,* lack of concise terms or of standardized methods to develop and assess GBI) and ethical concerns (*e.g.,* unfamiliarity or technophobia, unrealistic expectations of improvement and skill generalization, the possibility of physical harm, addiction, or social isolation) have been reported [5,17,18].

From a clinical point-of-view, it is of great concern the absence of a conceptual or clinical rationale supporting GE selection depending on patient's clinical conditions and/or on targeted cognitive outcomes. One rare exception can be found in the work of Lumsden et al. [17], where the authors clearly stated that GE such as rewards and feedback seem to be particularly suitable for persons with Attention Deficit Hyperactivity Disorder (ADHD), who are especially responsive to immediate reinforcement, feedback and clear definition of goals and objectives. On the other hand, the subjective and somehow arbitrary use of GE in vulnerable populations [18] can impair the successful clinical usage of GBI and can introduce deleterious effects on users' performance [19] or psychological/emotional health. Take as example a life bar (score system element) in a serious game for cancer survivors, where patients lose points every time they do not achieve the game's goal.

To the authors knowledge, this research represents a first effort to overcome the aforementioned limitations, namely the lack of a theoretical framework supporting GE selection in interventions focused on cognitive promotion. For this purpose, a systematic review of literature (following PRISMA guidelines [20]) was conducted to identify which GE were most frequently present in GBI used for cognitive assessment, training or rehabilitation. Furthermore, considerations were made regarding the capacity of those GE to promote patient's adherence to the cognitive intervention, reflecting on the adequacy of such GE to the study of the targeted cognitive outcomes.

2. Materials and methods

2.1. Search strategy

Search-terms related to "game-based interventions" and "cognitive outcomes" were identified on basis of an exploratory narrative review and discussion between members of the research team. Medical Subject Headings (MeSH) terms were used whenever possible. A total of 46 "game-based interventions" terms were combined listwise with 14 search-terms related with "cognitive outcomes" (*i.e.,* each search-term of the first category was individually combined with each term of the second category) (see Supplementary Table S1 for details on the search strategy). This keyword combination allowed us to minimize the exclusion of potential entries that could be masked by the use of less common terms, which is not unusual in recent research fields.

2.2. Information sources and search

Electronic database search was conducted on 24 January 2017 and then updated on 22 March 2019. PubMed, SciELO, and EBSCO – Psychology and Behavioral Sciences Collection were searched, with a restriction to the following inclusion criteria: (1) publication date (PubMed: 24 January of 2006 to 21 March of 2019, SciELO: 2007–2019; EBSCO: 1 January of 2006 to 21 March of 2019); (2) full text in English (PubMed and EBSCO); and (3) search field (title and abstract). Furthermore, search was restricted to peer-reviewed papers (EBSCO database) and studies with humans as study's subjects (PubMed). Book chapters were excluded.

2.3. Additional sources of information

Eighteen journals with editorial interests on serious games and games for health were identified and manually searched to locate additional studies of interest published between 2012 and 2019 (see Supplementary Table S1 for details). Additionally, reference lists of (1) each paper included for data extraction and (2) the literature reviews (narrative or systematic ones) identified during the screening process were also hand-searched for identification of additional relevant papers. Literature reviews were considered only as potential source to identify empirical papers (*i.e.* for reference search purposes; not for data extraction).

2.4. Screening and eligibility

The set of initially retrieved entries was assigned to three pairs of reviewers and independently screened by each researcher in the pair, considering title and abstract analysis. Studies were eligible for data extraction if: (1) empirical and original data were presented; (2) a video game (commercial, adapted or applied) was used for cognitive assessment, training or rehabilitation; (3) the intervention targeted and explicitly reported individual measures of attention, working memory or inhibitory control outcomes; and (4) the full text was available in English, Portuguese or Spanish. To be considered as a video game, the software had to include at least one of the following GE: (1) score system (in software that presented unrelated tasks, a final/total score system had to be present); (2) performance feedback system (non-numeric); or (3) continuous narrative context between tasks. Multigame platforms (*e.g.,* unrelated mini-games), computerized cognitive training programs (*e.g.*, RehaCom®), software programs that were merely digital version of paper-and-pencil instruments (no GE added) and studies that used more than one video game per group were excluded. Entries from the update search (n = 464) were screened by the first author and 10% of those entries were cross-checked by the last author. Disagreements between researchers concerning data eligibility were solved by a third independent senior element, who approved the final list of studies to be included for data extraction.

Narrative context – storyline in which the main action of the game unfolds. Storytelling adds meaning and guides action whether in a fantasy (*e.g.,* save the princess) or real-like scenario (*e.g.,* shopping).
Avatar/Character – player's virtual representation whether human-like or other (*e.g.,* spaceship).
Score system – numeric feedback system that informs player about his or her performance and progression in the game. Points, money, missions, levels, leaderboards, and progression bars were included in this category.
Reward system – visual feedback system related to the achievement of specific challenges and skills. Badges, medals, awards, extra powers, access to virtual world restricted areas, and written and/or auditory messages related to player's performance were included in this category.
Win and Lose condition – it is shown to the player, in an explicit way, that he or she was able or not to achieve the goal of the game (*e.g.,* death, return to a previous level).
Time pressure – implementation of time constraints to complete a task or achieve the best score possible.
Multiplayer – more than one player influences gameplay simultaneously. This includes cooperation and/or competitive modes.

Fig. 1. Game-elements description.

2.5. Data collection process

A data extraction spreadsheet, including a glossary of concepts (*e.g.*, GE, cognitive outcomes), was developed and used by all team members. This was done to promote harmonization of the extraction process. Three sections were considered: "General paper information" section, "Video game descriptive information" section, and "Interventions details and cognitive/health outcomes" section (see Supplementary Table S2 for details). Extraction fields presented two different formats of response: pre-defined option (closed-answer format), or strings of information (open-answer format). When it was not possible to characterize study's elements according to the available options, researchers could select the option *not clear/not sure*.

2.5.1. General paper information section

In this section, information regarding title, authors' name, journal's title, year of publication, publication quartile (in 2017), and area of expertise (*i.e.*, area in which the study had the highest quartile in 2017 according to the Scimago Journal & Country Rank) were gathered. Papers were coded according to the following four categories of scientific expertise: (1) Health Sciences (included journals focused on Neurology, Neurosciences, Pediatrics, Perinatology and Child Health, Medicine, Rehabilitation, Geriatric, Gerontology); (2) Social Sciences (Psychology, Neuropsychology, Physiological Psychology, Clinical Psychology, Cognitive Neuroscience, Behaviour Research and Therapy); (3) Computer Sciences (Computer Sciences Applications, Engineering, Health Informatics); and (4) Other (Public Health, Environment and Occupational Health, Language and Linguist, Multidisciplinary).

2.5.2. Video game descriptive information section

2.5.2.1. General description. This section addressed information regarding the game's title, main activity, type of platform, and virtual components. The central action/task that the player must perform to achieve the game's goal was considered the main activity (*e.g.,* drive a car, collected/find/selected stimuli, shopping, play tennis). Three types of platforms were considered: game's console, touch-based devices (*i.e.,* smartphone/tablet) and computer. Finally, video games were classified as being exergames or not, having virtual reality (VR) or not, or having another virtual component.

2.5.2.2. Purpose and cognitive utility of video game. Two types of video games were considered according to the purpose for which the video game was initially developed: (1) applied games (AG) [4], which encompasses serious games – video games specifically developed to achieve a change in the player's patterns of behavior [3] – and gamified software, a software that underwent a process of intentional use of GE in order to enhance a game experience in non-game tasks [5]; and (2) commercial video games (CG), developed for the main purpose of entertainment and leisure [21]. Commercial video games which were adapted (*e.g.,* using a different game controller or interface such as brain computer interface) were classified as AG if targeting behavior change. Cognitive utility of game refers to the objective for which video games were used, namely: assessment, training or rehabilitation of cognitive functions.

2.5.2.3. Game-elements. Studies were searched for the presence of seven GE. Since there is no widely-accepted definition of what or how many are the basic GE that compose video games, an initial set was gathered based on the information reported elsewhere [2,22–24]. That initial set was then refined to include a total of seven GE whose definitions were subject of discussion between research team members until a consensus was reached (see Fig. 1). To obtain an in-depth description of each of the video games included in the selected papers, an additional web-based search was conducted. Official websites were the main source of information to CG. University, research groups and video-sharing (*e.g.,* YouTube) websites were also searched in the case of AG. Information extracted from these two sources was introduced separately.

2.5.3. Intervention details and cognitive/health outcomes section

This section was dedicated to the extraction of information regarding intervention and sample characteristics. Therapy aims to help individuals to regain the capacity to self-regulate his or her behavior in order to being able to live autonomously [25]. Having this perspective in mind, three cognitive functions were selected within the core components of cognitive control and self-regulation theory [26]:

- *Attention*: process that enables individuals to consciously process stimuli/information in our environment [27]. All studies that focused on attention outcomes were considered for data extraction purposes regardless of modality (*e.g.,* visual, auditory) or type (*e.g.,* sustained, selective) except for studies focused on sensory attention, which were excluded.

- *Working memory:* system that enables the temporary storage and manipulation of information necessary to adequately respond to environmental demands [28]. Working memory outcomes were always considered when presented as a single expression ("working memory") in the analyzed paper.
- *Inhibitory control*: capacity to inhibit a dominant and automatic response in order to (deliberately) select a more adequate one regarding environment or task's characteristics [29]. Inhibitory control or inhibitory capacity were both accepted and considered as equivalent terms.

The presence of other cognitive or health-related outcomes was also registered. Finally, information on near transfer capacity (impact on related cognitive functions targeted by the video game), far transfer capacity (impact on non-related cognitive or health outcomes targeted by the video game) [30], user-experience (UX) evaluation (user's perceptions on software usability, hedonic experience), and sample characteristics were also extracted.

2.6. Statistical analysis

Analysis of data was done using the program Statistical Package for the Social Science (IBM-SPSS), version 24.0. Studies that presented more than one intervention arm, with a different video game per arm, provided different entries in the database. This was done because the sample unit for data analysis was the video game, not the paper. Important to highlight that this was done only when each intervention arm included only one game (as explained in the screening and eligibility section, studies which entailed more than one video game for the same intervention arm were excluded). Overall, 118 interventions with video games were identified in the 91 papers included in the qualitative analysis.

Three sampling bases were considered for data analysis (see Fig. 2). For GE frequency analysis, video games reported in different papers were considered only once ($n_{video.games} = 72$); this is, therefore, the total number of video games without duplication across papers. For GE frequency analysis by cognitive utility of the games (*i.e.,* assessment, training or rehabilitation), video games reported in different papers targeting the same cognitive utility were considered only once ($n_{cog.utility} = 80$). For instance, if one video game was reported in two or more papers for assessment purposes, the video game was counted only once; but if the same video game was reported for assessing cognitive functions in one paper and for training cognitive functions in another paper, then the video game was considered twice.

Finally, for two types of analyses (comparing the number of GE described in the papers and the number of GE really existent in the video games; and characterizing the association between GE really existent in the video games and cognitive outcomes), the total sample of video games interventions ($n_{all.entries} = 118$) was considered; this means that all entries were considered regardless of duplication across papers. This decision was based on the fact that some video games were used in different papers to evaluate different cognitive functions.

Data normality was tested by using Kolmogorov-Smirnov test and considering kurtosis and skewness (normality assumed when kurtosis and skewness ranged between −2 and 2) [31]. Results were considered significant for a *p*-value ≤ 0.05. Because normality was observed for all variables and for all comparison groups, parametric tests were applied. Paired-samples t-tests were conducted to determine whether the number of GE reported in the papers and those that actually compose video games (as observed in webpages describing the games) differed significantly. This was done for all different video games altogether ($n_{all.entries} = 118$), and for commercial games (n = 51) and applied games (n = 67). Paired-samples t-tests were also used for assessing if the number of GE reported in the papers and those that actually compose video games differ according to the cognitive utility of the video games (assessment, n = 28; training, n = 67; rehabilitation, n = 23). Differences between commercial and applied games regarding the number of GE as described in video games webpages were tested through independent sample *t*-test ($n_{video.game} = 72$). Differences between the cognitive utility of the video games (assessment, training and rehabilitation) regarding the number of GE as described in video games webpages were tested with one-way ANOVA with Bonferroni Post-Hoc test ($n_{cog.utility} = 80$).

Chi-square tests of independence were applied to study the association between different pairs of GE (with Cramer's V for assessing the strength of the associations); this was also done for testing the independence between each GE and cognitive outcomes (attention, working memory, inhibitory control), cognitive utility of the game (assessment, training, rehabilitation), having health-related outcomes or not, virtual reality or another virtual component (*e.g.,* brain-computer interfaces); being an exergame, or not; and type of game platform (console, smartphone/tablet, computer). Chi-square tests of homogeneity were applied to check if each GE was more frequently used in applied or commercial video games.

