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A rapid review of serious games:

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K.Sipiyaruk[1,2], J.E.Gallagher[1], S.Hatzipanagos[3], P.A.Reynolds[4]

[1]*King's College London Dental Institute, Denmark Hill Campus, Bessemer Road, London SE5 9RW, UK*

[2]*Faculty of Dentistry, Mahidol University, 6 Yothi Road, Bangkok 10400, Thailand*

[3]*Graduate School, University of West London, London W5 5RF, UK*

[4]*King's College London Dental Institute, Central Office, Floor 18 Tower Wing, Guy's Hospital, St Thomas's St, London SE1 9RT, UK*

Corresponding author:

Kawin Sipiyaruk

E-mail addresses: kawin.sipiyaruk@kcl.ac.uk, kawin.sipiyaruk@gmail.com

Telephone number: +442032995171

Fax number: +442032994074

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Abstract

Introduction: Games involving technology have the potential to enhance hand-eye coordination and decision-making skills. As a result, game characteristics have been applied to education and training, where they are known as serious games. There is an increase in the volume of literature on serious games in healthcare education; however, evidence on their impact is still ambiguous.

Aims: The aims of this study were (1), to identify high-quality evidence (systematic reviews or meta-analyses) regarding impacts of serious games on healthcare education; and (2), to explore evidence regarding impacts of serious games in dental education.

Methods: A rapid review of the literature was undertaken to synthesise available evidence and examine serious games in healthcare education (Stage 1) and dental education (Stage 2).

Results: Nine systematic reviews were included in Stage 1, four of which were of high, three of moderate, and two of low quality. For Stage 2, two randomised control trials with moderate quality were included. The findings demonstrated that serious games are potentially effective learning tools in terms of knowledge and skills improvement, although outcomes of serious games over traditional learning approaches were not consistent. In addition, serious games appeared to be more engaging and satisfying for students, which could be considered as the most important positive impact.

Conclusion: Serious games provide an option for healthcare and dental education but remain under-utilised and researched. At best, they offer a similar experience to other methods in relation to educational outcome; however, they can provide a supplementary strategy to engage students and improve learner satisfaction.

Introduction

21st century students currently spend a significant amount of time on video games (1-3). By employing advanced technologies, video games can create an immersive and engaging environment for players. Concerns on how long children should spend on gaming activity as well as concerns about their content (for instance violence) have been raised, Additionally, users are able to play video games anywhere and anytime due to the availability of various gaming platforms. In education, video games can create an interactive learning environment (3). When playing a game, learners need to make decisions on how to achieve a game goal, but usually they are not able to complete a game task with the first attempt. Following failure, they need to reconsider their strategies in order to complete the game; this learning process is known as the role of failure (4). Therefore, students have the potential to learn in the interactive environment of video games.

Games also have the potential to enhance hand-eye coordination and decision-making skills (5-7). The concept of gaming has been applied to education and training, rather than merely for entertainment purposes, resulting in what is known as 'serious games'. Compared with traditional approaches, they can create interactive learning environments, which can engage learners to improve their knowledge or skills increasing motivation (8-10). This approach consequently has been applied to education and training in various fields, such as the military, engineering, computing, health, and education (11, 12). In healthcare education, research in medical and nursing education found positive attitudes of students towards computer games and technology-enhanced learning (13, 14). Therefore, serious games should be an option in education and training for healthcare professionals and students.

Given the significance of this emerging area of dental education, it is important to systematically review the wider health care literature as well as looking at dentistry in particular. Consequently, the aims of this study are:

1) to identify high-quality evidence (systematic reviews or meta-analyses) regarding the impact of serious games on healthcare education; and,

2) to explore empirical evidence (with any level of quality) regarding impact of serious games on dental education.

Methods

Stage 1: Serious games in healthcare education

Study design

This stage employed a rapid review methodology to synthesise the evidence from articles that focused on serious games in healthcare education. A rapid review, conceptualised by Khangura et al. (15), is a technique for synthesis of evidence for a comprehensive or systematic search of the literature, but it requires a shorter timeframe, compared with traditional systematic approaches. This approach gives priority to evidence from systematic reviews (15).

Criteria for including articles in this stage

Articles were included if they were systematic reviews and/or meta-analyses and evaluated outcomes of serious games in healthcare education, designed for learning and training of undergraduate or postgraduate students or qualified professionals in healthcare areas (involving patient care) from individual level to population level. The rapid review excluded systematic reviews relevant to the impact of video game use or video game experience on healthcare education. If an included systematic review evaluated impact of both serious games and video games, only the outcomes of serious games would be considered. The outcomes of the investigation were categorised according to knowledge gain, skill development, attitude improvement towards learning topics, and satisfaction with the use of serious games. Inclusion and exclusion criteria are summarised in Table 1.

Search methods

The search terms were refined based on literature review, medical subject headings (MeSH), group discussions, and iterative searches (Table 1). The search was performed by one researcher (KS), but it was verified afterwards by two researchers (SH and PR) to reduce a selection bias. The last search was performed in June 2016 using ten databases: Embase, Medline, PsychInfo, PubMed, CINAHL, ERIC, British Education Index, British Nursing Index, Scopus, and the Cochrane Database of Systematic Reviews. The literature search included areas of healthcare, technology, and social science, to assure that as many as possible of relevant articles were identified. The searches were limited to articles published between 2005 and 2016.

Data extraction

The information extracted from each article included author, year, aims of studies reviewed, type of interventions, methods of studies included, results, authors' conclusion, and quality of each systematic review (Table 2).

Quality appraisal

The quality of each systematic review was assessed using the AMSTAR checklist (16) as 'high' if it achieved a score between eight and eleven, 'moderate' if five and seven, and 'low' if it achieved a score between zero and four (17, 18).

