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A retrospective analysis and systematic review of the areas of entertainment computing and persuasive technologies for health

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The areas of entertainment computing and persuasive technologies are interdisciplinary fields that have gained increasing attention in the last decades. Health is one of the domains that has leveraged the benefits of fun to improve the results of its technology-enabled interventions. Previous work has reviewed the area of health entertainment from many different perspectives; however, an integrative analysis across disciplines (health sciences and computer science and engineering) throughout the development and validation cycle of technologies in this domain is missing. Having such an in-depth retrospective analysis would shed light on how research on entertainment computing and persuasive technologies for health has evolved, acknowledging its contributions, recognizing its strengths and limitations, and, as a result, allowing for the definition of ways forward. This paper engages in an unprecedented systematic review of the work produced between 2004 and 2017 in this area. From an initial total of 10,350 retrieved results, a total of 1,307 full-texts were included in this review and were thoroughly examined to gain a retrospective understanding of the type of studies that have been produced. Among others, this systematic review reports on the trends, venues of publication, and the characteristics of the studies including methodologies, sample characteristics, study design, the type of solutions produced, the conditions and domains of application, and the purpose of the studies. Results show that there is a growing body of research in the area, with most studies being published in roughly the same venues, and where the lion's share of solutions fall into the area of health rehabilitation and motor conditions. With regards to the most addressed health domains, our review shows that most solutions produced are aimed at stroke and fitness, followed by balance training. Most studies (82.3%) are conducted with their target population, mostly adults (18–49 y), and are conducted either in the lab or in clinical settings. However, the median sample size of the studies has remained stable ($N = 20$) in the last decades. Regarding technology, 2D and 3D solutions are equally used, and most systems employ movement sensors and are single-user. Finally, only 21.4% of the studies are performed using validated instruments.

KEYWORDS

health, entertainment, technology, computing, games, virtual reality, augmented reality, review

1. Introduction

Entertainment computing and persuasive technologies for health add up to a significant part of the research in the fields of health sciences and computer science and engineering. In the health sciences, entertainment technology-enabled interventions contribute to a diversity of health branches, from cardiology (Domínguez-Téllez et al., 2020) to psychiatry (Vajawat et al., 2021), and to a wide range of health care practices, from prevention to rehabilitation and treatment of illness (Wattanasoontorn et al., 2013; Cabrita et al., 2018). In the disciplines of computer science and engineering, the research in this area makes up for an equally wide range of fields, including human-computer interaction, mobile and ubiquitous computing, augmented, virtual and mixed reality, and game design, among others (Kim et al., 2018; Aldenaini et al., 2022). However, how has the research at the intersection of the fields of health sciences and computer science and engineering evolved over the years? What types of solutions have been produced and what specific health domains do they target? How have those solutions been developed and validated? These are some of the questions we aim to answer with this systematic review. By reviewing 1,307 full-texts published between 2004 and 2017 of studies involving at least five users, we take an in-depth retrospective analysis of this broad field of research to gain an understanding of its specific contributions. By including research from a variety of related fields, we integrate what so far have been partial views of the field, bridge between disciplines and bring a shed of light on the knowledge and understanding of this multidisciplinary and vast field of research. By reviewing works published after 2004, we wanted to determine any changes that could have emerged from the introduction of mobile computing, namely the iPhone in 2007, as well as activity trackers, such as Fitbit in 2013 and other technologies such as the Wii and Kinect. These technologies were disruptive and we wanted to assess their potential impact.

1.1. Different terms and formats of entertainment computing and persuasive technologies for health

Technology-enabled interventions in the field of health entertainment can take many forms such as a Virtual Reality (VR) simulation to treat phobias or a gamified mobile application to promote the general health and wellness of the population. The different nuances introduced, for example, by the researchers' background, the technology used, and the specific design strategies employed to develop solutions, have led to a proliferation of terms in this domain. As a result, when searching the literature in the broad area of health and entertainment, we come across several terms such as digital games, persuasive technology, gamification, serious games, computer games, augmented, virtual and mixed reality. To define each of these terms is beyond the scope of this paper, however, this panoply of terms does make it challenging to develop an integrated understanding of the field of entertainment computing for health, as each term provides only a partial view of it. Nevertheless, the solutions produced do have two aspects in common: the health outcome they aim to achieve and the means through which technology proposes to achieve it: entertainment. These different areas have emerged and gained significance at different moments in time, with research reporting on the sustained interest in augmented reality (Zhou et al., 2008; Lau et al., 2017), the impulse of serious games by the year 2002 or the surge of interest in gamification in e-health at the beginning of 2014 (Skjæret et al., 2016). Moreover, regardless of the specific research area, studies generally report on the potential and positive health outcomes of persuasive technologies (Orji and Moffatt, 2018), namely in supporting healthy behaviors and alleviating the healthcare services burden (Cabrita et al., 2018). Research further highlights the potential of games in the health of young individuals (Holtz et al., 2018) and, for example, of exergames to overcome a sedentary lifestyle in older age (Kappen et al., 2019). Vision-based serious games and VR systems for rehabilitation, for example, have also gathered the interest of healthcare professionals (Ayed et al., 2019). Regardless, of the overall potential of solutions at the intersection of health and entertainment, it is important to acknowledge that they can take different formats and can be referred to through different terms, and to analyse them only in isolation, while crucial, does not allow for a comprehensive understanding of the areas of entertainment computing and persuasive technologies for health.

1.2. Synopsis and contribution of this review

The scale of growth of areas of entertainment computing and persuasive technologies for health has been systematically increasing in the last decades. This paper engages in a systematic review of 14 years of research to provide a bird's-eye view of how these areas have evolved to highlight trends, uncover pitfalls and suggest directions for future research. Following the scrutiny of 1,307 full-text papers, important information is analyzed and summarized to gain an understanding of (i) the domains of application; (ii) the characteristics of the studies, with regards to their sample size and demographics, the conditions and stage of the disease of the participants; (iii) the characteristics of the technology, namely in terms of their purpose, the type of technology, features, and devices which are most used, and whether solutions are custom made or commercial; and (iv) the methodological qualities of the studies, namely in terms of the measurement instruments used and the clarity of participants inclusion and exclusion criteria. This is an unprecedented effort to understand this vast area of research not only due to the high volume of articles examined but also because the studies reviewed cover a panoply of research fields and health conditions, from VR to gamification, from anxiety to traumatic brain injury. As a result, this systematic review contributes to an integrated overview of the different perspectives and facets of the field of digital technologies for health and an understanding of how the field has evolved.

1.3. Distinction and relation to previous reviews

A literature search in a regular scientific database shows a large corpus of research, namely systematic reviews, in the area of entertainment computing and persuasive technologies for health. However, more often than not, these systematic reviews tend to focus on specific facets of these areas of research, instead of covering a wider realm of domains that could provide an integrated view and understanding of this multidisciplinary and vast field. Looking into the literature, we find that reviews that focus on specific health conditions such as chronic conditions (Holtz et al., 2018), mental health (Lau et al., 2017), rehabilitation (Ayed et al., 2019), sedentary behavior and physical activity (Bonnechère et al., 2016; Aldenaini et al., 2022) are relatively common and easy to locate. Likewise, there are systematic reviews with a focus on specific populations, from children (Holtz et al., 2018) to older adults (Bleakley et al., 2015), or focusing on specific technologies such as robots, VR, or vision-based solutions and even specific features such as sound design (Kharrazi et al., 2009; Baur et al., 2018; Ayed et al., 2019). There are even systematic reviews focusing on specific games such as Pokémon go (Wang, 2021). However, to our best knowledge, only a limited number of systematic reviews have a wider focus. We found four articles that we considered worth mentioning.

In 2013, Wattanasoontorn et al. (2013) examined 108 academic and commercial serious games aimed at health. Their search covered works produced between January 2004 and December 2012. The outcome of their work is a proposal for the classification of serious games according to four different categories: game purpose, functionality, stage of the disease, and player's wellness, and 15 characteristics, from a game genre to type of feedback and area of application among others. Their main results showed that 69.07% of games were aimed at non-patients whereas nearly half the games were aimed at training professionals (24.07%) and health and wellness (23.15%). Concerning the disease targeted, the largest portion of the games (39.81%) was aimed at general health, followed by specific conditions, where stroke, diabetes and brain health take the lead, all with 4.63% each. In terms of application area, their review reports that 58.54% of the games are placed in a cognitive application area, against 39.02% in a motor, and 2.44% in a motor/cognitive area of application. The interaction tool used to operate the game was mostly the mouse (50.93%); there was then a variety of interaction tools, from the Wii to the Kinect, EEG, among others, where a typical game is a portable PC game, using mouse interaction and including progress monitoring, performance feedback and adaptability. Much has happened since 2012 and besides, while the authors engaged in a very thorough review process that covered a wide range of aspects, their review was not a systematic review.

Another study conducted a systematic review with a specific focus on gamification and serious games in e-health, covering 15 years of research in the area, from 2000 to 2015 (Sardi et al., 2017). In their final review, the authors included 46 articles that they analyzed to explore the various gamification strategies employed in e-Health and to discuss the contributions in the area. Their work highlights the prevalence of gamified solutions targeting chronic disease and rehabilitation as well as physical activity in comparison to serious games mostly targeting chronic disease and rehabilitation as well as mental health. Their work further reports that 35% of the studies reviewed did not empirically evaluate their work. With regards to the length of time solutions that were evaluated, the longest time for gamification solutions was 6 vs. 2 months for serious games. Finally, the paper reports on other aspects of the solutions such as game mechanics and the challenges encountered by those using them. While the review is still pertinent, it included a relatively small number of papers, and, by focusing on gamification, the authors might have left out other types of entertainment and persuasive technologies.

A study by Orji and Moffatt (2018) systematically analyzed persuasive technology in the health domain and applied quantitative content analysis to develop an understanding of the effectiveness of this technology for health and wellness. The study addressed the trends in the technology design, research methods, motivational strategies, theories, and health behaviors targeted by the research studies reviewed. Their work covered 16 years of research, from 2000 to 2015, and included the examination of 85 articles. While the rich analysis and conclusions about the specific persuasive technology strategies employed in the solutions are very comprehensive and interesting, it is out of the scope of this work and, for that reason, we will not expand on them here. Yet, the results of their review show a steep increase in the research produced in the area around the year 2005, with most studies (38%) originating from the United States. Their research also highlights that 46% of the studies employed a mixed methods approach, combining both quantitative and qualitative methods, where this approach is followed by a quantitative (39%) and lastly a qualitative approach (15%). The duration of the evaluations spanned from 15 min to 3 years and the sample included mostly adults (66%), sometimes children (16%) and seldom older adults (13%). The devices used to display the solutions were typically mobile and handheld devices (28%) and the least frequent platform was made available through ambient and public displays (5%). Due to its specific focus, the review does not investigate more specific aspects of the study such as inclusion and exclusion criteria, if the measurement instruments used in the study are validated or not, or whether devices/solutions are custom-made or off-the-shelf solutions.