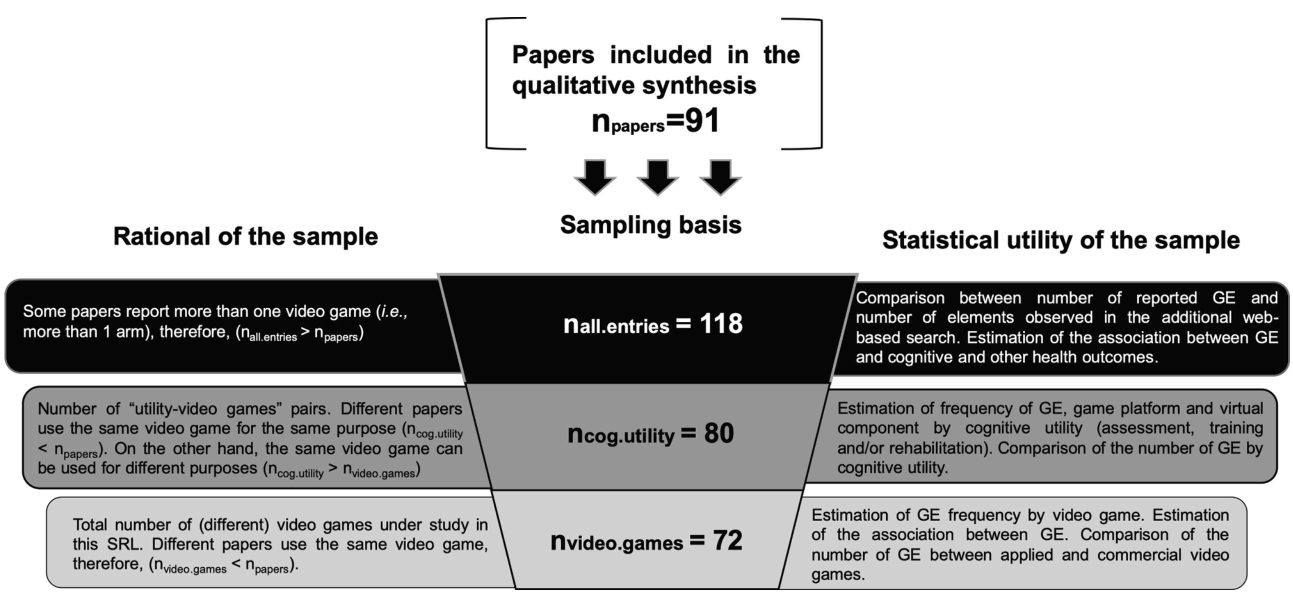

Fig. 2. Sampling bases used in statistical analysis.

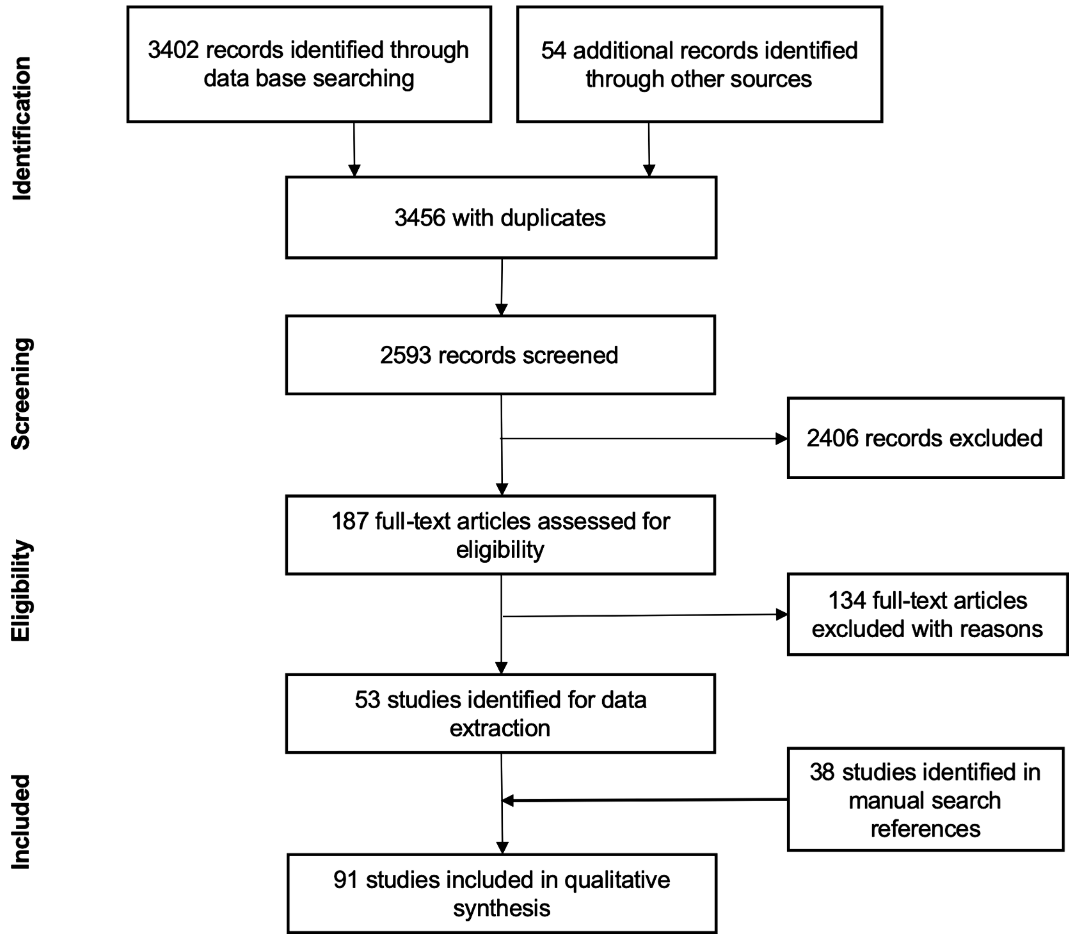

Fig. 3. PRISMA flow diagram.

3. Results

3.1. Study selection

Overall, 3456 papers matched the set of inclusion criteria (see Fig. 3). Fifty-four papers were added after manual search of additional journals focusing on serious games and/or games for health areas. After removing duplicates, 2593 papers were screened considering title and abstract. Overall, 2406 papers were excluded on basis of this analysis. From the 187 eligible papers for full-text analysis phase, 53 were included in the current review. Common reasons for exclusion of papers were: no use of video game (n = 17); use of game platforms or more than one video game simultaneously in the same study arm (n = 16); attention, working memory and inhibitory control were not assessed as cognitive outcomes (n = 28); literature reviews (n = 28); different scope (n = 17) (*e.g.,* roundtable discussions); full-text was not available, even after e-mail contact with authors (n = 2); and two or more of the aforementioned reasons combined (n = 26). Thirty-eight papers were later added from manual search of the list of references of included papers and literature reviews. A total of 91 papers were included for data extraction, in which 72 different video games were identified.

3.2. Bibliometric characterization of GBI studies

Year of publication of studies ranged from 2006 to 2018, with publication peak at 2013 (n = 15). More than half of the studies were published in journals ranked in the first quartile (54/91). Sixteen studies were published in journals in the second quartile, six studies in the third quartile and five studies in the fourth quartile. Ten studies were published in journals with no impact factor attributed.

From the 81 papers published in journals with impact factor, 42 were published in journals scoping Health Sciences, 25 Social Sciences, eight Computer Sciences, and six other scientific disciplines. Additional analysis considering quartile of publication by area of expertise showed that from the 54 studies published in the first quartile, 26 were indexed to Health Sciences, 22 to Social Sciences, one to Computer Sciences, and five to the category “other” (see Supplementary Table S3 for details).

3.3. Purpose and cognitive utility of GBI

From the 72 identified video games, 42 are AG and 30 CG. Sixteen video games were used for cognitive assessment (of which 15 are AG and one CG), 46 for cognitive training (of which 18 are AG and 28 CG) and 18 for cognitive rehabilitation purposes (of which 14 AG and 4 CG). The difference between the number of identified video games ($n_{video.games}$ = 72), the number of entries according to cognitive utility ($n_{cog.utility}$ = 80), and the total number of entries ($n_{all.entries}$ = 118) is due to the fact that: (1) eighteen papers reported data regarding more than one video game (one video game per intervention arm) [32–49]; (2) nine CG (Medal of Honor: Allied Assault [34,41]; Medal of Honor: Pacific Assault, EA Games [44,49,50]; Rise of Nations, SEGA [34,51]; Brain Age / Dr. Kawashima’s Brain Training, Nintendo [37,38,47,48,52,53]; Tetris [34,36,41,46–48,54]; Modern Combat: Sandstrom, Gameloft [32,39,40]; Big Brain Academy, Nintendo [55,56]; Ballance, Atari [44,49]; and The Sims, EA Games [32,43,45]); and (3) 13 AG (Neurofeedback Game [95,96]; VRROOM [116,117]; VRST [81,82]; VRCPAT [75–78,99]; Braingame Brian [86,87,103]; Working memory program, Cogmed Systems [33,107,108];

Table 1
Description of video games entries identified in the included ($n_{all.entries}$ = 118).

Purpose and utility of the game		Game-elements							Cognitive Outcomes		
Game's name main activity	Study that used the video game	Narrative context	Avatar/ character	Score system	Reward system	Win/lose	Time pressure	Multiplayer	Attention	Working memory	Inhibitory control
Applied games for cognitive assessment											
Art Gallery Test (AGT) – To identify differences between two images, construct puzzles and finding the details.	Gamito et al. [57]	Yes	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	No	No	Yes	Yes	Yes
Aula Nesplora – To respond as quickly as possible to target stimuli while inhibiting any responses to non-target stimuli.	Areces et al. [58]	Yes	Not clear /sure	No	No	Not clear /sure	Yes	No	Yes	Yes	Yes
	Iriarte et al. [59]								Yes	No	No
	Díaz-Orueta et al. [60]								Yes	Yes	No
Raiders of the Lost Treasure – To collect/find hidden objects.	Silva and Frère [61]	Yes	Yes	Yes	Yes	Not clear /sure	No	Not clear /sure	Yes	No	No
Shoe Closet Test – To match each pair of shoes with the color's compartments in a virtual closet.	Oliveira et al. [62]	Yes	Not clear /sure	Not clear /sure	No	Not clear /sure	Not clear /sure	No	Yes	No	No
Space Matrix – To destroy spaceships.	McPherson and Burns [63]	Yes	No	Yes	Yes	Not clear /sure	Yes	Yes	No	Yes	No
Tap the little hedgehog – To perform different operations on abstract patterns such as copying, reproducing sequences from memory and mirroring patterns.	Verhaegh, Fontijn and Aarts [64]	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	No
Timo's Adventure – To collect stars.	Peijnenborgh et al. [65]	Yes	Yes	Yes	Yes	Not clear /sure	Yes	No	Yes	Yes	Yes
Towi Games – To make arrangements to travel	Rosetti et al. [66]	Yes	Not clear /sure	Yes	No	Not clear /sure	Not clear /sure	No	Yes	Yes	Yes
ClinicaVR: Classroom-CPT – To maintain vigilance and react to a specific stimulus within a set of continuously presented distractors.	Parsons et al. [67]	Yes	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Yes	No	Yes	No	No
	Negut, Jurma and David [68]								Yes	Yes	No
	Nolin et al. [69]								Yes	No	Yes
	Gilboa et al. [70]								Yes	No	No
	Moreau et al. [71]								Yes	No	Yes
	Adams et al. [72]								Yes	No	No
	Nolin, Martin and Bouchard [73]								Yes	No	Yes
Virtual Library Task – To perform several tasks associated with the day-to-day running of a library.	Renison et al. [74]	Yes	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Yes	No	No	Yes	Yes
Virtual Reality Cognitive Performance Assessment Test (VRCPAT) – To select stimuli while driving a car.	Parsons and Rizzo [75]	Yes	Not clear /sure	Yes	Not clear /sure	Not clear /sure	Yes	Not clear /sure	Yes	No	No
	Parsons et al. [76]								Yes	No	No
	Parsons et al. [77]								Yes	No	No
	Parsons et al. [78]								Yes	No	No
ClinicaVR: Apartment Stroop – To select target stimuli.	Henry, Joyal and Nolin [79]	Yes	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Yes	No	Yes	No	Yes
VR-Based MET – To shop.	Raspelli et al. [80]	Yes	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	No	Yes	Yes	No
Virtual Reality Stroop Task (VRST) – To respond to a Stroop-like condition while driving a car.	Parsons et al. [81]	Yes	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	No	Yes	No	Yes
	Armstrong et al. [82]								Yes	No	Yes
VR Office Environment – To learn 16 target items, depicted among numerous other office distractors.	Matheis et al. [83]	Yes	Not clear /sure	No	No	No	Yes	No	Yes	No	No
Applied games for cognitive training											
3-D virtual reality kayak program – To paddle a Kayak.	Park and Yim [84]	Yes	No	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Yes	No	No
Adaptive WM task variant – To select target stimuli.	Jaeggi et al. [85]	Yes	No	Yes	Yes	Not clear /sure	Not clear /sure	No	No	Yes	No
Braingame Brian – To help and befriend the game-worlds inhabitants by creating increasingly elaborate inventions.	van der Oord et al. [86]	Yes	Yes	Yes	Yes	Not clear /sure	Yes	Not clear /sure	No	Yes	Yes
	Verbeken et al. [87]								No	Yes	Yes