Stage 2: The use of serious games in dental education

Study design

When systematic reviews are not available, a rapid review can include other types of studies. We employed a similar methodology to the one used in Stage 1 for this stage, in addition to including empirical studies, focusing on computer-based serious games for undergraduate or

postgraduate students as well as qualified professionals in dental education. Similar to the first stage, this review excluded studies which is relevant to only the impact of video game use or video game experience. The inclusion and exclusion criteria are summarised in Table 1.

This stage involved the same databases as before with the exclusion of British Nursing Index and inclusion of ProQuest Dissertations & Theses to ensure any unpublished research was included. Search terms for this stage are presented in Table 1. The last search was performed in July 2016. This review limited the searches to articles published between 1975 and 2016.

The information extracted from each study included author, year, aims, characteristics of interventions, methods, results, authors' conclusion, and quality of each study (Table 3). To assess the quality of included studies, the Medical Education Research Study Quality Instrument (MERQSI) was employed, which is an instrument for measuring "the quality of experimental, quasi-experimental, and observational studies (19)". MERQSI was considered to be appropriate, as it covers any non-qualitative research study (20).

Results

Stage 1: Serious games in healthcare education

Literature identified

The initial search across ten databases identified 483 articles. After removal of 238 duplicate papers, titles and abstracts of 245 items were reviewed to assess whether these were systematic reviews and relevant to serious games for training or educating healthcare students or professionals. Based on the information provided in titles and abstracts, 225 articles were excluded, 20 papers were accessed in full-text, of which 11 were excluded following further review: two were not available in English; one was not a systematic review; three were protocols of systematic reviews; one was an older version with a recent update; two did not contain findings on the impact of serious games; one systematic review did not focus only on serious games but included simulations/virtual reality studies, without identifying in the outcomes which was which; and one article reviewed serious games for health improvement rather than training or education. Consequently, a total of nine systematic reviews were included. This information is presented in a PRISMA flow diagram (Figure 1).

Figure 1

Quality of the literature

Four systematic reviews were of 'high' quality based on the AMSTAR scoring system (21-24); three of 'moderate' (25-27); and two of 'low' quality (28, 29). Most common missing scores were for 'a priori design' and 'assessment of publication bias'. According to the AMSTAR checklists, a review should define a research question and inclusion criteria before conducting the review, and publication bias should be assessed including a combination of graphical aids and/or statistical tests (16).

Overview of the included systematic reviews

All systematic reviews aimed to review the use of serious games for healthcare professionals. However, four reviews focused on serious games for particular fields in healthcare education, e.g. for mental health education (21), medical education (22, 26), or for geriatric medicine (23). From included studies, whilst three of the reviews included only computer-based serious games (26-28), five included only non-computer-based serious games, e.g. card games, board games, or interactive team quizzes (21, 23-25, 29), and one included both computer-based and non-computer-based formats (22).

Of the nine papers included, four systematic reviews included only experimental studies, of which three included only randomised control trials (RCTs), while one included controlled parallel-arm clinical trials (CCTs) in addition to RCTs; the others included different types of study designs.

Outcomes of serious games

Assessed outcomes included knowledge improvement, knowledge retention, skills development, attitude improvement towards the subject of the game and positive attitudes towards the use of serious games.

Knowledge improvement and retention

Knowledge improvement was the most common outcome (21-25, 29), especially in the systematic reviews that included RCTs, comparing serious games and traditional approaches or no intervention. This outcome was evaluated using post-knowledge assessment or both pre- and post-knowledge assessment. The post-interaction assessment was immediate or delayed assessment (for instance after 3 or 6 months) and was used to evaluate knowledge improvement and knowledge retention.

No consistent outcome of knowledge improvement was reported in the systematic reviews. For example, Bhoopathi and Sheoran (21) found that the average post-test score was higher in the game group; in addition, in the review of Akl et al. (22), three studies supported the claim that games had positive effect over traditional approaches or no intervention, but one study in this review reported no difference between the two groups, and the post-test score was higher than the pre-test score in both groups. Likewise, two systematic reviews suggested there was no difference between the two groups (23, 24). Abdulmajed et al. (29) reviewed the use of table-top games and reported that knowledge improvement was found, also suggesting that one strength of educational games over traditional teaching approaches was to create interactive learning by providing immediate feedback to students and tutors, allowing them to explore how much students understood. Blakely et al. (25) also reported that evidence of knowledge improvement was not consistent in their systematic review. In conclusion, despite the inconsistency of evidence to support the effectiveness of serious games over traditional learning approaches, serious games had a positive effect on knowledge improvement, supported by three reviews of mix quality evidence (21, 25, 29).

Two systematic reviews reported an outcome of knowledge retention. Akl et al. (24) reported that one study demonstrated that knowledge retention in the game group was significantly enhanced in relation to the control group. This finding was in accordance with four studies included in the review of Blakely et al. (25); however, three studies included in Blakely et al. (25), reported that there was no significant difference between

the two groups. Similar to the knowledge improvement, evidence to support this argument was inconsistent, but it could be suggested that serious games seemed to be effective in term of knowledge retention, at least at the same level as traditional learning approaches, according to two reviews, of which one is high quality (24), and one is moderate quality (25).

Skills development

Only two systematic reviews investigated the use of serious games for training in medical skills, and studies of simulations were excluded. The aim of the first study was to review serious games for training professionals in the medical and the surgical fields (26). Graafland et al. (26) claimed that serious games could create training environments to train healthcare professionals in multitasking or teamwork. Serious games could also be beneficial for error reduction in clinical practice for team training to handle crisis situations. Wang et al. (27) included different types of studies regarding serious games for medical skill training. Evidence to support serious games over traditional methods was neither refuted nor confirmed. However, according to two reviews of moderate quality evidence (26, 27), serious games could be used for skill training in medical fields, as skills were improved after completing serious games.