Lu and Kharrazi (2018) conducted a systematic quantitative content analysis of 1,743 digital games for health released between 1983 and 2016, however, their work is based on a review of nine international English health game databases and directories. While the work is not based on the examination of scientific articles, the results provide relevant insight into the trends and contributions of the field. For example, the authors report on a sudden surge of health games in 1999 and a dip after 2013. The target audience of the games is mostly a healthy population and the most common health topic is cognitive training (37.41%). Games are usually web-based (72.38%). The authors thoroughly investigate the design features of the games, however, by solely focusing on games and by conducting their research based on a database and not scientific publications, they provide a different perspective from the one this paper aims to provide.

Because the applied research areas at the intersection of health entertainment computing have become so wide, as Lu and Kharrazi

(2018) point out, "it is crucial to document the field's scale of growth". This article aims to provide a retrospective and integrative analysis that encompasses the works produced in different research fields, from health to the more technical and the more human-centered areas of research, to then analyse trends and characteristics of the solutions, the health conditions addressed, and the specific aspects of the interventions and of the study design employed in assessing those. This justifies that we seek to continue investigating this area and we hope to provide a different yet complementary bird's-eye view of this growing area of research.

1.4. Organization of this article

This section sets the stage for this research and provided the necessary grounding and scoping of this work. Section 2 describes the systematic review methodology and presents our search strategy, eligibility criteria and data extraction strategy. Section 3 consists of the bulk of the work and presents our results, which are divided into 5 subsections, each presenting the results concerning the publication trends, the domains of intervention, the characteristics of the study participants, the characteristics of the technology-enabled solutions, and the design of the studies. Before presenting the conclusions, Section 4 discusses the research, highlighting strengths and limitations, identifying the implications of this research, and eliciting opportunities for future research.

2. Review methodology

2.1. Research questions

The overarching goal of this systematic review is to develop an in-depth understanding of the areas of entertainment computing and persuasive technologies for health. To achieve this goal, four research questions guided this research. Table 1 lists these questions as well as the corresponding rationale for each of them.

2.2. Search strategy and eligibility criteria

The search strategy for this review used the following terms: ((health OR rehab*) AND (((serious OR computer OR interactive OR video OR online) AND gam*) OR exergames OR gamification OR ("virtual reality" OR "augmented reality" OR "mixed reality"))). To maximize coverage, the authors conducted a systematic search in three databases: IEEE Xplore, PubMed and the ACM Digital Library. Following the search phase, the records retrieved were reviewed to identify eligible studies. Articles were included when: dated between January 2004 and December 2017; peer-reviewed; in English; involving five or more subjects; application domain related to health; and use of entertainment technology. Articles were excluded when: not accessible/possible to locate; in the form of a book, poster, demo, workshop, keynote, study protocol, review, editorial, letter, commentary, clinical perspective, or appraisal.

2.3. Data and information extraction strategy

The above-described searches yielded a total of 10,556 articles, which were gathered in Zotero. After removing duplicates, a total of 10,350 remained. These articles and their metadata were migrated to a Google Spreadsheet, through a cvs file. Two reviewers then screened all titles, abstracts, and type of publication for eligibility, according to the inclusion and exclusion criteria. When necessary, the reviewers downloaded the article and skimmed it to determine article eligibility. 7,949 articles were deemed irrelevant and were discarded, and 126 could not be located/downloaded. The full-texts of the remaining 2,275 articles were downloaded for full-text eligibility assessment. A further 968 articles were removed after analyzing its full-text. Finally, 1,307 articles remained for analysis. Figure 1 shows an overview of the process.

2.3.1. Pre-coding training and refinement of data extraction form

To support information extraction, a data extraction form was created to capture the data that could answer the research questions. To create the preliminary data extraction form, three pre-coding training sessions involving all reviewers were conducted to refine goals, themes, concepts, and a final set of data fields. Once the preliminary data extraction form was available, reviewers jointly coded five articles, with the goal to make any necessary adjustments. After these meetings, a final version of the data extraction form was created to support data extraction.

2.3.2. Data extraction form and information extraction strategy

Information extraction was supported by the data extraction form that resulted from the previously described process and included the following fields: Year of publication, Type of publication, Venue, Reason for exclusion, Study participants' age/same as target/sex/health condition, Health and application domain, Stage of the disease, Type of intervention, Type of technology, Purpose of technology, Sample size, and Purpose of the study. To consistently extract information, the strategy adopted by the authors was to, regardless of the possible interpretations of the reviewers about the technology the paper was reporting on, enter the exact terms, as used by the authors in the papers, in the data extraction form. For example, even if the technology could be interpreted as Mixed Reality or Augmented Reality, the term inserted in the data extraction form was always the term used by the authors. This strategy was adopted for all data fields.

2.3.3. Consensus and data extraction agreement

Once the terms of the data extraction were clarified, reviewers independently coded four additional articles, and an agreement percentage was calculated. There was a 93% agreement among reviewers; that percentage was

TABLE 1 Research questions and rationale.

Research question	Rationale
RQ1: How has the research entertainment computing and persuasive technologies for health been distributed over years?	To examine the different sources in which articles related to entertainment computing and persuasive technologies for health are being published and to explore the emerging temporal trends and venues of publication.
RQ2: Which domains of intervention have been privileged in the research produced in the areas of entertainment computing and persuasive technologies for health?	To identify the domains of application most frequently targeted in the areas of entertainment computing and persuasive technologies for health and their frequency and possible co-occurrences.
RQ3: What technology-enabled solutions have been produced in the areas of entertainment computing and persuasive technologies for health and for which purposes?	To gain an understanding of the type of technologies, devices, and features of the solutions produced and explore the most frequently addressed purposes of technology-enabled solutions in the areas of entertainment computing and persuasive technologies for health.
RQ4: What characterizes the types of studies related to the areas of entertainment computing and persuasive technologies for health?	To determine the characteristics and types of research studies that were conducted in the areas of entertainment computing and persuasive technologies for health in terms of their study design and characteristics of the samples of participants.

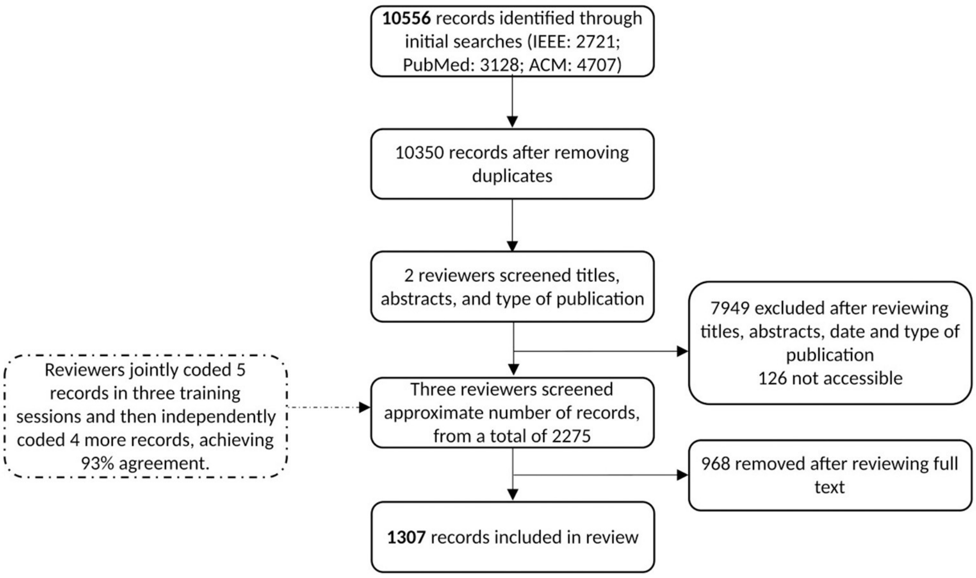

FIGURE 1
Overview of screening and selection process. The selection process resulted in 1307 articles included (688 journals, 619 conferences).

deemed appropriate to allow for subsequent independent coding. Three reviewers divided the remaining articles and examined them independently. Any questions and conflicts were resolved by discussion and consensus in regular reviewers' meetings.

2.3.4. Exclusions

The most frequent reasons for exclusion are the lack of subjects ($N = 298$) and a sample size smaller than 5 or unspecified ($N = 245$), followed by non-full papers (Poster/Short Paper/Demo) ($N = 243$), and not in the areas of health, technology and/or entertainment ($N = 135$). The rest were excluded because they were not in English ($N = 35$) and because the information available was insufficient to fully examine the paper ($N = 13$).

3. Results and findings

The analysis of existing research in the area of entertainment computing and persuasive technologies for health revealed interesting insights and trends. Below we present our findings under the following categories: Publication trends, Domain of intervention, Characteristics of the sample, Characteristics of the technology-enabled solutions, and Design of the studies.

3.1. Publication trends

3.1.1. Yearly trends

Figure 2 shows the yearly trends for the included articles. A 20-fold increase in publications can be observed between 2004 and 2017, consisting mainly of conference contributions until 2012,

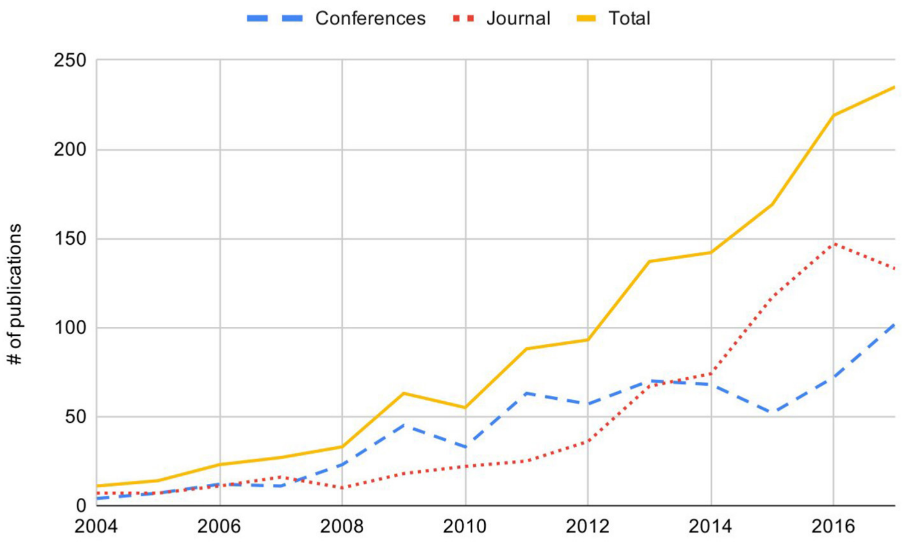

FIGURE 2
Yearly publication trends in journals and conferences.