(*continued on next page*)

Table 1 (*continued*)

Purpose and utility of the game		Game-elements							Cognitive Outcomes		
Game's name main activity	Study that used the video game	Narrative context	Avatar/ character	Score system	Reward system	Win/lose	Time pressure	Multiplayer	Attention	Working memory	Inhibitory control
Card-pairing memory game – To open or close cards on screen.	Lee et al. [88]	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	No	Yes	No	No
City Builder Game – To remember and order a set of squares in a specific order.	Boendermaker et al. [89]	Yes	No	Yes	Yes	No	Yes	No	No	Yes	No
Cybercycle – To cycle.	Anderson-Hanley et al. [90]	Yes	No	Yes	No	No	Yes	No	Yes	No	No
Desktop VR System – To execute daily life activities.	Gamito et al. [91]	Yes	Not clear /sure	Yes	Not clear /sure	Not clear /sure	Not clear /sure	No	Yes	No	No
EVET - Edinburgh Virtual Errands Test – To shop.	Logie et al. [92]	Yes	No	Yes	Not clear /sure	No	Yes	No	No	Yes	No
Interactive Videogame Technology – To collect and deliver the largest amount of contraband items.	Russell and Newton [93]	Yes	Yes	Yes	Not clear /sure	Not clear /sure	Yes	Yes	Yes	No	No
Labyrinth – To select a set of stimuli while avoiding a snake within a time limit.	Montani, De Grazia and Zorzi [94]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
Neurofeedback Game – To refill a set of elements.	Thomas et al. [95]	No	No	Yes	Yes	Yes	No	No	Yes	No	No
Neurofeedback Game – To refill a set of elements.	Thomas et al. [96]	No	No	Yes	Yes	Yes	No	No	Yes	No	No
NeuroRacer – To drive the car on a road.	Anguera et al. [16]	Yes	Yes	Yes	Yes	Not clear /sure	Yes	No	Yes	Yes	No
Physical exercise plus high cognitive demand – To collect different colored coins and corresponding colored dragons.	Barcelos et al. [42]	Yes	No	Yes	Not clear /sure	No	Yes	No	Yes	No	Yes
Cybercycle – To cycle		Yes	No	Yes	No	No	Yes	No	Yes	No	Yes
Space Fortress – To shoot missiles and destroy a space fortress while protecting your spaceship against damage.	Maclin et al. [97]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
	Nikolaidis et al. [98]								Yes	Yes	No
Virtual Reality Cognitive Performance Assessment Test (VRCPAT) – To select stimuli while driving a car.	Parsons and Rizzo [99]	Yes	Not clear /sure	Yes	Not clear /sure	Not clear /sure	Yes	Not clear /sure	Yes	No	No
Working memory program, Cogmed systems – To remember both location and order of a number of visual stimuli.	Thorell et al. [33]	No	No	Yes	Yes	Not clear /sure	Yes	No	Yes	Yes	Yes
Inhibitory control program, Cogmed systems – To respond according to a certain stimulus.		No	No	Yes	Yes	Not clear /sure	Yes	No	Yes	Yes	Yes
Working memory task with game-elements – To memorize a one-digit number (key-digit); to classify a simple arithmetic decision task as either true or false.	Ninaus et al. [100]	Yes	No	Yes	No	Yes	Not clear /sure	Not clear /sure	No	Yes	No
Applied games for cognitive rehabilitation											
3D classroom environment – To select target stimuli.	Ali and Puthusserypady [101]	Yes	Yes	Yes	Not clear /sure	Yes	Not clear /sure	Not clear /sure	Yes	No	No
3D video game rehabilitation training – To explore each street with minimal backtracking.	Caglio et al. [102]	Yes	Yes	Not clear /sure	Not clear /sure	Not clear /sure	No	No	No	Yes	No
Braingame Brian – To help and befriend the game-worlds inhabitants by creating increasingly elaborate inventions.	Dovis et al. [103]	Yes	Yes	Yes	Yes	Not clear /sure	Yes	Not clear /sure	No	Yes	Yes
Desktop VR System – To execute daily life activities.	Gamito et al. [104]	Yes	Not clear /sure	Yes	Not clear /sure	Not clear /sure	Not clear /sure	No	Yes	No	No
Motion Rehab – To select target stimuli and ignore distractors.	Martel, Colussi and Marchi [105]	Yes	Yes	Yes	Not clear /sure	Not clear /sure	Not clear /sure	No	Yes	No	No
'Odd Yellow' training – To reproduce the location of the odd-one-out and the location of the yellow figure shape.	van der Molen et al. [106]	No	No	Yes	No	Yes	Yes	No	No	Yes	Yes
Working memory program, Cogmed systems – To remember both location and order of a number of visual stimuli.	Chacko et al. [107]	No	No	Yes	Yes	Not clear /sure	Yes	No	No	Yes	No
	Beck et al. [108]								No	Yes	No
RoboMemo, Cogmed systems – To reproduced sequence of stimuli (lights/numbers) in direct or backward order.	Gray et al. [109]	Yes	No	Yes	Yes	Not clear /sure	Yes	No	Yes	Yes	No
	Westerberg et al. [110]								Yes	Yes	Yes

(*continued on next page*)

Table 1 (*continued*)

Purpose and utility of the game		Game-elements							Cognitive Outcomes		
Game's name main activity	Study that used the video game	Narrative context	Avatar/ character	Score system	Reward system	Win/lose	Time pressure	Multiplayer	Attention	Working memory	Inhibitory control
Space Fortress – To destroy the Space Fortress.	Janssen et al. [111]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
The Virtual Supermarket – To shop.	Carelli et al. [112]	Yes	Not clear /sure	Yes	Not clear /sure	Yes	Not clear /sure	No	Yes	No	No
Virtual reality environment – To perform quotidian activities.	La Paglia et al. [113]	Yes	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Not clear /sure	Yes	No	No
VR Setup – To execute daily living activities.	Gamito et al. [114] Gamito et al. [115]	Yes	Not clear /sure	Yes	Not clear /sure	Not clear /sure	Not clear /sure	No	Yes Yes	Yes Yes	No No
VRROOM - Virtual Reality and Robotic Optical Operations Machine – To hold the handle of the robot and move it toward spherical targets.	Larson et al. [116] Dvorkin et al. [117]	No	No	No	Yes	No	Yes	No	Yes Yes	No No	No No
WM training task with game elements – To reproduce sequences of randomly lit-up squares in a 4x4 grid.	Prins et al. [118]	Yes	Yes	Yes	Yes	Yes	No	Not clear /sure	Yes	Yes	No
Commercial video games for cognitive assessment											
Tetris – To form a horizontal line without leaving any gaps.	Lau-Zhu et al. [54]	No	No	Yes	Yes	Yes	Yes	No	No	Yes	No
Commercial video games for cognitive training											
Big Brain Academy, Nintendo – To respond as quickly as possible to the different tasks.	McLaughlin et al. [55]	No	Yes	Yes	Yes	No	Yes	Yes, not clear if active	Yes	No	No
Mario Kart DS, Nintendo – To race.	Boot et al. [38]	Yes	Yes	Yes	Yes	No	Yes	Yes, but not active	Yes	No	No
Brain Age / Dr. Kawashima's Brain Training: How old is your brain, Nintendo – To solve mathematical questions and memorize information.		No	Yes	Yes	No	No	Yes	No			
New Super Mario Bros, Nintendo – To rescue the princess.	Lorant-Royer et al. [37]	Yes	Yes	Yes	Yes	No	No	Yes, not clear if active	Yes	Yes	No
Brain Age / Dr. Kawashima's Brain Training: How old is your brain, Nintendo – To solve mathematical questions and memorize information.	Nouchi et al. [47]	No	Yes	Yes	No	No	Yes	No	Yes	No	No
Tetris – To form a horizontal line without leaving any gaps.		No	No	Yes	Yes	Yes	Yes	No			
Brain Age / Dr. Kawashima's Brain Training: How old is your brain, Nintendo – To solve mathematical questions and memorize information.	Nouchi et al. [48]	No	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes
Tetris – To form a horizontal line without leaving any gaps.		No	No	Yes	Yes	Yes	Yes	No			
Modern Combat: Sandstorm, Gameloft – To navigate in hostile enemy territory and to achieve predetermined objectives such as deactivating enemy equipment.	Oei and Patterson [40]	Yes	Yes	Yes	Yes	Yes	No	Yes, not clear if active	Yes	No	No
Metal Gear Solid, Konami – To kill enemies.		Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	No
Super Sniper, Addicting Games – To kill enemies.		Yes	No	Yes	Not clear /sure	Yes	Yes	No	Yes	No	No
Deer Hunter, Atari, Glu Mobile – To hunt.		Yes	No	Yes	Yes	Not clear /sure	No	No	Yes	No	No
Computerized Card Game "Belote" – To complete a set of missions.	Cujzek and Vranis [35]	No	No	Yes	No	Yes	No	Yes	No	Yes	Yes
Computerized Ludo – To place all of the figures on the specific fields before other players.		No	Yes	No	No	Yes	No	Yes	No	Yes	Yes
Unreal Tournament 2004 – To kill enemies and avoid death.	Green and Bavelier [46]	Yes	No	Yes	Yes	Yes	Yes	Yes, not clear if active	Yes	No	No
Tetris – To form a horizontal line without leaving any gaps.		No	No	Yes	Yes	Yes	Yes	No			

(*continued on next page*)

Table 1 (*continued*)

Purpose and utility of the game		Game-elements							Cognitive Outcomes		
Game's name main activity	Study that used the video game	Narrative context	Avatar/ character	Score system	Reward system	Win/lose	Time pressure	Multiplayer	Attention	Working memory	Inhibitory control
Tetris – To form a horizontal line without leaving any gaps.	Schubert et al. [41]	No	No	Yes	Yes	Yes	Yes	No	Yes	No	No
Medal of Honor: Allied Assault, EAGames – To kill enemies and avoid being killed.	Boot et al. [34]	Yes	Yes	Yes	Not clear /sure	Yes	Yes	Yes, not clear if active	Yes	Yes	No
Tetris – To form a horizontal line without leaving any gaps.		No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Rise of Nations, SEGA – To build new cities, to improve city infrastructures and to expand one's national border.		Yes	No	Yes	Not clear /sure	Yes	No	Yes, not clear if active	Yes	Yes	No
	Basak et al. [51]								Yes	Yes	Yes
Hidden-object game: Expedition-Everest, Big Fish Games – To find hidden objects.	Oei and Patterson [32]	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Match-3: Bejewelled 2, PopCap Games – To line up at least three similar colors either horizontally or diagonally by switching the positions of adjacent square.		No	No	Yes	Yes	Yes	No	No	Yes	Yes	No
Memory matrix 1.0, Tvishi Technologies – To reproduce a sequence by touching each tile.		No	No	Yes	Not clear /sure	Yes	Not clear /sure	Not clear /sure	Yes	Yes	No
The Sims 3, EAGames – To accomplish tasks that mimic real-life activities.		Yes	Yes	Yes	Yes	Not clear /sure	Not clear /sure	No	Yes	Yes	No
Modern Combat: Sandstorm, Gameloft – To navigate in hostile enemy territory and to achieve predetermined objectives such as deactivating enemy equipment.		Yes	Yes	Yes	Yes	Yes	Not clear /sure	Yes, not clear if active	Yes	Yes	No
Modern Combat: Sandstorm, Gameloft – To navigate in hostile enemy territory and to achieve predetermined objectives such as deactivating enemy equipment.	Oei and Patterson [39]	Yes	Yes	Yes	Yes	Yes	Not clear /sure	Yes, not clear if active	No	No	Yes
Starfront Collision, Gameloft – To kill an alien bug specie.		Yes	Yes	Yes	Yes	Yes	Not clear /sure	Yes, not clear if active	No	No	Yes
Cut the Rope - Zepto Lab/Chillingo – To solve puzzles		Yes	No	Yes	Yes	Yes	Yes	No	No	No	Yes
Fruit Ninja – To get the highest score possible.		Yes	No	Yes	No	Yes	Yes	No	No	No	Yes
The Sims 3, EAGames – To accomplish tasks that mimic real-life activities.	Blacker et al. [43]	Yes	Yes	Yes	Yes	Not clear /sure	Not clear /sure	No	No	Yes	No
Call of Duty, Activision – To complete a set of missions.		Yes	Yes	Yes	Not clear /sure	Yes	Not clear /sure	Yes, but not active			
Ballance, Atari – To steer a ball through a hovering maze of paths	Wu and Spence [49]	Not clear /sure	Yes	Yes	Yes	Yes	No	No	Yes	No	No
Need for Speed: Most Wanted, EAGames – To drive a car.		Yes	Yes	Yes	Not clear /sure	Not clear /sure	Yes	Yes			
Medal of Honor: Pacific Assault, EAGames – To collect hidden objects and achieve 100% accuracy at the shooting range.	Wu et al. [50]	Yes	Yes	Yes	Yes	Yes	Not clear /sure	Yes, not clear if active	Yes	No	No
Medal of Honor: Rising Sun, EAGames – To collect hidden objects and achieve 100% accuracy at the shooting range.	Belchior et al. [36]	Yes	Yes	Yes	Yes	Yes	Not clear /sure	Yes, not clear if active	Yes	No	No
Tetris – To form a horizontal line without leaving any gaps.		No	No	Yes	Yes	Yes	Yes	Yes, not clear if active	Yes	No	No
StarCraft, Blizzard Entertainment – To create, organize, and command an army against an enemy army in a real-time map-based setting.	Glass, Maddox and Love [45]	Yes	No	Yes	Not clear /sure	Yes	Not clear /sure	Yes, not clear if active	Yes	Yes	Yes
The Sims 2, EAGames – To accomplish tasks that mimic real-life activities.		Yes	Yes	Yes	Yes	Not clear /sure	Not clear /sure	No	Yes	Yes	No
WoW - World of Warcraft, Blizzard Entertainment – To complete quests in a persistent virtual world.	Whitlock, McLaughlin and Allaire [119]	Yes	Yes	Yes	Yes	Yes	Yes	Yes, not clear if active	Yes	No	No