Attitude improvement towards learning topics

Two reviews found attitude improvement after completing the games. In the review of Alfarah et al. (23), none of the eight included studies found significant differences in attitude improvement between the test and control groups. Although one of those reviews reported significant attitude improvement and attitude score was higher in the intervention group, this review did not report whether there was statistically significant difference between two groups. Akl et al. (22) also included one study reporting that attitudes towards confidence to deal with handicapped children were not different amongst game group, traditional approach, and no intervention. Therefore, it can be concluded that serious games were as effective as traditional learning approaches, as supported by two reviews of high quality (22, 23).

Positive attitudes towards the use of serious games

More than a half of included systematic reviews evaluated satisfaction with the games. In the review of Blakely et al. (25), nine studies evaluated this outcome, using questionnaires as the most common technique. It seemed that there was a positive effect of serious games in terms of enjoyment, although one study reported negative written feedback. Learners were motivated and reinforced to learn through the aspects of fun and competition of serious games (25). Akl et al. (22) included one study reporting the satisfaction ratings were higher in the game group compared to the group that attended a traditional teaching session. Alfarah et al. (23) evaluated this outcome and found high levels of satisfaction among participants. Akl et al. (24) reviewed the use of serious games for qualified healthcare professionals and found that the game-based group had higher proportions of participants, compared to the control group, who agreed that they enjoyed the event, demonstrated high level of attention throughout the event, and would register for this kind of event again in the future. Elements of serious games to engage players could be entertainment and competition (28). Compared with traditional learning approaches, learners seemed to be more satisfied with serious games, and this outcome could be considered as the main strength of game-based learning, derived from five reviews, of which three are high (22-24), one moderate (25), and one low quality (28).

Limitations of serious game use in healthcare education

In the review conducted by Graafland et al. (26), there was a discussion of the limitations of serious games, requiring high development costs. As serious games had supported healthcare professionals to provide better patient care with minimal error, insurance companies could have a key role in supporting the game development. The review also recommended that there should be development of a basic game structure, where content could be uploaded by different departments. This would promote a wide use of serious games with low additional development costs.

Stage 2: The use of serious games in dental education

Literature identified

The initial search across ten databases identified 496 articles. After removal of 268 duplicates, titles and abstracts of 228 items were reviewed to identify whether they were relevant to the use of serious games for training or educating dental students or professionals. Based on information provided in titles and abstracts, 203 articles were excluded based on the exclusion criteria. This process resulted in 26 articles to be accessed in full-text, of which 24 were excluded following further review: three were abstracts only; four were not describing details of any serious game; three were not relevant to serious games; six were studies of non-computer-based serious games; two examined interventions which were not considered serious games; two studied serious games which were not specific to dental learners; and, one did not present the impact of the serious games. Consequently, only two empirical studies were included in the analysis. This information is presented in a PRISMA flow diagram (Figure 2).

Figure 2

Quality of the literature

The two included papers were appraised using MERQSI and assessed as moderate quality (Table 3).

Overview of the literature

Both included studies evaluated serious games amongst pre-clinical undergraduate dental students. The first, by Amer et al. (30), involved a serious game for teaching dentine bonding to first year dental students, which constitutes basic knowledge for composite resin filling in operative dentistry. The second by Hannig et al. (31), assessed Skills-O-Mat, a serious game for training in mixing alginate for dental impression, which is a mandatory skill for dental care; the participants being second year dental students.

Both studies were performed using randomised control trials, comparing between serious games (test group) and traditional learning style (control group). The usability questionnaire was provided after the use of serious games in both studies. Moreover, both studies assessed the serious games using pre- and post-evaluation questionnaires. Amer et al. (30) assigned knowledge tests, whereas self-evaluation questionnaires were used by Hannig et al. (31). In addition, Amer et al. (30) assigned a dentine bonding exercise to assess students' performance, requiring all students to bond a composite resin to extracted human teeth.

Outcomes of serious games

Knowledge and skill improvement

In the dentine bonding study (29), students' knowledge was evaluated before and after completing the game or watching a traditional video tutorial; the study reported no significant differences between the experimental and control groups in the scores of pre-test, post-test, and distribution difference scores. There were no significant differences reported between the pre-test and post-test scores; however, it was reported that the means of post-test scores increased by 2.07 and 1.54 (10 in total) in the control and game groups respectively. In addition, a practical examination was conducted to evaluate knowledge and performance of students. The examination was not a procedure in clinical or simulation-based environment, but students were required to bond a button of composite resin to dentine of an extracted human tooth, whose shear bond strength was assessed using a shear bond tester. The study found no significant difference between the two groups.

Instead of knowledge tests, Hannig et al. (31) assigned self-report evaluation tests (pre- and post-evaluations), assessing whether the learning process was supported by the game, and found that the post-evaluation was significantly better than the pre- evaluation in both control and experimental groups. They also found that the students from the game group learned more than the students in the control group. The score of the pre-test was higher in the control group, compared with the experimental group (except for one question), but the post-test scores were not much different between two groups, which were close to the top of the scale. However, no statistical test of the score improvements (difference between pre-and post-evaluations) was reported between the experimental and control groups.

Overall, two studies of moderate quality suggest that serious games are potentially effective learning tools for dental education. According to the included studies, there is evidence that students can gain knowledge or confidence in the subject areas, learnt from the games, at least at the same level when using traditional learning approaches.