TABLE 2 Top publication venues.

Conference	619	%	%ile	Journal	688	%	%ile
International conference on virtual rehabilitation (ICVR)	**76**	**12.3**	**12.3**	**Journal of neuro engineering and rehabilitation**	**38**	**5.5**	**5.5**
ACM SIGCHI conference on human factors in computing systems	**75**	**12.1**	**24.4**	**Games for health journal**	**30**	**4.3**	**9.9**
IEEE annual international conference on engineering in medicine and biology society (EMBS)	44	7.1	31.5	**IEEE transactions on neural systems and rehabilitation engineering**	**30**	**4.3**	**14.2**
IEEE international conference on rehabilitation robotics	28	4.5	36.0	**Disability and rehabilitation: assistive technology**	**22**	**3.2**	**17.4**
IEEE international conference on serious games and applications for health (SeGAH)	26	4.2	40.2	**The journal of physical therapy science**	**19**	**2.8**	**20.1**
Workshop on ICTs for improving patients rehabilitation research techniques	18	2.9	43.1	**Studies in health technology and informatics**	**16**	**2.3**	**22.5**
ACM SIGCHI annual symposium on computer-human interaction in play (CHI PLAY)	15	2.4	45.6	**JMIR serious games**	**14**	**2.0**	**24.5**
ACM SIGCHI conference on interaction design and children (IDC)	13	2.1	47.7	Annual review of cybertherapy and telemedicine	12	1.7	26.2
International conference on pervasive computing technologies for healthcare	10	1.6	49.3	Disability and rehabilitation	12	1.7	28.0
ACM international joint conference on pervasive and ubiquitous computing (UbiComp)	9	1.5	50.7	PLoS ONE	12	1.7	29.7

Publications in bold represent the top 25 percentile.

and later by journal publications. Interestingly, until that year, a larger number of conference publications is observed in odd years. This is related to the fact that conferences mainly drove publications in that period, and that two of the most contributing conferences took place every 2 years, the International Conference on Virtual Rehabilitation and the IEEE International Conference on Rehabilitation Robotics (Table 2).

3.1.2. Top venues

Table 2 shows the top conference and journal publication venues in the area. Whereas, there seems to be a large consensus on the most relevant conference venues (top five totalling 249 publications), this is not the case for journal venues (top five totalling 139 publications). Interestingly, the two top conferences alone (the International Conference on Virtual Rehabilitation and ACM SIGCHI Conference on Human Factors in Computing Systems) account for the top 25 percentile of all conference publications in the area. On the contrary, the top 25 percentile of journal publications are distributed among 7 different venues, being the Journal of NeuroEngineering and Rehabilitation, the Games for Health Journal and IEEE Transactions on Neural Systems and Rehabilitation Engineering the top three and accounting each for ∼5% of the publications. This trend is also visible in the higher number of journals where works have been published (260) compared to a considerably smaller number of conferences (184) for a comparable number of studies identified in this review (688 and 619 for journals and conferences, respectively).

3.2. Domain of intervention

3.2.1. General domain of intervention

We also investigated whether interventions were tackling motor, cognitive, social, or other domains of intervention. Results show that most studies focused on motor (890) concerns, followed by studies addressing cognitive (298) issues. A smaller number of studies dealt with social (71) or other types of issues (132). In this category, we included, for example, studies dealing with pain, or general health awareness. There are no substantial differences in the domains of application between publications in conferences and journals. So far, there has been a tendency to focus on one single domain of intervention, still, it is important to note that some studies address more than one domain.

3.2.2. Specific domain of intervention

Each study targeted one or more specific domains within the above-mentioned general domains of intervention. These could be as dissimilar as, for instance, balance, stroke, or cognitive rehabilitation, and those were labeled exactly as reported by the authors. Each article produced a heterogeneous number of labels, generally indicating multiple intervention domains. We computed the co-occurrence of domains by first uniformizing the nomenclature for multiple terms referring to the same domain (such as TBI and traumatic brain injury), and second producing a co-occurrence network diagram (Higuchi, 2016). This diagram reveals the relations between terms and how they cluster (Figure 3). The resulting network diagram shows us the most frequent intervention domains as nodes, their size according to the number of occurrences, and color indicating how central the role each domain plays in the network (betweenness centrality). Nodes (domains) are connected through edges according to their simultaneous frequency of appearance. For this analysis, we only considered cases of 3 or more co-occurrence of domains.

This analysis shows that the most central domains were Balance, Posture, Multiple Sclerosis and Dementia. However, the most frequent co-occurrence of terms were Stroke, Fitness and Balance, followed at some distance by Obesity, Traumatic Brain Injury, Parkinson's Disease and Autism. Interestingly, the centrality analysis shows that Balance is the most transversal area of study in the literature; however, it is not the most frequent area of study. Instead, Stroke and Fitness are the most frequent ones.

3.3. Characteristics of the sample

3.3.1. Sample size

The largest sample size identified was 2,530 participants, with a mean of 43.6 ± 129.6 and a median of 20. These metrics are slightly biased by a few studies ($N = 4$) with sample sizes above 1000 participants, being the most frequent sample size 10. Except for a few rare cases, journal publications tend to present slightly larger sample sizes (Mean = 48) than conferences (Mean = 39). As for the evolution over time, during the 2004–2017 period, the median sample size was kept stable for both conference and journal publications (Figure 4), with a minor tendency to increase in journal publications.

3.3.2. Sample demographics

The information available on the sample is often insufficient. Most studies do indicate whether they include male and female participants ($N = 942$), or solely male ($N = 51$) or female ($N = 35$) participants. However, there is still a considerable number of studies (279) that do not provide information on the sex of the study participants, most of which ($N = 205$) are conference publications. Furthermore, while numbers are quite even for journal publications (only female: 27, only male: 28, both: 559), in conference papers women are underrepresented (only female: 8, only male: 23, both: 383). Similarly, of the included articles, 179 (13.7%) do not report the age of their participants. The most frequent participants are, in this order, adults (18–49 years old) ($N = 724$), young seniors (50–64 years old) ($N = 564$) and seniors (65–84 years old) ($N = 474$). The least frequent participants were: teenagers (9–17 years old) ($N = 216$), children (6–8 years old) ($N = 120$), old senior citizen (>85 year old) ($N = 92$), baby or toddler (< than 6 years old) ($N = 33$). Some studies include participants of multiple age groups and hence have been accounted for in the different age ranges.

3.3.3. Condition of participants

Concerning the condition of participants, 557 studies included only patients, 408 included only healthy participants, 211 included both, and 114 studies did not indicate the condition of their participants. Overall, 82.3% of the studies included their target users, however, there was a clear difference between journal (91.4%) and conference (72.2%) publications. A remaining 14.6% did not include their target users, and for 3.1% of the studies, the information was not available.

3.3.4. Stage of the disease of the study participants

To understand the stage of the disease of the study participants, we relied on Merril's taxonomy (Merrill, 2010), as summarized by Wattanasoontorn et al. (2013) that considers the following stages: Susceptibility, Pre-symptomatic, Clinical disease, Recovery, and Disability (Wattanasoontorn et al., 2013). Of the studies included in this review, 540 included participants in the Susceptibility stage, 56 in the Pre-symptomatic stage, 539 in the Clinical disease stage (including transitory or acute conditions), and 710 in the Recovery

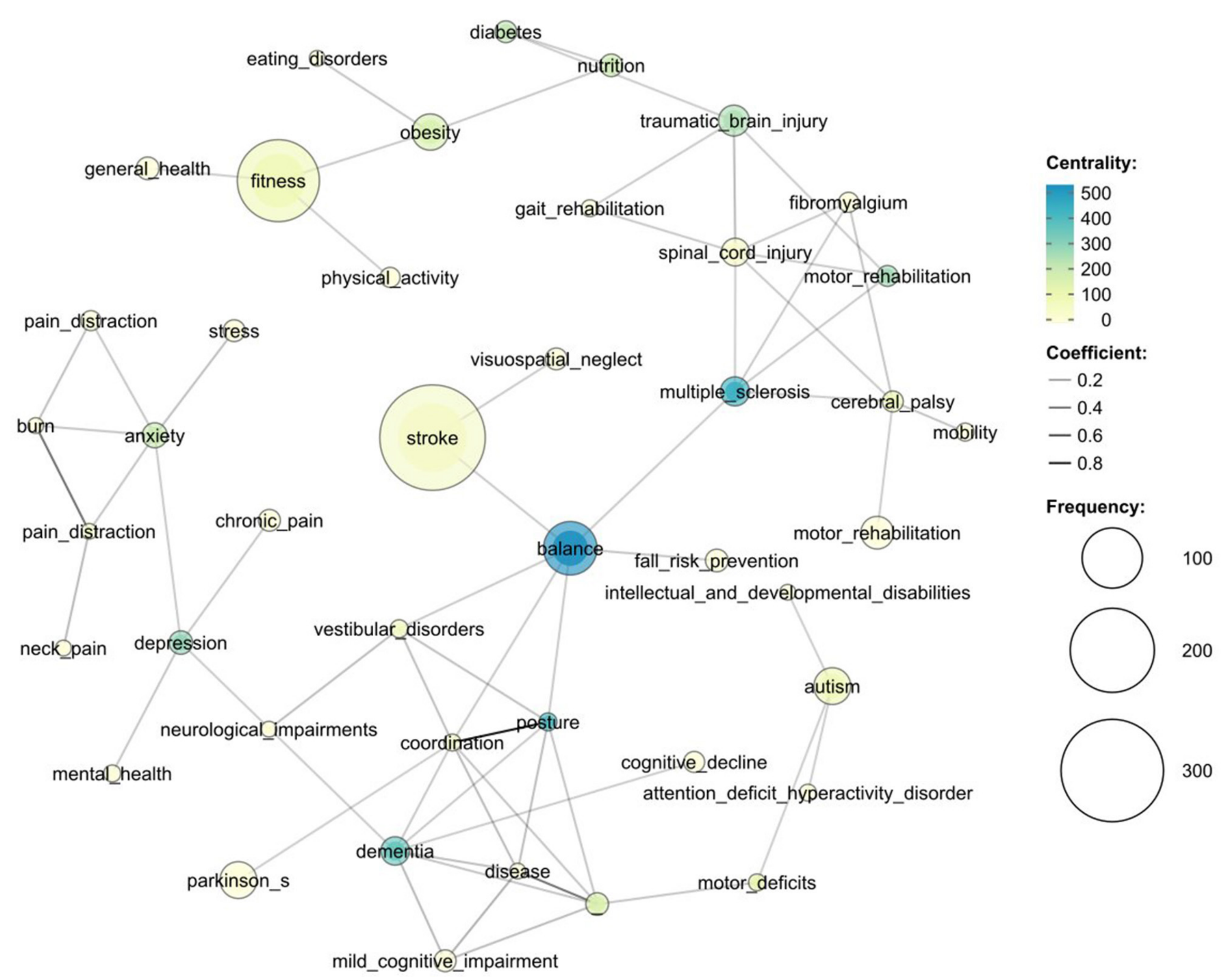

FIGURE 3
Co-occurrence network diagram of the specific domains of intervention.