(*continued on next page*)

Table 1 (*continued*)

Purpose and utility of the game Game's name main activity	Study that used the video game	Game-elements Narrative context	Avatar/ character	Score system	Reward system	Win/lose	Time pressure	Multiplayer	Cognitive Outcomes Attention	Working memory	Inhibitory control
Medal of Honor: Pacific Assault, EAGames – To collect hidden objects and achieve 100% accuracy at the shooting range.	Feng, Spence and Pratt [44]	Yes	Yes	Yes	Yes	Yes	Not clear /sure	Yes, not clear if active	Yes	No	No
Ballance, Atari – To steer a ball through a hovering maze of paths		Not clear /sure	Yes	Yes	Yes	Yes	No	No			
Commercial video games for cognitive rehabilitation											
Big Brain Academy, Nintendo – To respond as quickly as possible to the different tasks.	López-Martín et al. [56]	No	Yes	Yes	Yes	No	Yes	Yes, not clear if active	Yes	Yes	No
Brain Age/ Dr. Kawashima's Brain Training: How old is your brain, Nintendo – To solve mathematical questions and memorize information.	De Giglio et al. [53] Brem et al. [52]	No	Yes	Yes	No	No	Yes	No	Yes No	Yes Yes	Yes No
Colin McRea Rally3, CodeMasters – To drive a car.	Tahiroglu et al. [120]	Yes	Yes	Yes	Not clear /sure	Not clear /sure	Yes	Yes, but not active	Yes	No	No
Tetriminos – To manipulate and rotate the blocks to create a horizontal line without gaps.	Bikic et al. [121]	No	Not clear/ sure	Yes	No	Yes	Yes	Yes, not clear if active	Yes	Yes	No

RoboMemo, Cogmed Systems [109,110]; ClinicaVR: Classroom-CPT [67-73]; VR Setup [114,115]; AULA, Nesplora [59,60,122]; Desktop VR System [91,104]; Space Fortress [97,98,111,123]; and Cybercycling [42,90]) were reported in more than one study (see Table 1).

3.4. Game-elements used in GBI

Our results showed a significant difference ($t_{(117)} = 9.67$, $p < .001$) between the number of GE described in the papers ($M = 2.17$, $SD = 1.43$) and the number of GE really existent in the video games ($M = 3.60$, $SD = 1.53$). Statistically significant differences between the number of GE described in papers ($M = 1.92$, $SD = 1.43$) and GE really existing ($M = 4.49$, $SD = 1.19$) were also observed for CG ($t_{(50)} = 11.82$, $p < .001$) and for AG (GE described: $M = 2.36$, $SD = 1.42$; GE really existent: $M = 2.93$, $SD = 1.42$; $t_{(66)} = 4.63$, $p < .001$). Similar results were identified in video games used for cognitive assessment (GE described: $M = 2.04$, $SD = 1.26$; GE really existent: $M = 2.39$, $SD = 1.13$; $t_{(27)} = 2.79$, $p = .010$), training (GE described: $M = 2.33$, $SD = 1.50$; GE really existent: $M = 4.21$, $SD = 1.43$; $t_{(66)} = 9.14$, $p < .001$) and for rehabilitation (GE described: $M = 1.87$, $SD = 1.42$; GE really existent: $M = 3.30$, $SD = 1.30$; $t_{(22)} = 4.25$, $p < .001$). In average, CG presented more GE (observed through websites) than AG ($t_{(70)} = 0.11$, $p < .001$). Considering cognitive utility, there was a statistically significant difference between groups as determined by one-way ANOVA ($F_{(2,79)} = 7.34$, $p = .001$). Bonferroni Post Hoc Test revealed that video games used for training ($M = 4.17$, $SD = 1.54$) present more GE when compared to video games use for assessment ($M = 2.56$, $SD = 1.41$, $p = .001$).

As shown in Table 2, score system and narrative context were the two most used GE (57 out of 72 video games). Score system was the most frequent GE in CG (29/30), in video games used for training (43/46) and for rehabilitation purposes (15/18), whereas narrative context was the most used GE in AG (35/42) and in video games used for cognitive assessment (15/16). Score system was associated with reward system ($\chi^2_{(1)} = 14.32$, $p < .001$, *Cramer's* $V = 0.446$), avatar ($\chi^2_{(1)} = 5.21$, $p = .005$, *Cramer's* $V = 0.269$), and with win/lose condition ($\chi^2_{(1)} = 11.00$, $p = .001$, *Cramer's* $V = 0.388$). Thus, when video games have score systems, they tend to have reward systems (n = 31), win/lose condition (n = 31), and avatars (n = 26). No significant association was found between narrative context and the other GE. Finally, it was more likely to encounter avatar ($\chi^2_{(1)} = 6.84$, $p = .014$), score systems ($\chi^2_{(1)} = 9.55$, $p = .002$), win/lose condition ($\chi2(1) = 21.63$, $p < .001$), and multiplayer component ($\chi2(1) = 22.02$, $p < .001$) in CG than in AG.

3.5. Platform and virtual components

Computer was the most used platform to run video games (42/72), regardless of cognitive utility (see Figure S1). Game consoles were used to run eight video games in 11 papers [36–38,47–49,52,53,55,56,64], while the 12 video games that used touch-based devices correspond to only four studies [32,39,40,104]. Win/lose condition was associated with using a touch-based device ($\chi^2_{(1)} = 7.35$, $p = .007$), with 81.8% of video games running in touch-based devices having win/lose conditions. Avatar ($\chi^2_{(1)} = 8.95$, $p = .003$), time pressure ($\chi^2_{(1)} = 4.70$, $p = .030$) and multiplayer component ($\chi^2_{(1)} = 6.75$, $p = .009$) were frequent in video games that run in game consoles (87.5%, 87.5%, and 62.5%, respectively).

Twelve video games were categorized as using VR technology, six were exergames and six used specific interfaces such as brain-computer interface [88,101] (see Figure S2). More than half of all AG (24/42) presented some type of virtual component, with VR technology (n = 12) being more frequent in these type of video games ($\chi^2_{(1)} = 10.29$, $p = .001$) than in CG (none of the video games under this category reported VR). Video games used for cognitive assessment ($\chi^2_{(1)} = 16.74$, $p < 0.001$, *Cramer's* $V = 0.457$) and video games used

Table 2
Frequency of use of game-elements in video games ($n_{video.games}$ = 72) and according to cognitive utility ($n_{cog.utility}$ = 80).

Utility of the game (n)	Purpose of the game	Game-elements n (%)						
		Narrative context	Avatar/ character	Score system	Reward system	Win/lose	Time pressure	Multiplayer*
All games ($n_{video.games}$ = 72)	Applied games (n = 42)	35 (83.3%)	11 (26.2%)	28 (66.7%)	15 (35.7%)	9 (21.4%)	22 (52.4%)	2 (4.8%)
	Commercial games (n = 30)	22 (73.3%)	17 (56.7%)	29 (96.7%)	16 (53.3%)	23 (76.7%)	15 (50.0%)	16 (53.3%)
	Total	**57 (79.2%)**	**28 (38.9%)**	**57 (79.2%)**	**31 (43.1%)**	**32 (44.4%)**	**37 (51.4%)**	**18 (25.0%)**
Assessment ($n_{cog.utility}$ = 16)	Applied games (n = 15)	15 (100%)	2 (13.3%)	6 (40.0%)	4 (26.7%)	1 (6.7%)	9 (60.0%)	–
	Commercial games (n = 1)	–	–	1 (100.0%)	1 (100.0%)	1 (100.0%)	1 (100.0%)	–
	Total	**15 (93.8%)**	**2 (12.5%)**	**7 (43.8%)**	**5 (31.3%)**	**2 (12.5%)**	**10 (62.5%)**	**–**
Training ($n_{cog.utility}$ = 46)	Applied games (n = 18)	13 (72.2%)	5 (27.8%)	16 (88.9%)	9 (50.0%)	4 (22.2%)	11 (61.1%)	2 (11.1%)
	Commercial games (n = 28)	21 (75.0%)	16 (57.1%)	27 (96.4%)	16 (57.1%)	22 (78.6%)	13 (46.4%)	15 (53.6%)
	Total	**34 (73.9%)**	**21 (45.7%)**	**43 (93.5%)**	**25 (54.3%)**	**26 (56.5%)**	**24 (52.2%)**	**17 (37.0%)**
Rehabilitation ($n_{cog.utility}$ = 18)	Applied games (n = 14)	11 (78.6%)	6 (42.9%)	11 (78.6%)	5 (35.7%)	5 (35.7%)	6 (42.9%)	–
	Commercial games (n = 4)	1 (25%)	3 (75.0%)	4 (100.0%)	1 (25.0%)	1 (25.0%)	4 (100.0%)	2 (50.0%)
	Total	**12 (66.7%)**	**9 (50.0%)**	**15 (83.3%)**	**6 (33.3%)**	**6 (33.3%)**	**10 (55.6%)**	**2 (11.1%)**

* Cases where it was reported that this GE was not available/active during intervention were not included.

for cognitive training ($\chi^2_{(1)} = 10.53$, $p = .002$, *Cramer's* $V = 0.363$) were more likely to use VR technology.

3.6. Outcomes of GBI

As shown in Table 3, attention was the cognitive outcome most frequently targeted in GBI (94/118), followed by working memory (54/118) and inhibitory control (30/118). This trend was also observed in video games used for cognitive training and rehabilitation (see Supplementary Table S4 for details). None of the three main cognitive outcomes was associated with any of the GE under study. Other cognitive outcomes (*e.g.,* fine motor skills, reasoning, fluid intelligence) were assessed in 91 out of 118 interventions, and other health outcomes (*e.g.,* mood, ADHD symptoms, health-related quality of life) were analyzed in 24 out of 118 interventions.

Near transfer capacity was evaluated in most of the studies (109/118) and far transfer capacity for cognitive and other health outcomes was evaluated in 38/118 and in 13/118 interventions, respectively. User-experience evaluation was performed in 29/118 interventions, with the assessment of usability (15/118) or of hedonic aspects (*e.g.,* fun, enjoyment, immersion) performed in 21/118 interventions. Win/lose condition was associated (rarely occurring) with the evaluation of video game's impact on other health outcomes ($\chi^2_{(1)} = 18.18$, $p < .001$, *Cramer's* $V = 0.396$). Also, win/lose condition was associated (rarely occurring) with far transfer capacity to health outcomes ($\chi^2_{(1)} = 8.48$, $p = .004$, *Cramer's* $V = 0.270$). Finally, UX assessment was associated (rarely occurring) with video games that present multiplayer component ($\chi^2_{(1)} = 12.89$, $p < .001$, *Cramer's* $V = 0.333$). Evaluation of hedonic aspects of UX was found to be associated with multiplayer component ($\chi^2_{(1)} = 8.55$, $p = .002$, *Cramer's* $V = 0.271$). Usability evaluation was associated with all GE except for narrative context (*p-values between* $p \leq 0.001$ and $p = .027$; *Cramer's V between* 0.211 and 0.343). Overall, usability evaluation was rarely conducted.

Table 3
Frequency of game-elements by cognitive outcomes ($n_{all.entries}$ = 118).