Satisfaction in the use of serious games

The students who participated in game groups from both studies were asked to complete feedback questionnaires after game completion. According to the study of Amer et al. (30), students were satisfied with the dentine bonding game. They enjoyed using the game and believed that it could help them maintain interest in the topic. However, students disagreed with the complete replacement of the face-to-face session with a game. Likewise, Hannig et al. (31), reported high rating towards the game usability from the feedback questionnaire. Samples of positive feedback reported motivation, suitable learning atmosphere, humour, feedback, and incidental learning. In addition, oral feedback from six participants suggested that the rhythm of game music supported participants to learn the motion of alginate mixing and the accompanying music enhanced the motivation of the students. Overall, learners reported they were satisfied with the game-based learning approach.

Discussion

Differences in search methods between the two stages

Types of studies included in the two stages were different. A rapid review approach gives priority to evidence from systematic reviews, however it can include other types of studies if systematic reviews are not available (15). The wider review of healthcare included only systematic reviews over a shorter time frame, whilst the dental review comprised only empirical studies over a 41-year period because of the paucity of dental research in this field. 2016). Furthermore, the systematic reviews, drew on earlier published research. For instance, the systematic review of Akl

et al. (22) included a study published in 1985. The second stage included only empirical studies, therefore the searches were expanded to 41 years in order to achieve the comprehensive inclusion. In addition, whilst the second stage included only computer-based serious games, the first stage evaluated non-computer-based and computer-based games because both types were evaluated in the included systematic reviews.

The use of serious games in healthcare and dental education

The first part of the paper identified several systematic reviews of studies regarding the use of serious games in healthcare education, covering several sub-disciplines. However, there was no meta-analysis available in this area. Also, only a few serious games used by dental students were included. Akl et al. (22) included one dental educational game study, but it was a non-computer-based serious game. Another systematic review performed by Wang et al. (27) included a study of two computer-based quiz games for pathology. Quiz games are games designed to test the knowledge of the players by rewarding (32), players who can successfully answer a question (33). Therefore, both games were categorised as quiz games, as students were required to provide correct answers to various formats of questions (multiple choice, fill-in-the-blank, or matching) in order to proceed in the games. The games were designed for medical education, not specifically for dental education, although they could be used by both medical and dental students. Interestingly, no computer-based serious games designed specifically for dental education were included in any of the systematic reviews that were selected in Stage 1. A possible reason was that those systematic reviews focused on the use of serious games for medical or healthcare education, and the terms "dental" or "dentist*" were not included in searches in those systematic reviews. Therefore, the second stage was performed to explore the impact of computer-based serious games in dental education. Compared to medical education, the use of serious game seemed less popular in dental education. In addition, this review focused on only computer-based serious games specifically used for dental learners. Two randomised control trials of serious games for pre-clinical dentistry were identified during this review. Although both studies were about pre-clinical topics, they were important because they focused on learners acquiring pre-requisite skills in clinical practices.

Outcomes of serious games

Both stages of this rapid review found that the most common evaluated outcome was knowledge improvement, and serious games seemed effective for this outcome. This finding is concurrent to the study of Connolly et al. (34), which systematically reviewed the use of computer games and serious games. Our review also suggests that serious games could improve knowledge and skills of healthcare students or professionals. However, evidence supporting the effectiveness of serious games over the traditional approaches for these outcomes is not consistent.

Another important outcome is that serious games can motivate learners. Our review indicates that serious games could engage users within learning or training through entertainment and competition elements. This coincides with the definition of serious games by Michael and Chen (35) that entertainment is not a main purpose of serious games, but it does not mean that there is no entertaining element in serious games. Kron et al. (13) and Lynch-Sauer et al. (14) surveyed medical and nursing students respectively, and both studies reported students were interested in the use of serious games. Therefore, serious games should be applied to healthcare education due to their ability to engage and motivate learners in an interactive environment.

Our findings indicate that engaging and entertaining aspects of serious games are important and have impact on knowledge gain. According to the 'Input-Process-Outcome Game' model (36), there is a repetition of a process, where a learner needs to make a decision and provide an input to the game. After that, feedback is provided, where learners need to reconsider their strategies or answers to finish a game task. In other words, learners can learn from their unsuccessful input. 'Failure' in games is not 'failure', but is a gaming process to improve users' competencies, known as the 'role of failure' (4, 37). However, to achieve this process, serious games need motivation to engage users with the game. According to the included articles, both dental serious games seemed to be engaging, as presented in the results. This could support learning activities and knowledge gain was found in both games. The provision of immediate feedback is another strength of serious games, as they provide an opportunity for

leaners to know the outcomes or results of their choices and decisions immediately, so they can learn and improve their strategies without a long gap between submission and feedback.

Online learning environments within serious games

Another benefit of serious games for healthcare education is that they can create safe learning environments, where students can learn and practise their skills and knowledge (25). In addition, students can practise repetitively within serious games without additional cost of materials. Amer et al. (30) discussed that students need to perform repetitive sequential steps to have proper knowledge for performing dentine bonding. Therefore, the dentine bonding game enables students to repetitively perform the procedure without using dentine bonding materials. Although this game seems to improve only cognitive skill, it is acceptable, as Amer et al. (30) suggest that high psychomotor skills are not required for this performance.

Overcoming limitations of serious games and future action

Despite the educational value of serious games in healthcare education, there were several limitations reported in their use. Serious game development involves a large amount of resources. Cost and time are required to create serious games (38). Previous studies recommend that there should be a development of a basic game structure as a platform for a wider use, where learning content could be uploaded by different institutions and departments, and therefore an investment for additional development could be lessened. Serious games could be beneficial in the long term, as they could simulate learning environments, which are difficult to learn or practise in real situations due to resource and time constraints (39), such as training for surgical operations or dental public health. Whilst healthcare learners seemed to have positive attitudes towards the use of video games in education (13, 14), faculty members might not do so, as they might have views towards the use of games to learners (1, 2), however

there is no clear supporting argument (40). In addition, there were surveys reporting that academic staff seemed to have positive perceptions towards the use of digital games in education (41, 42).