stage (673 of which had chronic conditions), and 37 were in the Disability stage (meaning that systems do not aim to recover from the disease but rather to increase the quality of life). Studies considering multiple stages were accounted for in each of them. For 166 studies, this information was not available, and for 215 this taxonomy was not applicable (Figure 5).

3.4. Characteristics of the technology-enabled solutions

3.4.1. Purpose of technology

To classify the purpose of the technologies of the reviewed papers, we relied on the proposal by Wattanasoontorn et al. (2013) who created a taxonomy of serious games by target group: patient/non-patient (Wattanasoontorn et al., 2013). Targeting patients, Wattanasoontorn et al. (2013) considered the following purposes: Health monitoring, Detection, Treatment or therapy, Rehabilitation, and Education. For non-patients: Health and wellness games, Training and simulation games for professionals, and Training and simulation games for non-professionals.

Figure 6 provides an overview of the results, where studies aiming at patients (1,238) are more expressive than those targeting non-patients (314). The great majority of articles targeting patients report on studies which purpose is Rehabilitation (611); these are followed by studies aiming at Treatment or therapy (345). A smaller number of studies target Health monitoring (100), Detection (120), and Education (62). When looking into technology for non-patients, the Health and wellness category gathers the largest number of studies (286), while Training and simulation games for professional (10) and non-professional (18) numbers are residual (Figure 6). For the correct interpretation of results, it is important to mention that studies sometimes report on more than one single purpose. This is a frequent case for Treatment or therapy plus rehabilitation, and Health monitoring plus Detection. Still, these numbers are less expressive than the ones in categories such as Rehabilitation, Health and wellness and Treatment or therapy alone, which are the three areas that have been receiving the most

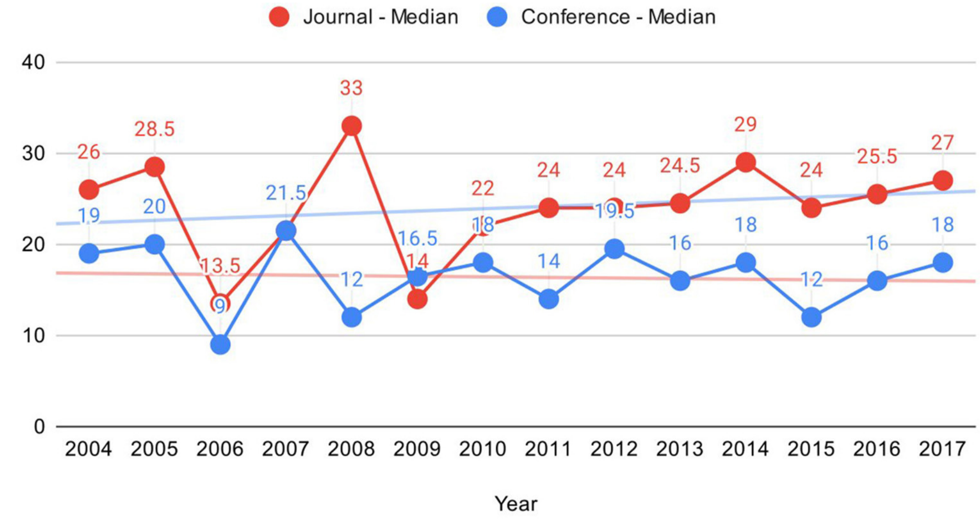

FIGURE 4
Median sample size across time and corresponding linear regressions.

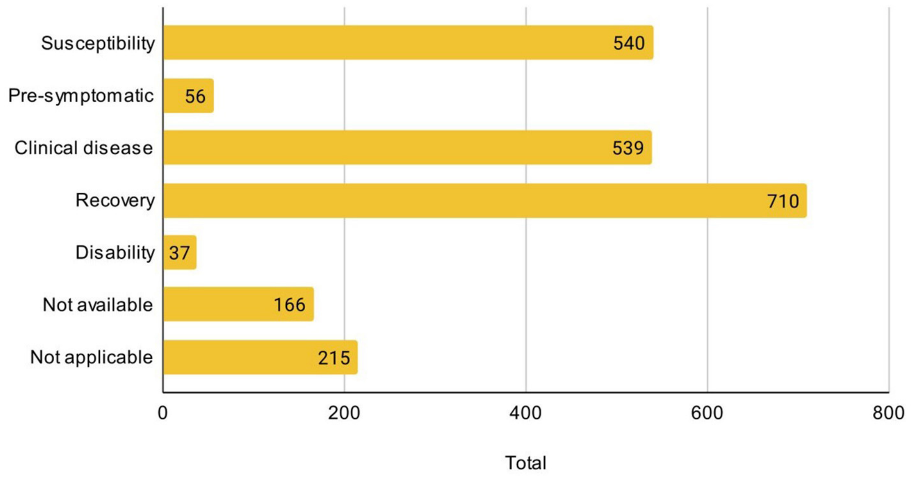

FIGURE 5
Number of studies by stage of the disease of participants according to Merrill (2010) taxonomy.

attention by the research community working in the intersection of health and entertainment technologies.

3.4.2. Type of technology

Each article focused on a specific type of digital solutions, which we grouped under one of the following categories: (1) Virtual reality, (2) Augmented reality, (3) Mixed reality, and (4) Other types of solutions (e.g., games, mobile games, desktop applications, etc.). We found that most studies referred to the term virtual reality (384), and few would refer to applications as augmented reality (29) or mixed reality (18). Instead, many studies would refer to other types of technologies (249). It was not possible to determine the type of technology used in 29 of the reviewed articles. When looking at the presentation format of the proposed systems, it was not available or applicable for 22.3% of the systems. The remaining ones were mostly 3D (58.0%), 2D (16.4%) and only a minority combined 2D and 3D (3.3%). Subsequently, we further analyzed the reported systems, classifying them into the following categories: (1) Coaches and trainers, (2) Games and gamified applications, (3) Simulations, and (4) Other, depending on the nature of the application. Data clearly show a predominance of games and gamified systems (59.4%), followed by simulations (25.0%) reported mostly in journal publications,

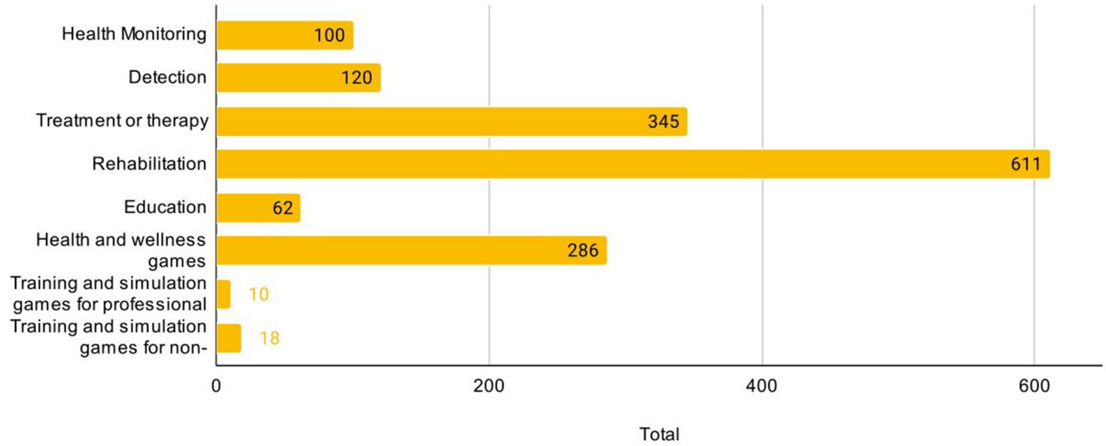

FIGURE 6
Purpose of technology.

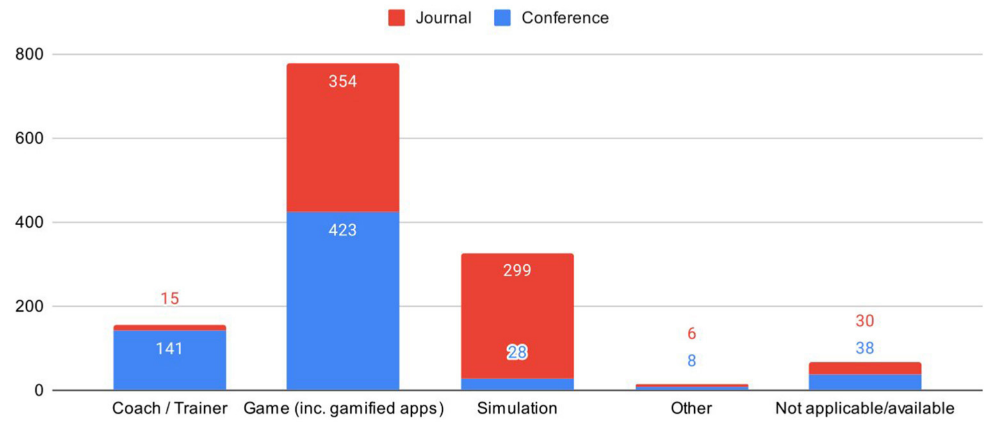

FIGURE 7
Type of technology by nature of the application.

and coaches and trainers (11.9%) reported mostly at conferences (Figure 7).