Game-elements	Cognitive outcomes n (%)		
	Attention (n = 94)	Working memory (n = 54)	Inhibitory control (n = 30)
Score system	70 (76.1%)	46 (85.2%)	19 (65.5%)
Narrative context	70 (76.1%)	36 (66.7%)	20 (69.0%)
Time pressure	55 (59.8%)	33 (61.1%)	19 (65.5%)
Reward system	33 (35.9%)	25 (46.3%)	10 (34.5%)
Win/lose	33 (35.9%)	22 (40.7%)	8 (27.6%)
Avatar/character	37 (40.2%)	21 (38.9%)	10 (34.5%)
Multiplayer***	25 (27.2%)	10 (18.5%)	5 (17.2%)

**The association between each GE and each cognitive outcome was done by cell (chi-square test for independence).

*** Cases where it was reported that this GE was not available/active during intervention were not included.

4. Discussion

The aim of this study was to identify, integrate and report which GE have been used in GBI for cognitive assessment, training or rehabilitation. For this purpose, a systematic review of literature following PRISMA guidelines [20] was conducted. Ninety-one papers were included in the qualitative synthesis, covering a total of 72 different video games.

A significant difference between the number of GE described in the studies included and those that actually compose video games was found. The lack of a detailed description of the video games used constitutes a serious methodological limitation which hinders the analysis and interpretation of GBI results. To our knowledge, this is the first review on GBI where the information extracted from the studies included was compared to the description available in other sources of public access. Despite unusual, the methodological decision to complete data extraction with information gathered through less traditional sources (webpages describing video games) enabled to uncover this methodological shortcoming, thus contributing to future research and data reporting on GBI.

Score system was the most frequently used GE in CG and in video games used for training and rehabilitation purposes. Similar findings have been reported for digital learning environments [124] and health and fitness apps [23]. Numeric feedback systems such as points, levels and leaderboards are considered goal metrics, since they establish a clear link between user's effort and performance [125]. The assumption that users highly value this element contributes to its widespread use (for *pointsification* perspective review see [126]). However, that assumption is not always verified [23]. In fact, implementation of tangible and predictable rewards, such as those provided by score systems, were previously associated with a decrease of free-choice behavior [127] and considered by some as the less exciting and engaging feature of video games [128].

However, since the motivational affordance [129] of each GE, as well as how different GE interact to promote human behavior, is still to determine, no elements should be dismissed at this point without a careful study of its impact. For instance, Mekler and colleagues [125] showed that GE (*i.e.,* points, leaderboards and levels) within the same category (*i.e.,* score system) can impact human behavior differentially. By using an image annotation task where participants received 100 points for each tag created in a set of 15 abstract paintings, Mekler and colleagues showed that participants who received points for each created tag outperformed participants in the non-gamified version group (no points assigned) but were outperformed by the participants allocated to the group where points were used to classify participants in relation with themselves (*i.e.*, levels of difficult condition) or in relation to other participants (*i.e.*, leaderboard condition) [125]. It is also plausible to consider that score systems may undermine adherence if associated with a progressive difficult-level system (*i.e.,* getting more points depends on individuals' skills for playing the game) whereas that is less the case if no individuals-skills improvement is required for points-accumulation (namely, if a game narrative is associated).

Narrative context was the most used GE in AG and in video games used for cognitive assessment. Unlike the other GE analyzed in this study (*e.g.,* score and reward systems and win/lose condition), narrative context has no association with player's performance [24]. This GE is used primarily to contextualize and to add meaning to game's main activity, inspiring motivation and long-term willingness towards tasks that may be perceived as boring and repetitive in its non-gamified version [24]. Meaningful storylines, especially if in line with one's personal goals, may improve/maintain patients' long-term motivation and promote skills transference to other (real-life) contexts [130]. Although no significant associations were found between narrative context and purpose, utility or cognitive outcomes, the high frequency of this GE is encouraging, because it suggests a concern for developing GBI with meaningful game narratives that promote participants' long-term adherence.

The possibility to interact with other players is an attractive feature of video games [131] since it provides an opportunity to learn and develop meaningful relationships [132]. However, as our study revealed, multiplayer component was the less used GE. This can be explained by the fact that interacting with other players also means to be exposed to other's judgment. Fear of failure and performance-related frustration are two possible behavioral responses when competing or collaborating with others [133]. Design and implementation complexity, necessity to combine schedules, share game control and relying on other' players skills [134] may also contribute for the low usage of this GE in cognitive therapeutic settings.

Attention, working memory and inhibitory control capacity are essential components of cognitive control [28] and self-regulated behavior [26]. Attention supports all processes involved in human thought [28], and a non-adequate assessment of attentional deficits may result in diagnostic errors and failure to prescribe suitable cognitive interventions [135]. Hereby, it was not surprising that attention was the most frequently targeted outcome in the included studies, since it plays such a central role in human cognition. Closely related to (and dependent of) attentional resources, working memory capacity and inhibitory control are essential cognitive components for fluid reasoning, comprehension and learning [28,136], as well as crucial skills for our ability to function in the real world [137]. However, in our study no association was found between the assessment of attention, working memory or inhibitory control and any of the GE, nor between the study of those cognitive indicators and utility (assessment, training, rehabilitation) or purpose (commercial/applied) of the game. The lack of association between GE and the study of these cognitive functions may be the result of the absence of a theoretical and empirical framework that guides GE selection for the study of video games impact on human health.

Game-based interventions seem to follow the trends of video games industry. In our study, as in ESA annual report [138] computer was the most popular gaming platform. On the other hand, touch-based devices were the less used game platform being reported only in four studies. Touch-based devices, such as tablets, are particularly suitable in fragile populations such as older adults [139,140]. Intuitive interfaces, direct manipulation [141] and bigger screens (compared to smartphones) are some of the features that contribute to technology adaptation by less familiar users. However, none of the studies that used older adults as participants reported tablets as game's platform. Other market trend is VR technology to develop video games. VR through high-detailed three dimensional (3D) environments, and increasingly natural ways of interact with it [142], promises to be a remarkable improvement in the assessment of the capacity to perform daily living tasks (ecological validity), compared with traditional neuropsychological tools (Sbordone, 1996 cit. by [143]). Taking this into account, it was not surprisingly to find out that this component was primarily present in video games used for assessment purposes, area in which diversity and standardization of stimuli display, as well as performance measurement, are fundamental requirements.

4.1. Limitations

The findings of this study should be interpreted in the context of some limitations. First, the strategy used to identify additional journals scoping serious games and games for health may have excluded studies published in scientific journals in which these terms do not appear as part of the title/abstract or scoping interests. Second, electronic database selection may have unintentionally excluded work published in conferences or other type of meetings (a popular path to publish work in the engineering and computational science fields). A strong point, nevertheless, regards the fact that the search strategy was based on Cochrane's guidelines for conducting Systematic Reviews of Literature [144], such as consulting three different databases for locating papers, using specialist databases, searching reference lists of the included papers as well as reference lists of literature reviews identified during screening process. Third, the additional web-based search may have contributed to obtain more detailed descriptions of CG vs AG, since more sources of information with detailed descriptions are available to these video games than to AG. The absence of both a consensual GE classification system and a clear definition of what is and is not a video game introduced some degree of subjectivity in eligibility criteria and data extraction. Such bias was minimized by carefully defining the search protocol and by developing GE definitions based on the results obtained in the narrative review, which underwent a process of active discussion and reformulation, within the research team.

5. Conclusions

This study aimed to identify which GE have been used in GBI for cognitive assessment, training or rehabilitation. Score system and narrative context were the two most frequently used GE. However, the development of GBI that are based on the implementation of numeric feedback systems may jeopardize the main objective with which this type of interventions has been used: promotion of intrinsic motivation towards long-term goals. Moreover, the lack of any other significant association between GE used and the targeted cognitive outcomes emphasizes the necessity of defining a theoretical framework that supports the strategic selection of GE according to patient/pathology features, as well as according to the features of cognitive constructs that are targeted by specific game-based intervention.

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.

Acknowledgements

The authors wish to thank José Peixoto for his assistance during the screening phase of this project. They also want to express a special acknowledgement to Timothy Sloan for his thorough revision of the manuscript.

Funding source

This research was carried out as part of the doctoral studies of the first author [Ref: PDE/BDE/127784/2016] and for which she received scholarships from the following entities: Nippon Gases Portugal and Fundação para a Ciência e a Tecnologia through European Social Fund and Human Capital Operational Programme, cofinanced by Portugal 2020 and European Union.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbi.2019.103287.

References

[1] V. Manera, G. Ben-Sadoun, T. Aalbers, H. Agopyan, F. Askenazy, M. Benoit, D. Bensamoun, J. Bourgeois, J. Bredin, F. Bremond, C. Crispim-Junior, R. David, B. De Schutter, E. Ettore, J. Fairchild, P. Foulon, A. Gazzaley, A. Gros, S. Hun, F. Knoefel, M.O. Rikkert, M.K. Phan Tran, A. Politis, A.S. Rigaud, G. Sacco, S. Serret, S. Thümmler, M.L. Welter, P. Robert, Recommendations for the use of serious games in neurodegenerative disorders: 2016 Delphi Panel, Front. Psychol. 8 (2017) 1–10, https://doi.org/10.3389/fpsyg.2017.01243.

[2] S. Deterding, D. Dixon, R. Khaled, L. Nacke, From game design elements to gamefulness: defining "Gamification," in: MindTrek'11, Tampere, Filand. doi: 10.1145/2181037.2181040, 2011. pp. 28–30.

[3] S. McCallum, Gamification and serious games for personalized health, Stud. Health Technol. Inform. 177 (2012) 85–96, https://doi.org/10.3233/978-1-61499-069-7-85.

[4] T. Fleming, L. Bavin, K. Stasiak, E. Hermansson-Webb, S. Merry, C. Cheek, M. Lucassen, H. Lau, B. Pollmuller, S. Hetrick, Serious games and gamification for mental health: current status and promising directions, Front. Psychiatry. 7 (2017) 1–7, https://doi.org/10.3389/fpsyt.2016.00215.

[5] K. Seaborn, D.I. Fels, Gamification in theory and action: a survey, Int. J. Human-Comput. Stud. 74 (2015) 14–31, https://doi.org/10.1016/j.ijhcs.2014.09.006.

[6] E. Boyle, T.M. Connolly, T. Hainey, The role of psychology in understanding the impact of computer games, Entertain. Comput. 2 (2011) 69–74, https://doi.org/10.1016/j.entcom.2010.12.002.

[7] R.M. Ryan, E.L. Deci, Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being, Am. Psychol. 55 (2000) 68–78, https://doi.org/10.1037/0003-066X.55.1.68.

[8] L.S. Vygotsky, Interaction between learning and development, in: Mind Soc., Harvard University Press, Cambridge, 1978. p. 79–91. doi: 10.1016/S0006-3495(96)79572-3.

[9] D. Wood, J.S. Bruner, G. Ross, The role of tutoring in problem-solving, J. Child Psychol. Psychiatry. 17 (1976) 89–100, https://doi.org/10.1111/j.1469-7610.1976.tb00381.x.

[10] D. Bavelier, C.S. Green, D.H. Han, P.F. Renshaw, M.M. Merzenich, D.A. Gentile, Brains on video games, Nat. Rev. Neurosci. 12 (2015) 763–768, https://doi.org/10.1038/nrn3135.Brains.

[11] American Psychological Association, APA Review Confirms Link Between Playing Violent Video Games and Aggression, (2015). < https://www.apa.org/news/press/releases/2015/08/violent-video-games.aspx > (accessed October 31, 2018).

[12] S. Kühn, D.T. Kugler, K. Schmalen, M. Weichenberger, C. Witt, J. Gallinat, Does playing violent video games cause aggression? A longitudinal intervention study, Mol. Psychiatry. (2018) 1–15, https://doi.org/10.1038/s41380-018-0031-7.

[13] A.K. Przybylski, N. Weinstein, Violent video game engagement is not associated with adolescents' aggressive behaviour: evidence from a registered report, R. Soc. Open Sci. 6 (2019), https://doi.org/10.1098/rsos.171474.

[14] H.M. Lau, J.H. Smit, T.M. Fleming, H. Riper, Serious games for mental health: Are they accessible, feasible, and effective? A systematic review and meta-analysis, Front. Psychiatry. 7 (2017), https://doi.org/10.3389/fpsyt.2016.00209.

[15] A.M. Kueider, J.M. Parisi, A.L. Gross, G.W. Rebok, Computerized cognitive training with older adults: a systematic review, PLoS ONE 7 (2012), https://doi.org/10.1371/journal.pone.0040588.

[16] J. a Anguera, J. Boccanfuso, J.L. Rintoul, F. Faraji, J. Janowich, E. Kong, C. Rolle, E. Johnston, A. Gazzaley, S. Francisco, Video game training enhances cognitive control in older adults, Nature 501 (2013) 97–101, https://doi.org/10.1038/nature12486.Video.