Limitations of this review

One of the limitations in the first stage of this review was that it gathered findings and suggestions from systematic review articles to synthesise and summarise the outcomes of serious games. Therefore, a quantitative analysis could not be performed. Another limitation was that not many systematic reviews with high quality methods were available. The quality of included systematic reviews for Stage 1 is considered as acceptable, as four of them were considered as high quality, while only two systematic reviews were assessed as low quality. Moreover, both non-computer-based and computer-based serious games, were included in this rapid review. Therefore, more systematic reviews of high quality in this field are needed. Visualisation should also be considered; a three-dimensional virtual learning environment appears to be more effective than a two-dimensional one in performance and preference of students (43). Therefore, a systematic review including only studies of two- or three-dimensional serious games can be useful in this field.

According to the second stage, there was a limitation in a number of serious games for dental education, especially studies with an empirical study design. Regarding the quality of included studies, the average score of included article is 11.25, which is higher than the score of 10.5 in the systematic review of Wang et al. (27) and the score of 9.95 in the study of Reed et al. (19), who calculated this score from 210 medical education research studies. Although the score is higher than other studies, it can be argued that it is because only RCTs were included in this stage. Therefore, there is a need of high quality research in dental education for both pre-clinical and clinical dentistry.

Conclusions

Evidence from this review supports the claim that serious games are as effective as other more traditional learning and teaching methods. In addition, learners tend to be more engaged with the game format. However, the evidence does not appear to support a complete replacement of traditional teaching approaches with serious games. Although more trials are required to compare serious games to other learning approaches, the idea of using serious games as supplemental tools to traditional learning formats should also be taken into consideration. Further studies should focus on comparisons between impact of serious games and traditional learning approaches, and they should also investigate how to design an effective serious game as well as how to implement it in healthcare education, including dental education.

In conclusion, whilst serious games are increasingly being used in healthcare education, they have not been widely used in dental education. There is limited evidence that serious games are effective learning/training tools to improve knowledge and skills in interactive learning environments in healthcare and dental education, and evidence to support their effectiveness over traditional learning approaches is equivocal. However, there is evidence that serious games can engage students and improve learner experience. Further research in this field is recommended.

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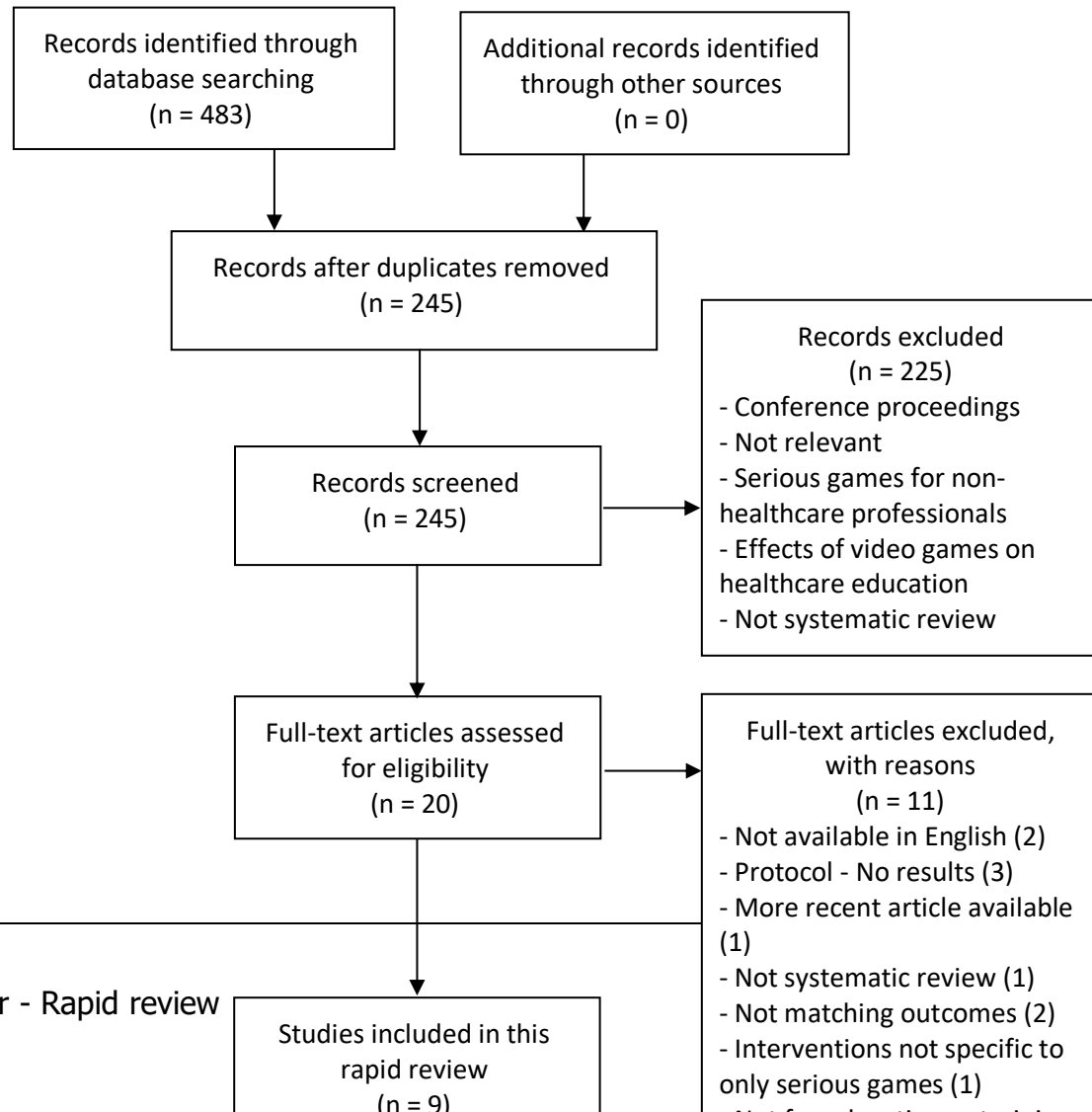
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PRISMA 2009 Flow Diagram

```
┌─────────────────────────────┐   ┌─────────────────────────────┐
│ Records identified through  │   │ Additional records identified│
│    database searching       │   │   through other sources     │
│        (n = 483)            │   │        (n = 0)              │
└─────────────────────────────┘   └─────────────────────────────┘
                │                               │
                └───────────────┬───────────────┘
                                ▼
            ┌─────────────────────────────────┐
            │ Records after duplicates removed │
            │           (n = 245)             │
            └─────────────────────────────────┘
                                │
                                ▼
            ┌──────────────────────┐      ┌─────────────────────────────┐
            │  Records screened    │      │ Records excluded            │
            │     (n = 245)        │─────▶│      (n = 225)              │
            │                      │      │ - Conference proceedings    │
            └──────────────────────┘      │ - Not relevant              │
                                          │ - Serious games for non-    │
                                          │ healthcare professionals    │
                                          │ - Effects of video games on │
                                          │ healthcare education        │
                                          │ - Not systematic review     │
                                          └─────────────────────────────┘
                                │
                                ▼
            ┌──────────────────────┐      ┌─────────────────────────────┐
            │ Full-text articles   │      │ Full-text articles excluded,│
            │ assessed for         │      │     with reasons            │
            │ eligibility          │─────▶│       (n = 11)             │
            │     (n = 20)         │      │ - Not available in English (2)│
            └──────────────────────┘      │ - Protocol - No results (3) │
                                          │ - More recent article available│
                                          │ (1)                         │
                                          │ - Not systematic review (1) │
                                          │ - Not matching outcomes (2) │
                                          │ - Interventions not specific to│
                                          │ only serious games (1)      │
                                          └─────────────────────────────┘
                                │
                                ▼
            ┌──────────────────────┐
            │ Studies included in  │
            │    this rapid review │
            │       (n = 9)        │
            └──────────────────────┘
```