3.4.3. Adaptability and feedback

Another important characteristic of these systems is their capability to be adapted or personalized to their users. Surprisingly, in half of the studies, this information was not available, and only 34.7% reported some type of adaptability or customization capability. Similarly, most studies did not report on the type of feedback provided to the user. Only 31.1% reported providing Knowledge of Results (KR - feedback on the success of an action) and 40.9% Knowledge of Performance (KP - feedback on how an action is performed) (Figure 8).

3.4.4. Commercial vs. custom-made systems

We were also interested in finding out whether the solutions in use were (or not) commercial. We found that 46.4% (607) of the solutions were custom-made, while 23.3% (304) were commercial, and for the remaining 396 of the articles, it was not possible to determine the nature of the solution. Of the reported commercial systems, the most common strategy was repurposing game consoles (91.7%), whereas commercial systems specifically designed for health represented a minority (Figure 9). While the fact that almost half of the papers report on custom-made solutions is not surprising, especially because this study is sourced from research papers, this also reflects the potential that researchers perceive in embedding entertainment in technological solutions targeting health, and a potential reduced number of commercial alternatives. Hence, this important investment by researchers

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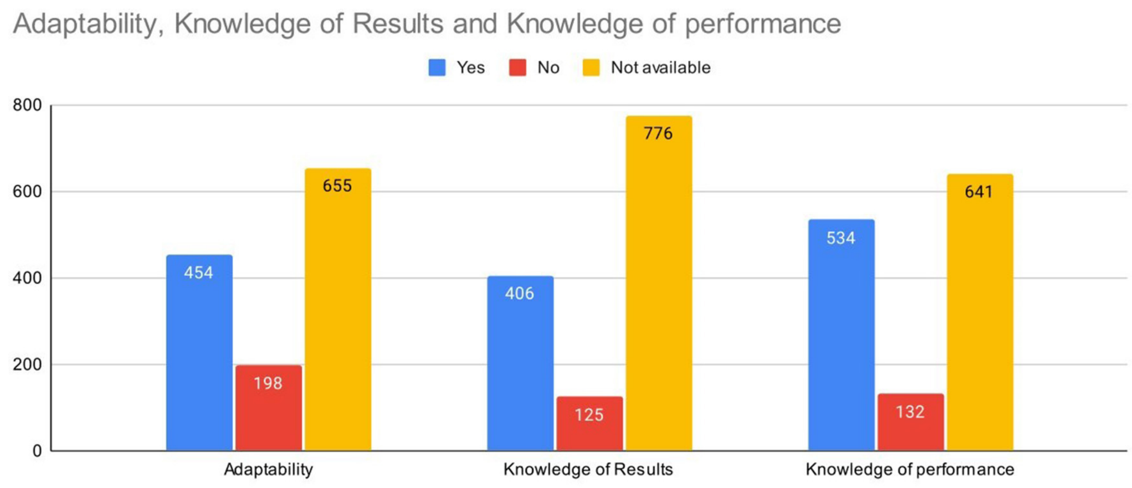

FIGURE 8
Adaptability and feedback provided by the systems.

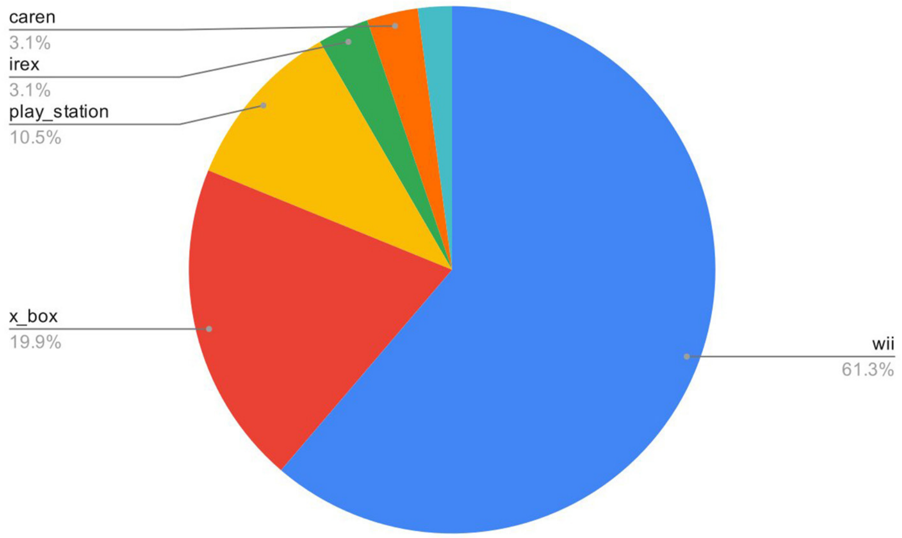

FIGURE 9
Most reported commercial systems.

may foresee an increase of solutions in the market leveraging play, game elements, or some sort of entertainment to attain health goals.

3.4.5. Top devices

The systems identified in the literature report the use of a large variety of devices. Figure 10 shows the top devices (26) that are reported at least 15 times divided by input (A) output (B) devices, and implemented in a variety of computing platforms (C). This analysis considers only the setup as reported by the authors, and it indicates that most systems are computer-based (50.0%) and rely primarily on movement (38.3%) or electrophysiological sensors (10.5%). The main presentation format reported is through a computer screen (8.5%), followed by Head-Mounted Displays (HMD) (6.8%), smartphones (4.8%), projection-based solutions (3.5%), and tablets (3.3%). The co-occurrence network analysis (Higuchi, 2016) shows us the most frequent devices as nodes, their size according to the number of occurrences, and in this case, color indicates clusters of devices. Nodes (devices) are connected through edges with other devices according to their simultaneous frequency of appearance. For this analysis, we considered cases of at least 3 or more co-occurrences. The diagram in Figure 11 shows that the most frequent configuration of devices combines a computer with movement and physiological sensors, with either an HMD or a screen, and in the latter case, sometimes combined with a treadmill. The second most frequent configuration is made up of commercial game consoles (Wii, XBOX, and PlayStation) used with

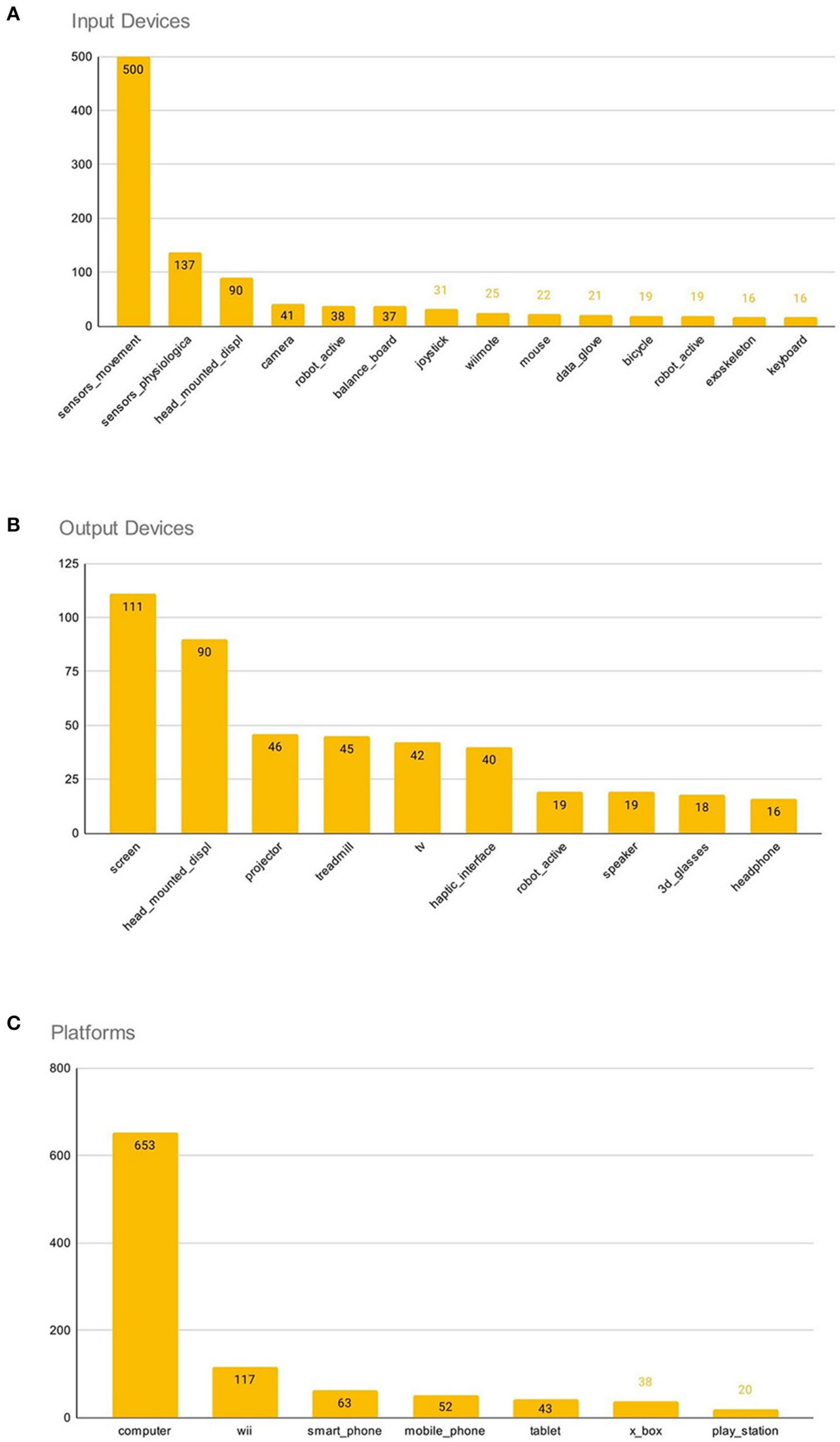

FIGURE 10
Most reported **(A)** input devices, **(B)** output devices, and **(C)** platforms.

their respective motion interfaces such as accelerometers, cameras, or balance boards. A third relevant cluster identifies robotic setups, consisting mostly of exoskeletal robotic systems with data gloves and haptic feedback. Finally, it also indicates that motion platforms,