[17] J. Lumsden, E.A. Edwards, N.S. Lawrence, D. Coyle, M.R. Munafò, Gamification of cognitive assessment and cognitive training: a systematic review of applications and efficacy, JMIR Serious Games 4 (2016) 1–14, https://doi.org/10.2196/games.5888.

[18] P.H. Robert, A. König, H. Amieva, S. Andrieu, F. Bremond, R. Bullock, M. Ceccaldi, B. Dubois, S. Gauthier, P.-A. Kenigsberg, S. Nave, J.M. Orgogozo, J. Piano, M. Benoit, J. Touchon, B. Vellas, J. Yesavage, V. Manera, Recommendations for the use of serious games in people with Alzheimer's disease, related disorders and frailty, Front. Aging Neurosci. 6 (2014) 1–13, https://doi.org/10.3389/fnagi.2014.00054.

[19] M.D. Hanus, J. Fox, Assessing the effects of gamification in the classroom: a longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance, Comput. Educ. 80 (2015) 152–161, https://doi.org/10.1016/j.compedu.2014.08.019.

[20] D. Moher, A. Liberati, J. Tetzlaff, D. Altman, Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, PLoS Med. 6 (2009), https://doi.org/10.1371/journal.pmed.1000097.

[21] A. DeSmet, R. Shegog, D. Van Ryckeghem, G. Crombez, I. De Bourdeaudhuij, A systematic review and meta-analysis of interventions for sexual health promotion involving serious digital games, Games Health J. 4 (2015) 78–90, https://doi.org/10.1089/g4h.2014.0110.

[22] A. Miller, J. Cafazzo, E. Seto, A game plan: Gamification design principles in mHealth applications for chronic disease management, Health Informatics J. (2014) 1–10, https://doi.org/10.1177/1460458214537511.

[23] C. Lister, J.H. West, B. Cannon, T. Sax, D. Brodegard, Just a fad? Gamification in health and fitness apps, JMIR Serious Games 2 (2014) 1–13, https://doi.org/10.2196/games.3413.

[24] M. Sailer, J.U. Hense, S.K. Mayr, H. Mandl, How gamification motivates: an experimental study of the effects of specific game design elements on psychological need satisfaction, Comput. Human Behav. 69 (2017) 371–380, https://doi.org/10.1016/j.chb.2016.12.033.

[25] L.A. Dwyer, M.J. Hornsey, L.G.E. Smith, T.P.S. Oei, G.A. Dingle, Participant autonomy in cognitive behavioral group therapy: an integration of self-determination and cognitive behavioral theories, J. Soc. Clin. Psychol. 30 (2011) 24–46, https://doi.org/10.1521/jscp.2011.30.1.24.

[26] M.J. Maraver, M.T. Bajo, C.J. Gomez-Ariza, Training on working memory and inhibitory control in young adults, Front. Hum. Neurosci. 10 (2016) 1–18, https://doi.org/10.3389/fnhum.2016.00588.

[27] M.M. Sohlberg, C.A. Mateer, Cognitive rehabilitation : an integrative neuropsychological approach, Guilford Press, 2001 < https://www.guilford.com/books/Cognitive-Rehabilitation/Sohlberg-Mateer/9781572306134 > (accessed April 8, 2019).

[28] A. Baddeley, Working memory: looking back and looking forward, Nat. Rev. Neurosci. 4 (2003) 829–839, https://doi.org/10.1038/nrn1201.

[29] A. Miyake, N.P. Friedman, M.J. Emerson, A.H. Witzki, A. Howerter, T.D. Wager, The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: a latent variable analysis, Cogn. Psychol. 41 (2000) 49–100, https://doi.org/10.1006/cogp.1999.0734.

[30] D. Park, G. Bischof, The aging mind: neuroplasticity in response to cognitive training, Dialogues Clin. Neurosci. (2013) 109–119.

[31] D. George, P. Mallery, SPSS for Windows step by step : a simple guide and reference, 17.0 update, 10th ed., Allyn and Bacon, Boston, 2010. < https://books.google.pt/books/about/SPSS_for_Windows_Step_by_Step.html?id=FhyQCNdQJjUC&source=kp_cover&redir_esc=y > (accessed December 20, 2018).

[32] A.C. Oei, M.D. Patterson, Enhancing cognition with video games: a multiple game training study, PLoS ONE 8 (2013), https://doi.org/10.1371/journal.pone.0058546.

[33] L.B. Thorell, S. Lindqvist, S.B. Nutley, G. Bohlin, T. Klingberg, Training and transfer effects of executive functions in preschool children, Dev. Sci. 12 (2008) 106–113, https://doi.org/10.1111/j.1467-7687.2008.00745.x.

[34] W.R. Boot, A.F. Kramer, D.J. Simons, M. Fabiani, G. Gratton, The effects of video game playing on attention, memory, and executive control, Acta Psychol. (Amst) 129 (2008) 387–398, https://doi.org/10.1016/j.actpsy.2008.09.005.

[35] M. Cujzek, A. Vranic, Computerized tabletop games as a form of a video game training for old-old, Aging Neuropsychol. Cogn. 24 (2016) 631–648, https://doi.org/10.1080/13825585.2016.1246649.

[36] P. Belchior, M. Marsiske, S.M. Sisco, A. Yam, D. Bavelier, K. Ball, W.C. Mann, Video game training to improve selective visual attention in older adults, Comput. Human Behav. 29 (2013) 1318–1324, https://doi.org/10.1016/j.chb.2013.01.034.

[37] S. Lorant-Royer, C. Munch, H. Mesclé, A. Lieury, Kawashima vs "super Mario"! Should a game be serious in order to stimulate cognitive aptitudes? Rev. Eur. Psychol. Appl. 60 (2010) 221–232, https://doi.org/10.1016/j.erap.2010.06.002.

[38] W.R. Boot, M. Champion, D.P. Blakely, T. Wright, D.J. Souders, N. Charness, Video games as a means to reduce age-related cognitive decline: attitudes, compliance, and effectiveness, Front. Psychol. 4 (2013) 1–9, https://doi.org/10.3389/fpsyg.2013.00031.

[39] A.C. Oei, M.D. Patterson, Playing a puzzle video game with changing requirements improves executive functions, Comput. Human Behav. 37 (2014) 216–228, https://doi.org/10.1016/j.chb.2014.04.046.

[40] A.C. Oei, M.D. Patterson, Enhancing perceptual and attentional skills requires common demands between the action video games and transfer tasks, Front. Psychol. 6 (2015) 1–11, https://doi.org/10.3389/fpsyg.2015.00113.

[41] T. Schubert, K. Finke, P. Redel, S. Kluckow, H. Müller, T. Strobach, Video game experience and its influence on visual attention parameters: an investigation using the framework of the Theory of Visual Attention (TVA), Acta Psychol. (Amst) 157 (2015) 200–214, https://doi.org/10.1016/j.actpsy.2015.03.005.