Paper - Rapid review

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Figure 1: PRISMA diagram presenting the article selection process for Stage 1

PRISMA 2009 Flow Diagram

Records identified through
database searching
(n = 496)

Additional records identified
through other sources
(n = 0)

Records after duplicates removed
(n = 228)

Records excluded
(n = 203)
- Effects of video games on
healthcare education
- Not relevant to serious games
- Interventions for pain or
anxiety reduction
- Interventions for
rehabilitation or educating
non-healthcare professionals

Records screened
(n = 228)

Full-text articles assessed
for eligibility
(n = 26)

Full-text articles excluded,
with reasons (n = 24)
- Not available in English (2)
- Not available in full-texts (3)
- Not relevant to serious games
(3)
- Not being considered as
serious games (2)
- Non-computer-based serious
games (6)
- Not serious games for dental
education (2)

Studies included in this
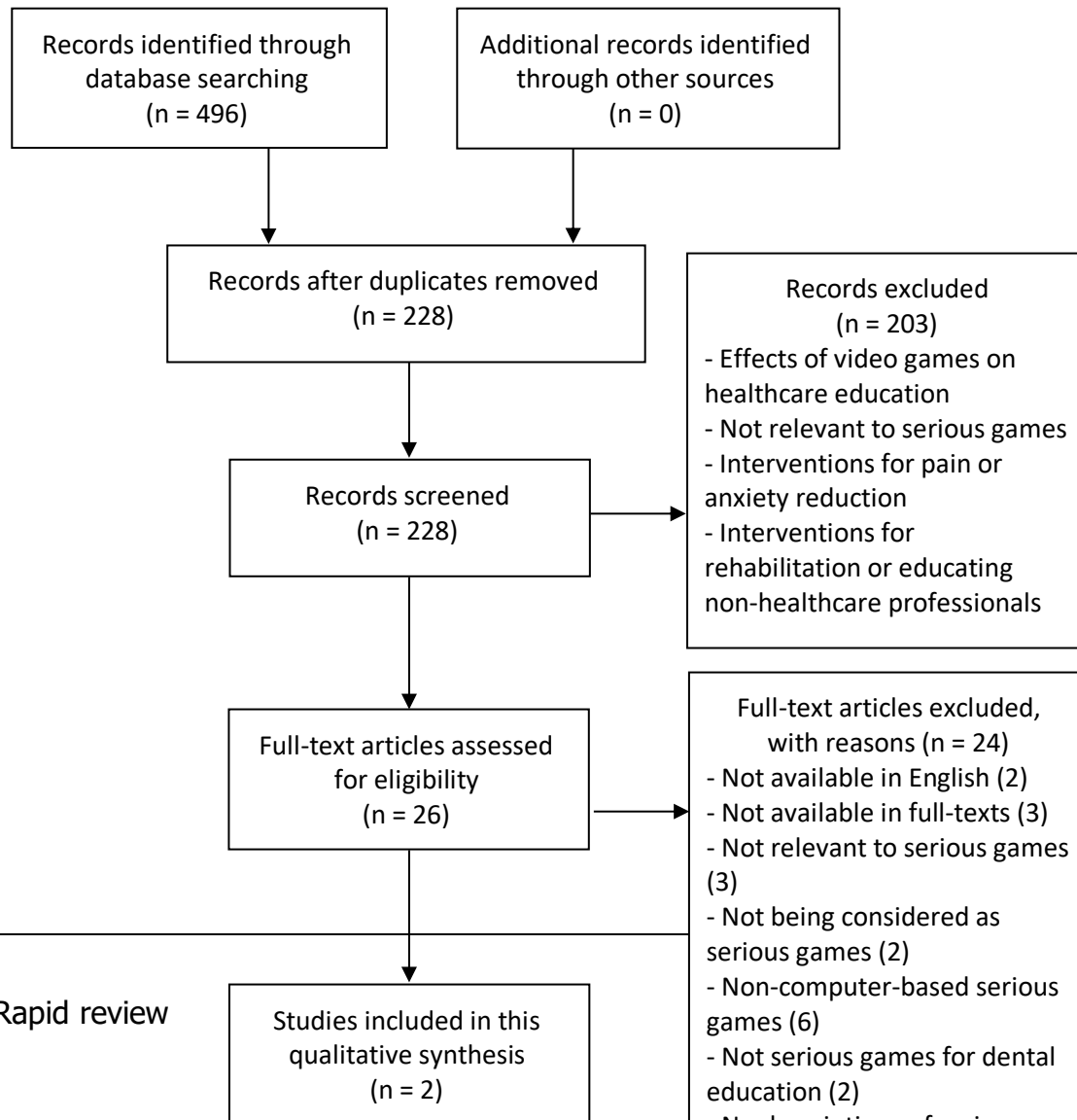qualitative synthesis
(n = 2)