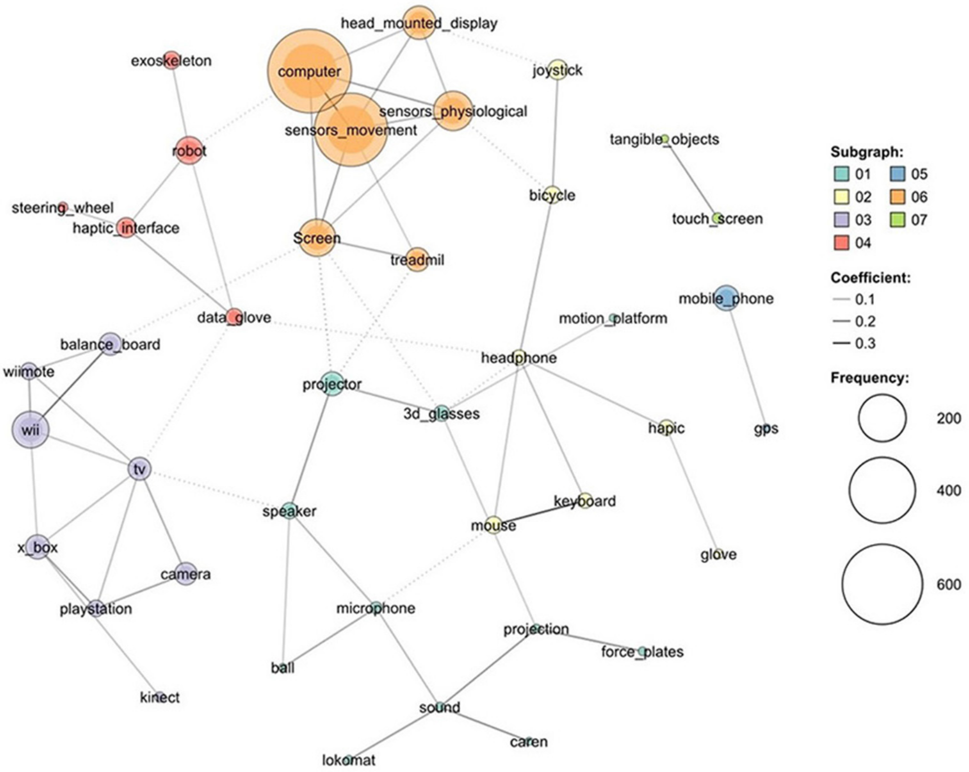

FIGURE 11
Co-occurrence network diagram of the devices used.

treadmill and force plates are generally used in combination with 3d glasses and projections.

3.5. Design of the studies

3.5.1. Purpose of the study

The analysis of the studies included in this review presented work at different stages of development and with different purposes. We sorted them according to the following categories: (1) Conceptualization, (2) User Research (before development), (3) Prototyping, (4) Evaluation (of the system itself), and (5) Validation (of the outcome of the system). Figure 12 shows that most studies contain a validation study (757) to verify if the proposed system fulfills its health-related goal. Nonetheless, articles devoted to technical aspects such as evaluation (522) of the system's functioning and prototyping (96) are also frequent. There are, however, fewer contributions concerning the conceptualization (50) and user research (85) phases, representing an important gap as these are crucial steps in the development of entertainment computing and persuasive technologies for health. It is important to highlight, however, that many contributions presented multiple studies or contributions in different categories. Overall, roughly 50% of the studies still focus on the development, prototyping, and technical evaluation phases only. This indicates that assessing the impact of some tools is still not the norm.

3.5.2. Procedure

Studies generally report poorly on the specific methodologies used to recruit the sample. The large majority of studies (54.4%; $N = 712$) does not report this information at all. From those that report it, convenience sampling is the most frequently used method (33.4%, $N = 437$), followed by self-selection (12.6%, $N = 165$), random selection method (1.5%, $N = 19$), and other method (0.5%, $N = 7$). This lack of systematicity in reporting the sampling strategies makes it difficult to critically analyse the results considering potential sampling biases and the generalization of the findings. Similarly, to the sampling method, detailed information on the procedure of the technology administration is frequently missing. 39.1% of the studies do not report who administers the technology. When they do, results show that it is mostly the researcher who administers the technology (27.7%) followed by a healthcare professional (17.1%) and the patient him/herself (16.1%). Most systems (72.9%) are designed to be used by a single user, and only a minority (12.5%) can be used in a multi-user configuration.

Regarding the length of the study, and duration and frequency of the sessions, we identified that 50.4% of the studies are delivered single-session, and 38.7% are multi-session. For 10.8% of the publications, this information was not available. In the case of multi-session studies, they are mostly clinical or field interventions to study the impact of a training program with technology. Figure 13 shows the distributions of Figure 13A the

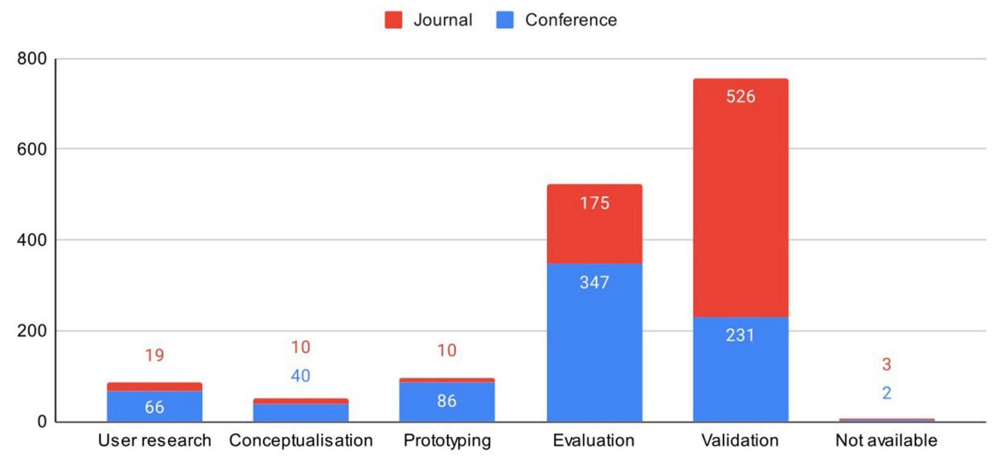

FIGURE 12
Purpose of the studies.

duration of the interventions, Figure 13B the session duration, and Figure 13C the frequency of sessions. Study duration spans from 1 week to 59 weeks. The most frequent durations are 4, 6, 8, and 12-week studies. Studies beyond 12 weeks are very infrequent, which clearly indicates that the long-term effects of entertainment technologies applied to health are under-studied. In terms of session durations, the most common lengths are 30 and 60 min, being most interventions of session lengths below 1 h. Regarding the frequency of the sessions (sessions per week), it mostly spans from 1 to 5 sessions/week, being 3 the most frequent.

3.5.3. Location, typology, and purpose of the study

Another aspect in which methodological detail is missing is the location where the studies took place, with 43.1% of studies not reporting this information, as shown in Figure 14A. From the remaining studies, the most frequent setting is a research laboratory (23.9%), followed by a clinic (18.1%) and home (7.4%). These data clearly show that there is a need for further research in this area. Most of the studies addressing this domain still take place in very controlled settings, whereas those reported in more uncontrolled and realistic settings are a minority. This fact can be related to the typology of the presented studies, which in its overwhelming majority report on studies other than field studies, such as user research, usability, technical validation and laboratory or pilot research (Figure 14B). Only about 23% of the publications address field research. As is to be expected, user research, usability and technological studies are reported mostly in conference publications, whereas laboratory, pilot and field research are mostly in journals. Interestingly, despite the different typologies and settings of studies, more than half of the works (58.1%) intend to validate the outcome of the use of the systems as opposed to the system itself (39.9%) or report on the development process (Figure 14C).

3.5.4. Measurement instruments

Of relevance is the choice of instruments used to study the presented technologies. Objective quantitative data provided by the systems themselves are reported in 43.4% ($N = 576$) of the studies, and custom-developed measurement instruments and questionnaires in 44.3% method ($N = 579$). However, only 21.4% ($N = 280$) of the studies report using standardized or validated instruments, which clearly limits the interpretability of data and hinders the ability to compare different approaches, studies and technologies and their reported impact.

3.5.5. Inclusion and exclusion criteria

The large number of studies that do not use standardized or validated instruments may indicate limited methodological rigor. This is again supported by our analysis of the reported inclusion and exclusion criteria. This analysis reveals that only 48.6% of the studies report criteria for inclusion (15.8%), exclusion (4.2%) or both (28.6%), with this information omitted in more than half of the cases.

4. Discussion and implications for future research

To the extent of our knowledge, this is the first attempt to provide a systematic review and a retrospective analysis of the area of entertainment computing and persuasive technologies for health. Our study protocol and method provide an unprecedented in-depth retrospective analysis of technology-enabled interventions in the field of health entertainment.

4.1. Publication trends

While growth in the field is reported by other related studies (Ayed et al., 2019), our publication trends for included articles