[42] N. Barcelos, N. Shah, K. Cohen, M.J. Hogan, E. Mulkerrin, P.J. Arciero, B.D. Cohen, A.F. Kramer, C. Anderson-Hanley, Aerobic and cognitive exercise (ACE) pilot study for older adults: executive function improves with cognitive challenge while exergaming, J. Int. Neuropsychol. Soc. 21 (2015) 768–779, https://doi.org/10.1017/S1355617715001083.
[43] K.J. Blacker, K.M. Curby, E. Klobusicky, J.M. Chein, Effects of action video game training on visual working memory, J. Exp. Psychol. Hum. Percept. Perform. 40 (2014) 1992–2004 http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L605018946%0Ahttps://doi.org/10.1037/a0037556%0Ahttp://ak7rt6cb3z.search.serialssolutions.com?sid=EMBASE&issn=19391277&id=doi:10.1037%2Fa0037556&atitle=Effects+of+action+video+game.
[44] J.F. Feng, I. Spence, J. Pratt, Playing an action videogame reduces gender differences in spatial cognition, Psychol Sci. 18 (2007) 850–855, https://doi.org/10.1111/j.1467-9280.2007.01990.x.
[45] B.D. Glass, W.T. Maddox, B.C. Love, Real-time strategy game training: emergence of a cognitive flexibility trait, PLoS ONE 8 (2013) 1–7, https://doi.org/10.1371/journal.pone.0070350.
[46] C.S. Green, D. Bavelier, Effect of action video games on the spatial distribution of visuospatial attention, J. Exp. Psychol. Hum. Percept. Perform. 32 (2006) 1465–1478, https://doi.org/10.1037/0096-1523.32.6.1465.
[47] R. Nouchi, Y. Taki, H. Takeuchi, H. Hashizume, Y. Akitsuki, Y. Shigemune, A. Sekiguchi, Y. Kotozaki, T. Tsukiura, Y. Yomogida, R. Kawashima, Brain training game improves executive functions and processing speed in the elderly: a randomized controlled trial, PLoS ONE 7 (2012), https://doi.org/10.1371/journal.pone.0029676.
[48] R. Nouchi, Y. Taki, H. Takeuchi, H. Hashizume, T. Nozawa, T. Kambara, A. Sekiguchi, C.M. Miyauchi, Y. Kotozaki, H. Nouchi, R. Kawashima, Brain training game boosts executive functions, working memory and processing speed in the young adults: a randomized controlled trial, PLoS ONE 8 (2013), https://doi.org/10.1371/journal.pone.0055518.
[49] S. Wu, I. Spence, Playing shooter and driving videogames improves top-down guidance in visual search, Attention Percept. Psychophys. 75 (2013) 673–686, https://doi.org/10.3758/s13414-013-0440-2.
[50] S. Wu, C.K. Cheng, J. Feng, L. D'Angelo, C. Alain, I. Spence, Playing a first-person shooter video game induces neuroplastic change, J. Cogn. Neurosci. 24 (2012) 1286–1293, https://doi.org/10.1162/jocn_a_00192.
[51] C. Basak, W.R. Boot, M.V. Voss, A.F. Kramer, Can training in a real-time strategy videogame attenuate cognitive decline in older adults? Psychol. Aging. 23 (2008) 765–777, https://doi.org/10.1037/a0013494.Can.
[52] M.H. Brem, S. Lehrl, A.K. Rein, S. Massute, S. Schulz-Drost, K. Gelse, P.M. Schlechtweg, F.F. Hennig, A. Olk, H.J. Jacob, J. Gusinde, Stop of loss of cognitive performance during rehabilitation after total hip arthroplasty-prospective, J. Rehabil. Res. Dev. 47 (2010) 891, https://doi.org/10.1682/JRRD.2010.01.0011.
[53] L. De Giglio, F. De Luca, L. Prosperini, G. Borriello, V. Bianchi, P. Pantano, C. Pozzilli, A low-cost cognitive rehabilitation with a commercial video game improves sustained attention and executive functions in multiple sclerosis: a pilot study, Neurorehabil. Neural Repair. 29 (2015) 453–461, https://doi.org/10.1177/1545968314554623.
[54] A. Lau-Zhu, E.A. Holmes, S. Butterfield, J. Holmes, Selective association between tetris game play and visuospatial working memory: a preliminary investigation, Appl. Cogn. Psychol. 31 (2017) 438–445, https://doi.org/10.1002/acp.3339.
[55] P.M. McLaughlin, A.F. Curtis, L.M. Branscombe-Caird, J.K. Comrie, S.J.E. Murtha, The feasibility and potential impact of brain training games on cognitive and emotional functioning in middle-aged adults, Games Health J. 7 (2018) 67–74, https://doi.org/10.1089/g4h.2017.0032.
[56] O. López-Martín, A.S. Fragoso, M.R. Hernández, I.D. Terrer, B. Polonio López, Efectividad deun programa de juego basado en realidad virtual para la mejora cognitiva en la esquizofrenia, Gac. Sanit. 30 (2016) 133–136, https://doi.org/10.1016/j.gaceta.2015.10.004.
[57] P. Gamito, J. Oliveira, D. Alghazzawi, H. Fardoun, P. Rosa, T. Sousa, I. Maia, D. Morais, P. Lopes, R. Brito, The art gallery test: a preliminary comparison between traditional neuropsychological and ecological VR-based tests, Front. Psychol. 8 (2017) 1–8, https://doi.org/10.3389/fpsyg.2017.01911.
[58] D. Areces, J. Dockrell, T. Garcia, P. Gonzalez-Castro, C. Rodriguez, Analysis of cognitive and attentional profiles in children with and without ADHD using an innovative virtual reality tool. PLoS ONE 13 (2018) e0201039, https://doi.org/10.1371/journal.pone.0201039.
[59] Y. Iriarte, U. Diaz-Orueta, E. Cueto, P. Irazustabarrena, F. Banterla, G. Climent, AULA—advanced virtual reality tool for the assessment of attention, J. Atten. Disord. 20 (2012) 542–568, https://doi.org/10.1177/1087054712465335.
[60] U. Díaz-Orueta, C. Garcia-López, N. Crespo-Eguílaz, R. Sánchez-Carpintero, G. Climent, J. Narbona, AULA virtual reality test as an attention measure: convergent validity with Conners continuous performance test, Child Neuropsychol. 20 (2013) 328–342, https://doi.org/10.1080/09297049.2013.792332.
[61] A.P. Silva, A.F. Frère, Virtual environment to quantify the influence of colour stimuli on the performance of tasks requiring attention, Biomed. Eng. Online. 10 (2011) 1–14, https://doi.org/10.1186/1475-925X-10-74.
[62] J. Oliveira, P. Gamito, D.M. Alghazzawi, H.M. Fardoun, P.J. Rosa, T. Sousa, L.F. Picareli, D. Morais, P. Lopes, Performance on naturalistic virtual reality tasks depends on global cognitive functioning as assessed via traditional neurocognitive tests, Appl. Neuropsychol. Adult. 25 (2018) 555–561, https://doi.org/10.1080/23279095.2017.1349661.
[63] J. McPherson, N.R. Burns, Assessing the validity of computer-game-like tests of processing speed and working memory, Behav. Res. Methods. 40 (2008) 969–981, https://doi.org/10.3758/BRM.40.4.969.
[64] J. Verhaegh, W.F.J. Fontijn, E.H.L. Aarts, W.C.M. Resing, In-game assessment and training of nonverbal cognitive skills using TagTiles, Pers. Ubiquitous Comput. 17 (2013) 1637–1646, https://doi.org/10.1007/s00779-012-0527-0.
[65] J. Peijnenborgh, P. Hurks, A. Aldenkamp, E. van der Spek, G. Rauterberg, J. Vles, J. Hendriksen, A study on the validity of a computer-based game to assess cognitive processes, reward mechanisms, and time perception in children aged 4–8 years, JMIR Serious Games 4 (2016) 1–15, https://doi.org/10.2196/games.5997.
[66] M.F. Rosetti, M.F. Gómez-Tello, G. Victoria, R. Apiquian, A video game for the neuropsychological screening of children, Entertain. Comput. 20 (2017) 1–9, https://doi.org/10.1016/j.entcom.2017.02.002.
[67] T.D. Parsons, T. Bowerly, J.G. Buckwalter, A.A. Rizzo, A controlled clinical comparison of attention performance in children with ADHD in a virtual reality classroom compared to standard neuropsychological methods, Child Neuropsychol. 13 (2007) 363–381, https://doi.org/10.1080/13825580600943473.
[68] A. Neguț, A.M. Jurma, D. David, Virtual-reality-based attention assessment of ADHD: clinicaVR: classroom-CPT versus a traditional continuous performance test, Child Neuropsychol. 23 (2017) 692–712, https://doi.org/10.1080/09297049.2016.1186617.
[69] P. Nolin, A. Stipanicic, M. Henry, Y. Lachapelle, D. Lussier-Desrochers, A. Rizzo, P. Allain, ClinicaVR: classroom-CPT: a virtual reality tool for assessing attention and inhibition in children and adolescents, Comput. Human Behav. 59 (2016) 327–333, https://doi.org/10.1016/j.chb.2016.02.023.
[70] Y. Gilboa, S. Rosenblum, A. Fattal-Valevski, H. Toledano-Alhadef, A.S. Rizzo, N. Josman, Using a virtual classroom environment to describe the attention deficits profile of children with neurofibromatosis type 1, Res. Dev. Disabil. 32 (2011) 2608–2613, https://doi.org/10.1016/j.ridd.2011.06.014.
[71] G. Moreau, M.-C. Guay, A. Achim, A. Rizzo, P. Lageix, The virtual classroom: An ecological version of the continuous performance test – a pilot study, Annu. Rev. CyberTherapy Telemed. (2006) 59–66.
[72] R. Adams, P. Finn, E. Moes, K. Flannery, A. Rizzo, Distractibility in attention/deficit/hyperactivity disorder (ADHD): the virtual reality classroom, Child Neuropsychol. 15 (2009) 120–135, https://doi.org/10.1080/09297040802169077.
[73] P. Nolin, C. Martin, Bouchard, S, Assessment of inhibition deficits with the virtual classroom in children with traumatic brain injury: a pilot-study, 2009. doi: 10.3233/978-1-60750-017-9-116.
[74] B. Renison, J. Ponsford, R. Testa, B. Richardson, K. Brownfield, The ecological and construct validity of a newly developed measure of executive function: the virtual library task, J. Int. Neuropsychol. Soc. 18 (2012) 440–450, https://doi.org/10.1017/S1355617711001883.
[75] T.D. Parsons, A.A. Rizzo, Initial validation of a virtual environment for assessment of memory functioning: virtual reality cognitive performance assessment test, CyberPsychology Behav. 11 (2008) 17–25, https://doi.org/10.1089/cpb.2007.9934.
[76] T.D. Parsons, A.A. Rizzo, J. Bamattre, J. Brennan, Virtual reality cognitive performance assessment test, Annu. Rev. CyberTherapy Telemed. 5 (2007) 143–149 http://search.proquest.com/docview/622189662?accountid=17261%5Cnhttp://sfx.bugalicia.org/vig?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&genre=article&sid=ProQ:ProQ:psycinfo&atitle=Virtual+Reality+Cognitive+Performance+Assessment+Test.&ti.
[77] T.D. Parsons, T.M. Silva, J. Pair, A. a Rizzo, Virtual environment for assessment of neurocognitive functioning: virtual reality cognitive performance assessment test, Stud. Health Technol. Inform. 132 (2008) 351–356.
[78] T.D. Parsons, L. Cosand, C. Courtney, A. Iyer, A.A. Rizzo, Neurocognitive workload assessment using the virtual reality cognitive performance assessment test, Lect. Notes Comput. Sci. (Including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics). 5639 LNA I (2009) 243–252, https://doi.org/10.1007/978-3-642-02728-4_26.
[79] M. Henry, C.C. Joyal, P. Nolin, Development and initial assessment of a new paradigm for assessing cognitive and motor inhibition: the bimodal virtual-reality Stroop, J. Neurosci. Methods. 210 (2012) 125–131, https://doi.org/10.1016/j.jneumeth.2012.07.025.
[80] S. Raspelli, F. Pallavicini, L. Carelli, F. Morganti, B. Poletti, B. Corra, V. Silani, G. Riva, Validation of a neuro virtual reality-based version of the multiple errands test for the assessment of executive functions, Annu. Rev. CyberTherapy Telemed. 9 (2011) 72–76, https://doi.org/10.3233/978-1-60750-766-6-92.
[81] T.D. Parsons, C.G. Courtney, B. Arizmendi, M. Dawson, Virtual reality stroop task for neurocognitive assessment, Stud. Health Technol. Inform. 163 (2011) 433–439, https://doi.org/10.3233/978-1-60750-706-2-433.
[82] C.M. Armstrong, G.M. Reger, J. Edwards, A.A. Rizzo, C.G. Courtney, T.D. Parsons, Validity of the virtual reality stroop task (VRST) in active duty military, J. Clin. Exp. Neuropsychol. 35 (2013) 113–123, https://doi.org/10.1080/13803395.2012.740002.
[83] R.J. Matheis, M.T. Schultheis, L.A. Tiersky, J. DeLuca, S.R. Millis, A. Rizzo, Is learning and memory different in a virtual environment? Clin. Neuropsychol. 21 (2007) 146–161, https://doi.org/10.1080/13854040601100668.
[84] J. Park, J. Yim, A new approach to improve cognition, muscle strength, and postural balance in community-dwelling elderly with a 3-D Virtual Reality Kayak Program, Tohoku, J. Exp. Med. 238 (2016) 1–8, https://doi.org/10.1620/tjem.238.1.
[85] S.M. Jaeggi, M. Buschkuehl, J. Jonides, P. Shah, Short- and long-term benefits of cognitive training, Proc. Natl. Acad. Sci. 108 (2011) 10081–10086, https://doi.org/10.1073/pnas.1103228108.
[86] S. van der Oord, A.J.G.B. Ponsioen, H.M. Geurts, E.L.T. Brink, P.J.M. Prins, A pilot