Figure 2: PRISMA diagram presenting the article selection process for Stage 2

Table 1: Search terms as well as inclusion and exclusion criteria for reviews of serious games in healthcare education and in dental education

Stage 1: Serious games in healthcare education	*Search terms*	*Intervention*	"Serious gam*", "Educational gam*", "Training gam*", "Video gam*", Videogam*, Gaming, Gamification, "Game-based learning", "Game based learning", "Online gam*", "On-line gam*", "On line gam*", "Web-based gam*", "Web based gam*", "Play and playthings", "Games, Experimental", "Games, Recreational"
		Field	Healthcare, "Health care", Medic*, Dental, Dentist*, Nurs*, Pharmac*, Clinic*, Physician*, "Public Health"
		Type of study	"Systematic review*", "Meta ana*", "Meta-ana*"

Inclusion criteria	*Exclusion criteria*

• Systematic reviews and/or meta-analyses of articles:
  - Studying serious games in healthcare education, designed for purposes of learning and training for students or qualified professionals.
  - Presenting outcomes of serious games such as knowledge gain, skill development, attitude improvement, and satisfaction.
  - Published between 2005 and 2016.
	• Not systematic reviews or meta-analyses.
	• Systematic reviews and/or meta-analysis of articles:
	  - Not relevant to serious games for training or learning purpose in healthcare education.
	  - Not specifically on serious games but including virtual reality or simulations.
	  - Not presenting impacts of the serious games.
	  - Not available in English.
	  - Not available in full-text.
	• Systematic reviews and/or meta-analysis with a more recent, similar version.

Stage 2: Serious games in dental education	Search terms	Intervention	"Serious gam*", "Educational gam*", "Training gam*", "Video gam*", Videogam*, Gaming, Gamification, "Game-based learning", "Game based learning", "Online gam*", "On-line gam*", "On line gam*", "Web-based gam*", "Web based gam*", "Play and playthings", "Games, Experimental", "Games, Recreational"
		Field	Dental, Dentist*
	Type of study		Any type of empirical studies

Inclusion criteria	Exclusion criteria
• Any type of empirical studies • Articles studying computer-based serious games in dental education, designed for learning and training any level of dental learners • Articles presenting outcomes of serious games such as knowledge gain, skill development, attitude improvement, and satisfaction • Articles published between 1975 and 2016	• Articles not relevant to serious games for educating and training for dental learners, e.g. serious games designed for educating or rehabilitating patients • Articles without describing details of any serious game or presenting any impacts of the serious games • Articles of interventions or activities, which were not considered as serious games (no game features adopted) such as traditional simulations • Articles of serious games, which were not specific for only dental learners • Articles of non-computer-based serious games • Articles not available in English • Articles not available in full-text

Author (Year)	Aims of studies reviewed	Populations included in studies reviewed	Type of interventions	Methods of studies included	Results	Authors' conclusion	Quality
Bhoop-athi & Sheoran (2006)	To assess the effects of educational games on knowledge attainment and clinical skills of mental health professionals compared to standard teaching approaches	Any mental health professional at any stage of training	Any educational game Note: Only non-computer-based serious game was included.	One paper and one dissertation were included, which reported only one randomized controlled trial (RCT), using non-computer-based game as intervention.	**Knowledge improvement** Average test score at the end of the study showed that students taking the test after the game scored six points more than those who did not play the game (n=34, 1 RCT, MD 6.00 CI 2.6 to 9.4).	Current limited evidence suggests educational games could help mental health students gain more points in their tests, especially if they have left revision to the last minute. This salient study should be refined and repeated.	High
Blakely et al. (2009)	To investigate the use of games to support classroom learning in the healthcare sciences	Nursing, health science or medical students aged 18 years or older (Both undergraduates and postgraduates)	Group games such as card or paper-based, board games or interactive team quizzes Note: Only non-computer-based serious games were included.	10 Experimental design studies 5 Quasi-experimental design studies 1 Systematic review	**Knowledge improvement** The effectiveness of educational gaming as a teaching tool varies. **Knowledge retention** Game-based reinforcement had a positive effect. However, three of seven studies reported no significant difference. **Satisfaction** Overall responses were positive, highlighting motivation, competition and the gaming's non-threatening stance as key factors.	Available research on use of games as an educational strategy is inadequate to enable judgements to be made about the effectiveness of such strategies in preparing healthcare professionals for practice.	Moderate
Akl et al. (2010)	To review the effect of educational games on medical students' satisfaction, knowledge, skills, attitude and behavior	Medical students Note: This review included one RCT, evaluating non-computer-based game (board game), used for learning to manage handicapped dental patients. The participants were senior dental students.	Educational games based on social and cooperative play Note: Both non- and computer-based serious games were included.	5 RCTs	**Knowledge improvement** Three studies suggested positive effect of games over lecture or no intervention. One study found post-test score was higher than pre-test score, but there was no difference between game and lecture. **Attitude (Confidence) improvement** One study evaluated attitude for confidence in dealing with handicapped children using pre- and post-assessments and found no difference amongst game, small group lecture, and no intervention.	The available evidence to date neither confirm nor refute the utility of educational games as an effective teaching strategy for medical students. There is a need for additional and better-designed studies to assess the effectiveness of these games and this article will inform this research.	High