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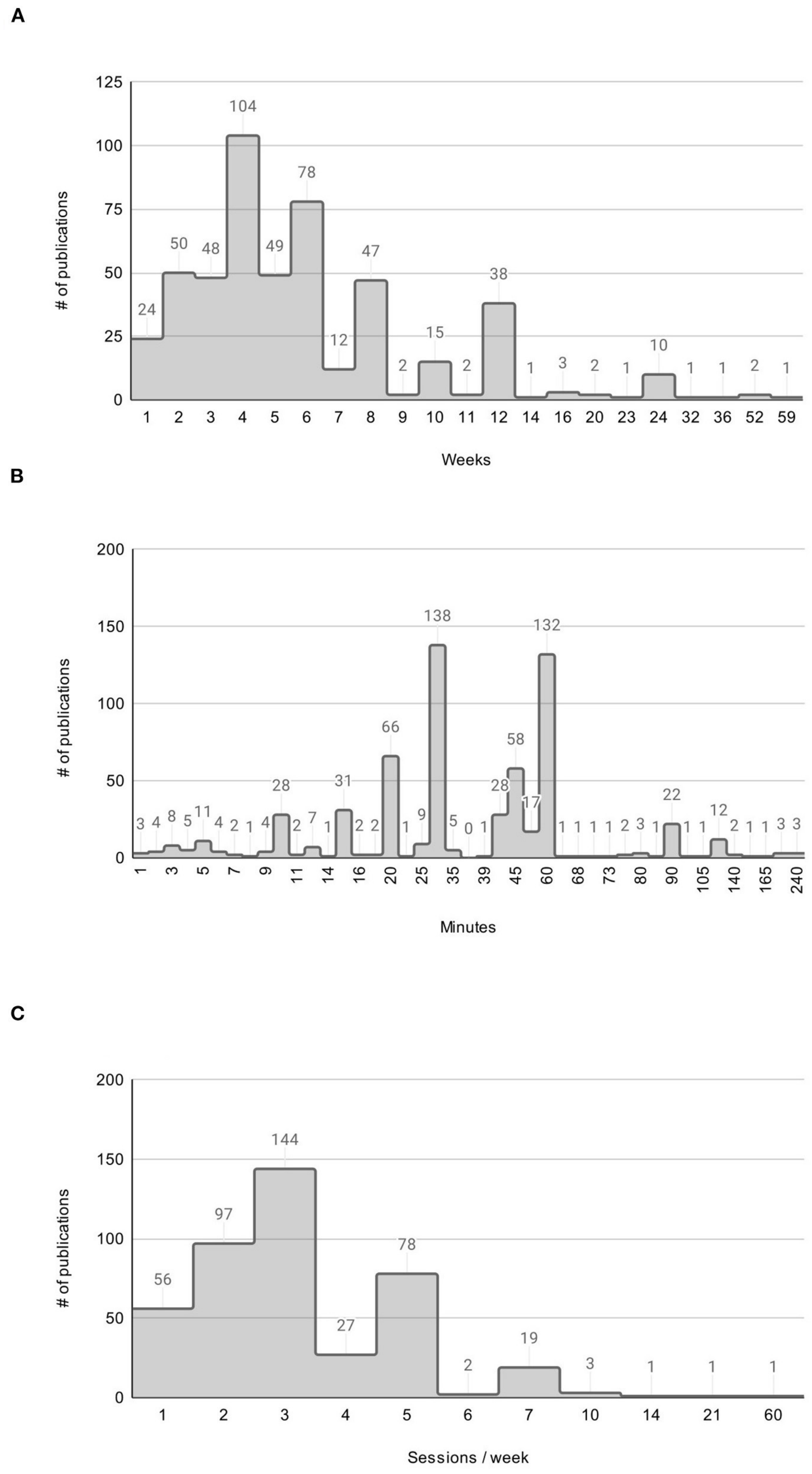

FIGURE 13
Distributions of **(A)** the duration of the interventions, **(B)** the session duration, and **(C)** the frequency of sessions in the revised studies.

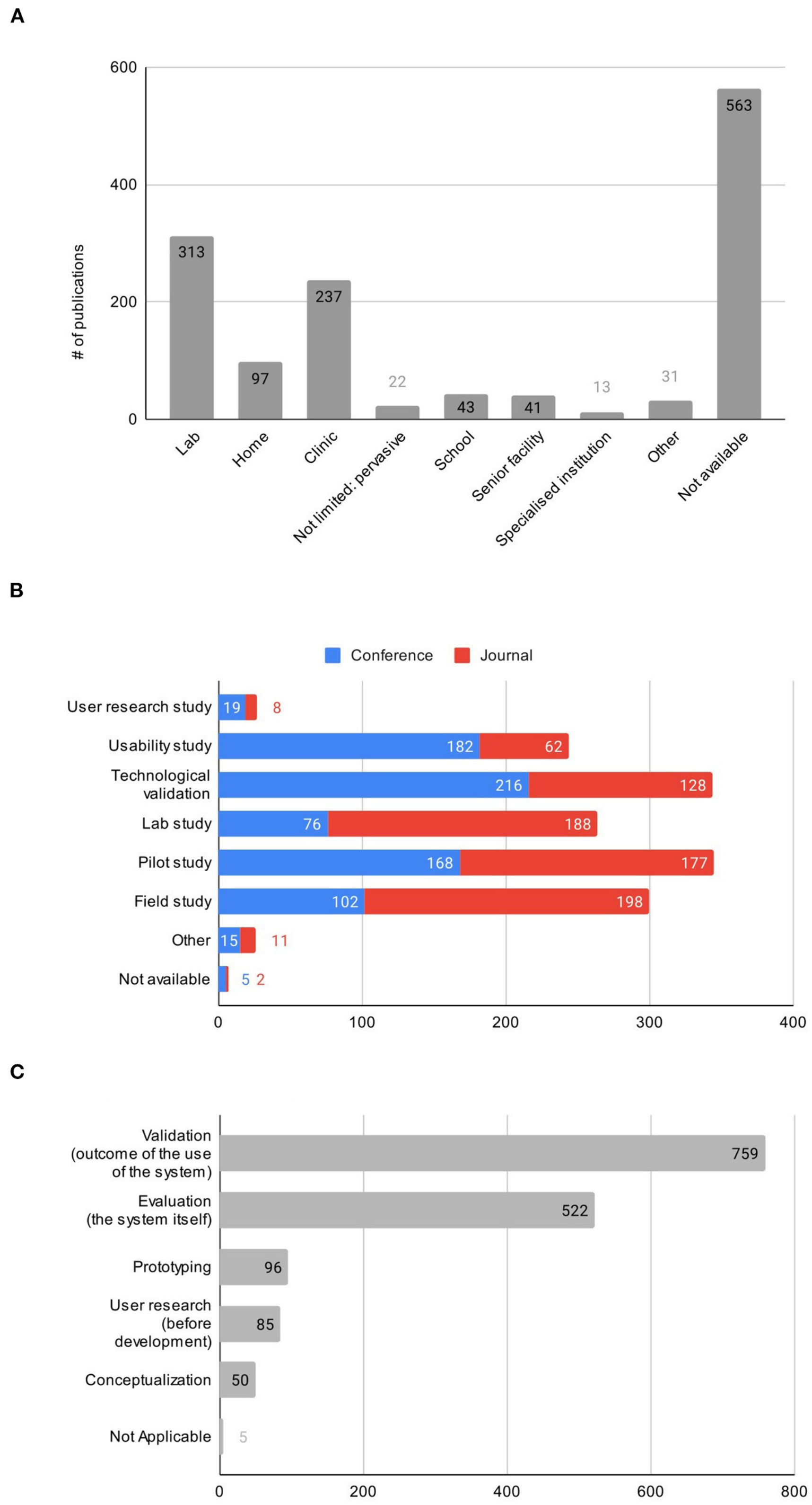

FIGURE 14
(A) Location, **(B)** type, and **(C)** purpose of studies.

show a 20-fold increase in publications between 2004 and 2017. Our results show that until 2012, contributions originated mainly from conferences, after which a decrease and inverted pattern is observed. This dip around the year 2012 has been previously reported by Lu and Kharrazi (2018). A study by Cipresso et al. (2018) also found similar trends in VR publications, where a scientometric study showed that until 2013, publication media on VR concerned both conference proceedings and journals, however, more recently, journals are the main venue for publication. Another interesting pattern is the repeated drop pattern in odd years, an oscillation that has also been observed in the results of other authors (Orji and Moffatt, 2018; Aldenaini et al., 2022) and that we attribute to the two of the most contributing conferences (the International Conference on Virtual Rehabilitation and the IEEE International Conference on Rehabilitation Robotics) taking place every 2 years. In terms of publication sources, our results show a top 25 percentile that consists only of a few conferences and journals (Table 2). Although our study differs in quantity, sources of information, and specific goals from that of Sardi et al. (2017), we would expect more overlapping with their results, but only one conference and one journal are also featured in our top 10: the IEEE International Conference on Serious Games and Applications for Health (SeGAH) and the Games for Health Journal, where only the latter is part of the 25 top percentile. The differences observed in comparison to the work of Sardi et al. (2017) may be explained by the specific focus of their work whose focus is solely on gamification. Furthermore, while we retrieved results solely from ACM DL, IEEE Explore and PubMed, Sardi et al. (2017) located their results also in Springer, Wiley Interscience, ScienceDirect, and Google Scholar databases.

4.2. Domains of intervention

The results of this review show that the great majority of the included studies were aimed at tackling motor, followed by cognitive concerns, where only a limited percentage of the studies focused on social or a multitude of domains. Results from previous reviews (Wattanasoontorn et al., 2013) report similar results when it comes to solutions targeting multiple domains, however, those same studies show an inverted tendency between motor and cognitive domains, where the cognitive domains prevail. The review by Wattanasoontorn et al. (2013) included research and commercial games. Our research shows that different technologies are used to address different concerns and that the terminologies used differ from area to area. For instance, in the area of Rehabilitation, the VR term is used to refer to both games and computer simulations, whereas games are preferred in the Health and Wellness application domain.

The results of this systematic review showed that the most frequent intervention health domains are stroke and fitness, results which align well with other previous studies that show chronic diseases and physical activity as the target of many gamification and serious games technologies (Sardi et al., 2017; Orji and Moffatt, 2018). Besides looking at the most frequent domains, our research also looked at the centrality of health topics, where results showed that Balance, Posture, Multiple Sclerosis and Dementia are the most central domains.

4.3. Technology-enabled solutions created

This systematic review shows that the vast majority of the digital solutions are aimed at patients, in particular those undergoing rehabilitation, followed by treatment and therapy. Looking at solutions for non-patients, most technology-mediated solutions fall under the health and wellness category. The results of our systematic review are concurrent with those of previous reviews on gamification and serious games in e-health (Sardi et al., 2017; Orji and Moffatt, 2018) that also reported on the prevalence of rehabilitation. However, they differ from the results of other studies such as those of Lu and Kharrazi (Lu and Kharrazi, 2018) who found most games were targeted at the healthy general public and Wattanasoontorn et al. (2013), who found most serious games were aimed at non-patients, with games for training professionals and for health and wellness games sharing expressive percentages. The fact that Wattanasoontorn et al. (2013) review included only serious games may explain these differences, as we identified that the VR terminology is more prevalent in the rehabilitation area. Interestingly enough, regardless of the different sources and number of studies reviewed, results show similar trends on technology used, where the computer is still the most common device used and consoles like the Wii, X-box/ Kinect are the most prevalent. The frequency of use of handheld devices observed by Wattanasoontorn et al. (2013) and Orji and Moffatt (2018) is less evident in our study, where these devices appear as much as robots and take second place to the typical computer or console-based setup. Looking at the presentation format and the users who can use the technology, we find similar trends to those of Wattanasoontorn et al. (2013) with regards to the presentation format, where both studies reveal that 3D is the most frequent format followed by 2D and a limited percentage of games combining the two, and, likewise, show that the vast majority of games is designed to be used by a single user and only a small percentage are designed to be multiplayer.