study of the efficacy of a computerized executive functioning remediation training with game elements for children with ADHD in an outpatient setting: outcome on parent- and teacher-rated executive functioning and ADHD behavior, J. Atten. Disord. 18 (2014) 699–712, https://doi.org/10.1177/1087054712453167.
[87] S. Verbeken, C. Braet, L. Goossens, S. van der Oord, Executive function training with game elements for obese children: a novel treatment to enhance self-regulatory abilities for weight-control, Behav. Res. Ther. 51 (2013) 290–299, https://doi.org/10.1016/j.brat.2013.02.006.
[88] T.S. Lee, S.J.A. Goh, S.Y. Quek, R. Phillips, C. Guan, Y.B. Cheung, L. Feng, S.S.W. Teng, C.C. Wang, Z.Y. Chin, H. Zhang, T.P. Ng, J. Lee, R. Keefe, K.R.R. Krishnan, A brain-computer interface based cognitive training system for healthy elderly: a randomized control pilot study for usability and preliminary efficacy, PLoS ONE 8 (2013), https://doi.org/10.1371/journal.pone.0079419.
[89] W.J. Boendermaker, T.E. Gladwin, M. Peeters, P.J.M. Prins, R.W. Wiers, Training working memory in adolescents using serious game elements: pilot randomized controlled trial, J. Med. Internet Res. 20 (2018) 1–13, https://doi.org/10.2196/games.8364.
[90] C. Anderson-Hanley, P.J. Arciero, A.M. Brickman, J.P. Nimon, N. Okuma, S.C. Westen, M.E. Merz, B.D. Pence, J.A. Woods, A.F. Kramer, E.A. Zimmerman, Exergaming and older adult cognition: a cluster randomized clinical trial, Am. J. Prev. Med. 42 (2012) 109–119, https://doi.org/10.1016/j.amepre.2011.10.016.
[91] P. Gamito, J. Oliveira, D. Morais, C. Coelho, N. Santos, C. Alves, A. Galamba, M. Soeiro, M. Yerra, H. French, L. Talmers, T. Gomes, R. Brito, Cognitive stimulation of elderly individuals with instrumental virtual reality-based activities of daily life: pre-post treatment study, cyberpsychology, Behav. Soc. Netw. 22 (2018) 69–75, https://doi.org/10.1089/cyber.2017.0679.
[92] R.H. Logie, S. Trawley, A. Law, Multitasking: multiple, domain-specific cognitive functions in a virtual environment, Mem. Cogn. 39 (2011) 1561–1574, https://doi.org/10.3758/s13421-011-0120-1.
[93] W.D. Russell, M. Newton, Short-term psychological effects of interactive video game technology exercise on mood and attention, Educ. Technol. Soc. 11 (2008) 294–308 citeulike-article-id:7693606.
[94] V. Montani, M.D.F. De Grazia, M. Zorzi, A new adaptive videogame for training attention and executive functions: design principles and initial validation, Front. Psychol. 5 (2014) 1–12, https://doi.org/10.3389/fpsyg.2014.00409.
[95] K.P. Thomas, A.P. Vinod, C. Guan, Enhancement of attention and cognitive skills using EEG based neurofeedback game, 2013 6Th Int. Ieee/Embs Conf. Neural Eng. (2013) 21–24. doi: 10.1109/NER.2013.6695861.
[96] K.P. Thomas, A.P. Vinod, C. Guan, Design of an online EEG based neurofeedback game for enhancing attention and memory, Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS. (2013) 433–436, https://doi.org/10.1109/EMBC.2013.6609529.
[97] E. Maclin, K. Mathewson, K. Low, W. Boot, A. Kramer, M. Fabiani, G. Gratton, Learning to multitask: effects of video game practice on electrophysiological indices of attention and resource allocation, Psychophysiology 48 (2011) 1173–1183, https://doi.org/10.1111/j.1469-8986.2011.01189.x.
[98] A. Nikolaidis, M.W. Voss, H. Lee, L.T.K. Vo, A.F. Kramer, Parietal plasticity after training with a complex video game is associated with individual differences in improvements in an untrained working memory task, Front. Hum. Neurosci. 8 (2014) 1–11, https://doi.org/10.3389/fnhum.2014.00169.
[99] T.D. Parsons, A.A. Rizzo, Neuropsychological assessment of attentional processing using virtual reality, Annu. Rev. CyberTherapy Telemedicine. Vol 6. 6 (2008) 21–26. < http://csaweb105v.csa.com.proxy.lib.wayne.edu/ids70/view_record.php?id=3&recnum=118&log=from_res&SID=nh6ff5fhjt3jpddet4pl1a7pv3 > .
[100] M. Ninaus, G. Pereira, R. Stefitz, R. Prada, A. Paiva, C. Neuper, G. Wood, Game elements improve performance in a working memory training task, Int. J. Serious Games 2 (2015) 3–16, https://doi.org/10.17083/ijsg.v2i1.60.
[101] A. Ali, S. Puthusserypady, A 3D learning playground for potential attention training in ADHD: a brain computer interface approach, in: Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS, 2015. pp. 67–70. doi: 10.1109/EMBC.2015.7318302.
[102] M. Caglio, L. Latini-Corazzini, F. D'Agata, F. Cauda, K. Sacco, S. Monteverdi, M. Zettin, S. Duca, G. Geminiani, Video game play changes spatial and verbal memory: rehabilitation of a single case with traumatic brain injury, Cogn. Process. 10 (2009) 195–197, https://doi.org/10.1007/s10339-009-0295-6.
[103] S. Dovis, S. van Der Oord, R.W. Wiers, P.J.M. Prins, Improving executive functioning in children with ADHD: training multiple executive functions within the context of a computer game. A randomized double-blind placebo controlled trial, PLoS One 10 (2015) 1–30, https://doi.org/10.1371/journal.pone.0121651.
[104] P. Gamito, J. Oliveira, P. Lopes, R. Brito, D. Morais, C. Cacoete, A. Leandro, T. Almeida, H. Oliveira, Cognitive training through mhealth for individuals with substance use disorder, Methods Inf. Med. 56 (2017) 156–161, https://doi.org/10.3414/ME16-02-0012.
[105] M. Martel, E. Colussi, A. Marchi, Efeitos da intervenção com game na atenção e na independência funcional em idosos após acidente vascular encefálico, Fisioter. e Pesqui. 23 (2016) 52–58, https://doi.org/10.1590/1809-2950/14643623012016.
[106] M.J. van der Molen, J.E.H. van Luit, M.W. van der Molen, I. Klugkist, M.J. Jongmans, Effectiveness of a computerised working memory training in adolescents with mild to borderline intellectual disabilities, J. Intellect. Disabil. Res. 54 (2010) 433–447, https://doi.org/10.1111/j.1365-2788.2010.01285.x.
[107] A. Chacko, C. Bedard, D.J. Mark, N. Feirsen, J.Z. Uderman, A. Chimiklis, E. Rajwan, M. Cornwell, L. Anderson, A. Zwilling, M. Ramon, A randomized clinical trial of cogmed working memory training in school-age children with ADHD: a replication in a diverse sample, J. Child Psychol. Psychiatry. 55 (2014) 247–255, https://doi.org/10.1038/nn.3871.Locus-Specific.
[108] S.J. Beck, C.A. Hanson, S.S. Puffenberger, K.L. Benninger, W.B. Benninger, A controlled trial of working memory training for children and adolescents with ADHD, J. Clin. Child Adolesc. Psychol. 39 (2010) 825–836, https://doi.org/10.1080/15374416.2010.517162.
[109] S.A. Gray, P. Chaban, R. Martinussen, R. Goldberg, H. Gotlieb, R. Kronitz, M. Hockenberry, R. Tannock, Effects of a computerized working memory training program on working memory, attention, and academics in adolescents with severe LD and comorbid ADHD: a randomized controlled trial, J. Child Psychol. Psychiatry Allied Discip. 53 (2012) 1277–1284, https://doi.org/10.1111/j.1469-7610.2012.02592.x.
[110] H. Westerberg, H. Jacobaeus, T. Hirvikoski, P. Clevberger, M.L. Östensson, A. Bartfai, T. Klingberg, Computerized working memory training after stroke – a pilot study, Brain Inj. 21 (2007) 21–29, https://doi.org/10.1080/02699050601148726.
[111] A. Janssen, A. Boster, H. Lee, B. Patterson, R. Prakash, The effects of video-game training on broad cognitive transfer in multiple sclerosis: a pilot randomized controlled trial, J. Clin. Exp. Neuropsychol. 37 (2015) 285–302, https://doi.org/10.1080/13803395.2015.1009366.
[112] L. Carelli, F. Morganti, B. Poletti, B. Corra, P.L. Weiss, R. Kizony, V. Silani, G. Riva, A NeuroVR based tool for cognitive assessment and rehabilitation of post-stroke patients: two case studies, Annu. Rev. CyberTherapy Telemed. 7 (2009) 243–247, https://doi.org/10.3233/978-1-60750-017-9-243.
[113] F. La Paglia, C. La Cascia, R. Rizzo, L. Sidelo, A. Francomano, D. La Barbera, Cognitive rehabilitation of schizophrenia through Neurovr Training, Annu. Rev. CyberTherapy Telemed. 191 (2013) 159–162.
[114] P. Gamito, J. Oliveira, J. Pacheco, D. Morais, T. Saraiva, R. Lacerda, A. Baptista, N. Santos, F. Soares, L. Gamito, P. Rosa, Traumatic brain injury memory training: a virtual reality online solution, Int. J. Disabil. Hum. Dev., Chile (2010) 309–312, https://doi.org/10.1515/IJDHD.2011.049.
[115] P. Gamito, J. Oliveira, C. Coelho, D. Morais, P. Lopes, J. Pacheco, R. Brito, F. Soares, N. Santos, A.F. Barata, Cognitive training on stroke patients via virtual reality-based serious games, Disabil. Rehabil. 8288 (2015) 1–4, https://doi.org/10.3109/09638288.2014.934925.
[116] E.B. Larson, M. Ramaiya, F.S. Zollman, S. Pacini, N. Hsu, J.L. Patton, A.Y. Dvorkin, Tolerance of a virtual reality intervention for attention remediation in persons with severe TBI, Brain Inj. 25 (2011) 274–281, https://doi.org/10.3109/02699052.2010.551648.
[117] A.Y. Dvorkin, F.S. Zollman, K. Beck, E. Larson, J.L. Patton, A virtual environment-based paradigm for improving attention in TBI. In: 11th IEEE Int. Conf. Rehabil. Robot., 2009: pp. 962–965. doi: 10.1109/ICORR.2009.5209629.
[118] P.J.M. Prins, S. Dovis, A. Ponsioen, E. ten Brink, S. van der Oord, Does computerized working memory training with game elements enhance motivation and training efficacy in children with ADHD? Cyberpsychology Behav. Soc. Netw. 14 (2011) 115–122, https://doi.org/10.1089/cyber.2009.0206.
[119] L.A. Whitlock, A.C. McLaughlin, J.C. Allaire, Individual differences in response to cognitive training: using a multi-modal, attentionally demanding game-based intervention for older adults, Comput. Human Behav. 28 (2012) 1091–1096, https://doi.org/10.1016/j.chb.2012.01.012.
[120] A.Y. Tahiroglu, G.G. Celik, A. Avci, G. Seydaoglu, M. Uzel, H. Altunbas, Short-term effects of playing computer games on attention, J. Atten. Disord. 13 (2010) 668–676, https://doi.org/10.1177/1087054709347205.
[121] A. Bikic, T. Christensen, J. Leckman, N. Bilenberg, S. Dalsgaard, A double-blind randomized pilot trial comparing computerised cognitive exercises to tetris in adolescents with attention-deficit/hyperactivity disorder, Nord. J. Psychiatry. 71 (2017) 1–9, https://doi.org/10.1080/08039488.2017.1328070.
[122] D. Areces, J. Dockrell, T. García, P. González-Castro, C. Rodríguez, Analysis of cognitive and attentional profiles in children with and without ADHD using an innovative virtual reality tool, PLoS ONE 13 (2018) 1–18, https://doi.org/10.1371/journal.pone.0201039.
[123] Y. Stern, H.M. Blumen, L.W. Rich, A. Richards, G. Herzberg, D. Gopher, Space Fortress game training and executive control in older adults: a pilot intervention, Neuropsychol. Dev. Cogn. B Aging Neuropsychol. Cogn. 18 (2011) 653–677, https://doi.org/10.1080/13825585.2011.613450.Space.
[124] S. Subhash, E.A. Cudney, Gamified learning in higher education: a systematic review of the literature, Comput. Human Behav. 87 (2018) 192–206, https://doi.org/10.1016/j.chb.2018.05.028.
[125] E.D. Mekler, F. Brühlmann, A.N. Tuch, K. Opwis, Towards understanding the effects of individual gamification elements on intrinsic motivation and performance, Comput. Human Behav. 71 (2017) 525–534, https://doi.org/10.1016/j.chb.2015.08.048.
[126] K. Werbach, (Re)Defining Gamification: A process approach, in: Persuas. 2014, 2014, pp. 266–272. doi: 10.1007/978-3-319-07127-5_23.
[127] E.L. Deci, R.M. Ryan, R. Koestner, A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation, Psychol. Bull. 125 (1999) 627–668, https://doi.org/10.1037/0033-2909.125.6.627.
[128] K. Kapp, Gamification: separating fact from fiction, Chief Learn. Off. (2014) 42–46. http://ww.w.cedma-europe.org/newsletter articles/Clomedia/Gamification - Separating Fact from Fiction (Mar 14).pdf.
[129] P. Zhang, Motivational affordances: reasons for ICT design and use, Commun. ACM 51 (2008) 145–147, https://doi.org/10.1145/1400214.1400244.
[130] J.P. Byrnes, Cognitive Development and Learning in Instructional Contexts, 3rd ed., Allyn & Bacon., Boston, 1996. < https://storage.googleapis.com/cozeberpu.appspot.com/160/Cognitive-Development-and-Learning-in-Instructional-Contexts-(3rd-Edition).pdf > (accessed September 10, 2018).
[131] H. Cole, M.D. Griffiths, Social interactions in massively multiplayer online role-playing gamers, CyberPsychology Behav. 10 (2007) 575–583, https://doi.org/10.1089/cpb.2007.9988.
[132] I.C. Rehm, E. Foenander, K. Wallace, J.A.M. Abbott, M. Kyrios, N. Thomas, What

role can avatars play in e-mental health interventions? Exploring new models of client-therapist interaction, Front. Psychiatry. 7 (2016) 1–6, https://doi.org/10.3389/fpsyt.2016.00186.

[133] H.H. Nap, Y.A.W. Kort, W.A. De, IJsselsteijn, Senior gamers: preferences, motivations and needs, Gerontechnology 8 (2009), https://doi.org/10.4017/gt.2009.08.04.003.00.

[134] M. Schmierbach, Q. Xu, A. Oeldorf-Hirsch, F.E. Dardis, Electronic friend or virtual foe: exploring the role of competitive and cooperative multiplayer video game modes in fostering enjoyment, Media Psychol. 15 (2012) 356–371, https://doi.org/10.1080/15213269.2012.702603.

[135] P.L. Kent, Working memory: a selective review, Appl. Neuropsychol. Child. 5 (2016) 163–172, https://doi.org/10.1080/21622965.2016.1167491.

[136] L.G. Weiss, D.H. Saklofske, J.A. Holdnack, A. Prifitera, J.A. Holdnack, A. Prifitera, L.G. Weiss, D.H. Saklofske, WISC-V and the personalized assessment approach. In: WISC-V Assess. Interpret., Academic Press, 2016. pp. 373–413. doi: 10.1016/B978-0-12-404697-9.00012-1.

[137] L. Ma, L. Chang, X. Chen, R. Zhou, Working memory test battery for young adults: computerized working memory assessment, PLoS ONE 12 (2017) 1–19, https://doi.org/10.1371/journal.pone.0175047.

[138] Entertainment Software Association, Essential facts about the computer and video game industry, 2018. < http://www.theesa.com/wp-content/uploads/2018/05/EF2018_FINAL.pdf > .

[139] W. Ijsselsteijn, H.H. Nap, Y. De Kort, K. Poels, Digital game design for elderly users. In: Proc. 2007 Conf. Futur. Play. Futur. Play '07, Toronto, 2007: pp. 17–22. doi: 10.1145/1328202.1328206.

[140] J. Wittland, P. Brauner, M. Zie, Serious games for cognitive training in ambient assisted living environments – a tecnology acceptance perspective, Int. Fed. Inf. Process. 9296 (2015) 453–471, https://doi.org/10.1007/978-3-319-22701-6.

[141] B. Shneiderman, The future of interactive systems and the emergence of direct manipulation†, Behav. Inf. Technol. 1 (1982) 237–256, https://doi.org/10.1080/01449298208914450.

[142] G. Tieri, G. Morone, S. Paolucci, M. Iosa, Virtual reality in cognitive and motor rehabilitation: facts, fiction and fallacies, Expert Rev. Med. Dev. (2018) 1–11, https://doi.org/10.1080/17434440.2018.1425613.

[143] D.M. Spooner, N.A. Pachana, Ecological validity in neuropsychological assessment: a case for greater consideration in research with neurologically intact populations, Arch. Clin. Neuropsychol. 21 (2006) 327–337, https://doi.org/10.1016/j.acn.2006.04.004.

[144] S. Green, J.P.T. Higgins, P. Alderson, C.D. Mulrow, A.D. Oxman, A.S. Green, J.P.T. Higgins, P. Alderson, M. Clarke, C.D. Mulrow, A.D. Oxman, Cochrane Handbook for Systematic Reviews of Interventions, (2015). http://handbook-5-1.cochrane.org/ (accessed December 15, 2018).