4.4. Types of studies

Our study found that studies rarely go beyond 12 weeks, where in most cases study duration is between 4 and 6 weeks, which shows that the long-term effects of the health entertainment interventions are not being assessed. Previous studies (Sardi et al., 2017) have found that study duration is different depending on the nature of the application, where typically gamification solutions may be assessed over 6 months (24 weeks), while serious games last only 2 months (8 weeks). We have not explored variability across study duration and nature of application, but this would be an interesting topic of research in the future. Despite the possible differences that we may find, for the majority of cases, the long-term impacts of the health entertainment technologies are not being measured, which exposes a limitation of the area.

Our results show that the participants of the studies are most often adults, a result that concurs with those of previous research (Orji and Moffatt, 2018). However, while Orji and Moffatt (2018) report that the sample rarely involves older adults, our results show that young seniors (50–64) and seniors (65–84) are the most frequent age range of the participants, which, if combined would actually surpass the numbers of studies where the participants fall under the adults age bracket (18–49).

Previous studies on the topic of persuasive technology found that only a very limited number of studies involved the target audience in their design (Orji and Moffatt, 2018). Likewise, our study shows that only very few articles (6.3%) report on the involvement of end-users in the design process, and 81.9% of the articles do not report the involvement of any stakeholder in the design of the technologies. This is consistent across most of the published work focussing on the evaluation and validation of technology, and only few reporting on the conceptualization phase (3.8%) or the user research (6.5%). This denotes a need for further research and specially publications in the areas prior to technology validation.

The most frequent sample size of the studies included in this review is 10, where the mean sample sizes for conferences is 39 and for journals is 48. There is however some variability, which could be linked to the specific type of study, where samples can reach over a thousand participants. Similar variability has been reported in a study on sample sizes within the CHI community (Caine, 2016), that found that the most common sample size is 12. In the future, it would be interesting to delve into these differences within our data and study whether different sample sizes are the norm for specific types of studies, for example among field study, experiment, and usability tests.

Studies generally report poorly on the specific methodologies used to recruit the sample. The large majority of studies (∼55%) does not report this information at all. From those that report it, convenience sampling is the most frequently used method followed by self-selection. This lack of systematicity in reporting the sampling strategies makes it difficult to critically analyse the results considering potential sampling biases and the generalization of the findings.

With this research, we have been able to ascertain that only a fraction of the studies used standardized or validated instruments. Still, it would be interesting to analyse which are the most common instruments and measurements used for the assessment and monitoring of the studies and which specific conditions these instruments are applied to. This warrants further research for which the data collection has already been done, but, due to time constraints, we have not been able to investigate.

5. Implications for future research and practice

Based on the results of this review, we identified specific gaps. Based on those gaps, we offer suggestions for improvement and moving the field forward:

- Less than 20% of the studies focus on user research (6.5%), conceptualization (3.8%), or prototyping (7.3%) stages of development of a solution. While we understand the importance of evaluating and validating solutions and that to some extent these phases are often associated with the end of a cycle, it is also important to produce accounts of the methodologies employed prior to evaluating a solution. In particular, these accounts could contribute a much-needed human-centered perspective to the development of digital solutions for health.
- Nearly half of the solutions, 46.7%, focus on rehabilitation, with treatment or therapy taking the next 26.4% slice of the categories we sought to organize following Wattanasoontorn et al. (2013) framework. More solutions developed with the purpose of health monitoring, detection, and education would enrich the community working on entertainment computing and persuasive technologies for health. These would be equally beneficial for society overall as these categories are the ones which focus on disease prevention.
- The studies targeted a wide range of specific domains of intervention, however when looking at the more general domains of application, results show that most studies target motor conditions. Considering a biopsychosocial approach to health, more research into cognitive and social/other domains would be vital to promote health and would contribute to advancing the field.
- While the literature provides tools to assess the usefulness and effectiveness of serious games (Graafland et al., 2014), the fragile quality of the studies is still a common critique in other systematic reviews (Bleakley et al., 2015; Holtz et al., 2018). This review equally exposed those limitations. Over 50% of the studies (671) included no details on the inclusion and/or exclusion criteria of participants. This is particularly surprising for journal articles, wherein a total of 688, 192 do not report on any inclusion and/or exclusion criteria. Likewise, only about 21% reported using standard validated measurement instruments in their studies. While we understand that custom-made instruments are necessary, we underline the need for research to use also validated instruments that allow for the necessary benchmarking of results across health interventions. Similar weaknesses were observed regarding the sampling methodology and the location of studies. We then stress the need for clear and detailed research reporting.
- The great majority of the papers included in this systematic review report on custom-made technology-enabled solutions, which not only indicates the potential that researchers perceive in solutions that embed entertainment in promoting health, but also may anticipate that an increase of solutions of this kind will meet the commercial market in the future.
- Studies included in this systematic report on different study durations that span from 1 to 59 weeks. Where the most frequent study durations are 4, 6, 8, and 12 weeks, if longer duration studies were to be the norm, it would allow for a more solid understanding of the effects and impacts of health interventions based on entertainment computing and persuasive technologies for

health; this would benefit researchers, practitioners and society overall.

6. Limitations

An important limitation of our work stems from the decalage between the dates of the works examined in this review and their time of publication. We have located articles published across 13 years, between January 2004 and December 2017, and examined the full-text of 1,307 articles. Still, at the rate at which technology advances and publications proliferate, a review of the works published since 2017 could possibly yield different results. It took five years to systematically scrutinize this high volume of studies, and as a result, there is now a hiatus that needs to be filled in by future research. While this was a herculean effort, we have found examples of other works which have required 2–3 years until publication. Examples of these are the review by Orji and Moffat in 2018 which inspected the full-text of 85 articles, and the review by Wang in 2021 which included 59 articles (Orji and Moffatt, 2018; Wang, 2021). In comparison, our review reports the findings of 1,307 articles. Besides the high volume of studies, which full-text we reviewed, and the fact that we were ambitious in terms of the wide time span we decided to cover, there are several reasons why a systematic review like ours was so demanding in terms of time, such as: the execution of exhaustive and comprehensive searches and the export of the results retrieved, the screening and selection of studies, and the systematic data extraction and analysis of the results to answer the research questions. Specially, this last step was extremely long in our case because we decided to analyse a vast number of data points. The fact that the authors are full-time lecturers managing difference research and academic commitments at the same time was also a challenge.

In our work, we did not look at the results by the domain of intervention, which is a limitation, especially when looking at data such as length of intervention, and duration and frequency of the sessions. While we did find that 4 weeks was the most common duration of intervention, that the most frequent session duration in minutes was 30 and 60, and that the most common frequency was 3 times a week, this may as well vary depending on the specific domain of application, as different health conditions require different healthcare practices.

7. Conclusions

This paper reports on a systematic review that summarizes the existing research regarding areas of entertainment computing and persuasive technologies for health. From an initial set of 10,350 papers retrieved from three main publication sources, 1,307 papers were included for full-text assessment. Four research questions guided the systematic review of these papers to identify publication trends, domains of intervention, technology-enabled solutions created, and types of studies. In answering RQ1, it was found that the field of entertainment computing and persuasive technologies for health has met a steady overall increase over the years, where a 20-fold increase in publications can be observed between 2004 and 2017. However, rising trends do not show the same pattern in journal and conference publications, where a decrease in numbers occurred between 2013 and 2015 for conferences, but not journals. With regards to the venues of publications, more papers are published in journals than in conferences, in the top 25 percentile concentrated in seven journals and two conferences.

In answering RQ2, results show that with regard to the general domain of intervention, most contributions in the field go toward motor and cognitive domains. Among the huge diversity of intervention domains, this systematic review shows that Balance, Posture, Multiple Sclerosis and Dementia are the most central domains and Stroke, Fitness and Balance are the domains where the most co-occurrences exist. Balance is the most transversal intervention domain, and Stroke and Fitness are the most frequent ones.

In addressing RQ3, it was found that rehabilitation is the most prevalent purpose of technology-enabled solutions developed in the areas of entertainment computing and persuasive technologies for health, followed by treatment and therapy, and health and wellness. Areas such as health monitoring, detection and education are a lot less common and the contributions to training residual. The digital solutions used to support those purposes are introduced by the authors as belonging in the VR category, where games and gamification are the most frequent type of approach employed, followed by simulations and coach/trainer applications. Results also show that simulations are predominantly published in journals while coach/trainer systems emerge from conferences papers. This systematic review also revealed that only a minority of papers report on features such as adaptability and type of feedback provided to the user. Still, among the studies that report on those features, 34% report on some sort of adaptability or customization, 31% on the knowledge of the results, and 41% on the knowledge of performance. Our systematic review also revealed that nearly half of the solutions reported in the articles are custom-made (46%) and only 24% stated using commercial solutions, of which 92% resort to game consoles such as the Wii in ∼60% of the cases, followed by the X-box with ∼20%, and the Play Station with about ∼10%. The most frequent devices used in entertainment technologies for health are computer-based and resort to movement and physiological sensors.

Finally, synthesizing the findings of RQ4, it was found that the great majority of the studies reported in the papers were carried out with the purpose of validating the outcome of the use of the system, followed by the evaluation of the system itself, while only a very small percentage of studies focus on the user research, conceptualization, and prototyping phases. In addition, there is an inverted tendency for evaluation and validation, studies on the validation of the system typically belong in journal papers and evaluation on conferences. Usually, study participants include the target population; this was the case for 82% of the studies, in relation to 15% that did not and 3% that did not report on this information. Median sample size is 48 for journals and 30 for conferences, where both journals and conference papers have kept their median sample sizes over time, with a slight tendency for an increase on journal publications. The sampling method is rarely explicitly disclosed, yet when reported, it is mostly convenience or based on participants volunteering to participate.

In most cases, no information is provided on the duration of the interventions, the session duration, and the frequency of sessions, still, when it does, the most frequent duration of the interventions is 4 weeks and durations beyond 12 weeks very rare, session duration is typically 30 and 60 min, and the most common frequency is 3 sessions per week. Studies typically take place at a lab or clinic, but also at home, but most studies fail to report on the study settings. Studies are also largely omissive into what concerns inclusion and exclusion criteria, where only ∼50% report on these. With regards to assessment instruments, only about 20% of the studies report using validated measurement instruments.

Author contributions

PS and SB defined the review methodology and analyzed the data. All authors analyzed the papers, interpreted the results, revised, and approved the current version of this manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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