Author (Year)	Aims of studies reviewed	Populations included in studies reviewed	Type of interventions	Methods of studies included	Results	Authors' conclusion	Quality
					Satisfaction One study reported that the satisfaction ratings in game group were better than lecture.		
Alfarah et al. (2010)	To review the medical literature to assess the effect of geriatric educational games on the satisfaction, knowledge, beliefs, attitudes and behaviors of health care professionals	Practitioners or students of the health care professions.	Educational games intended to improve health care of the geriatric population. Note: Only non-computer-based serious games were included.	5 RCTs 3 controlled parallel-arm clinical trials (CCTs).	**Knowledge improvement** One study reported no statistically significant difference between the intervention and control groups. **Attitude improvement** Seven studies found no significant difference between the intervention and control groups in attitude change. One study did not report whether the difference of attitude change between two groups was significant. However, there was significant difference of positive attitude change between before and after in intervention group, and score in this group was higher than control group. **Satisfaction** Two studies evaluating this outcome found high levels of satisfaction.	The available evidence does not support the use of role playing interventions in geriatric medical education with the aim of improving the attitudes towards the elderly.	High
de Wit-Zuurendonk & Oei (2011)	To evaluate the current status of serious gaming in medicine	Healthcare professionals	Serious games for education and learning skills of healthcare professionals Note: Only computer-based serious games were included.	All types of study 30 included studies	**Knowledge and skills improvement** • *Feedback* Debriefing contributes to meaningful connections between the gaming experience and the real world. **Satisfaction** • *Competitive element* The competitive element of a serious game improves the engagement with training through simulation.	The use of a game-based environment has the potential to actively stimulate the learning of skills in a flexible and fun way at low cost. Serious games potentially allow for the creation of scenarios that cannot be easily realized in the real world or through traditional simulation.	Low

Author (Year)	Aims of studies reviewed	Populations included in studies reviewed	Type of interventions	Methods of studies included	Results	Authors' conclusion	Quality
					• *Entertainment* Having fun attracts and holds players' attention on the video game. Sustained exposure leads to improved performance and behavioural change.		
Graafland et al. (2012)	To identify the value of serious games for training professionals in the medical and, in particular, the surgical field	Professionals in medicine were defined as individuals responsible for patient care (doctors, nurses, physiotherapists, paramedics, etc.).	Game-based learning programmes (Excluding virtual reality simulation and e-learning) Note: Only computer-based serious games were included.	**19 studies discussed 17 serious games designed for an educational purpose** - 9 articles including validity testing - 10 articles not including validity testing **6 studies assessed 13 commercially available games associated with training skills** - 6 articles including validity testing	**Skills development** 1. Some games were not linked directly to surgical practice, but could be viewed as interesting. 2. Serious games allow multiple professionals to train teamwork and allow one professional to train multitasking. 3. The current commitment to reduce error in clinical practice has led to recognition of team training in managing crisis situations, such as anaesthesia crisis resource management and emergency medicine crisis resource management. 4. Serious games allow such training in a relatively cheap, readily available environment with a large variety of cases, providing an alternative to expensive high-fidelity simulators.	Blended and interactive learning by means of serious games may be applied to train both technical and non-technical skills relevant to the surgical field. Games developed or used for this purpose need validation before integration into surgical teaching curricula.	Moderate
Akl et al. (2013)	To assess the effect of educational games on health professionals' performance, knowledge, skills, attitude and satisfaction, and on patient outcomes	Qualified health professionals (graduated or postgraduate training)	Educational game (Excluding role playing interventions or simulations) Note: Only non-computer-based serious games were included.	**2 studies** 1 RCT study - The game based on the television game show "Family Feud". - Using pre-, post-, and delayed post-tests to assess knowledge improvement 1 Cluster RCT - The game based on the "Snakes and Ladders" board game	**Knowledge improvement** *First study* - There was a statistically significant difference of knowledge retention in the game group compared with the control group (p=0.02). *Second study* - There was no difference between two groups on both knowledge tests. **Satisfaction**	The findings neither confirm nor refute the use of educational games for health professionals. There is a need for additional high-quality research to explore the impact of educational games on patient and performance outcomes.	High

Author (Year)	Aims of studies reviewed	Populations included in studies reviewed	Type of interventions	Methods of studies included	Results	Authors' conclusion	Quality
				- Using post-, and delayed post-tests to assess knowledge improvement	- Statistically significant higher proportions of participants in the game-based group agreed that: - The event was enjoyable. - Their attention was high throughout the event. - They would register for a similar event in the future.		
Abdul-majed et al. (2015)	To review the literature on educational games for the health professions to identify trends and investigate assessment tools used to measure its learning outcomes.	Students from all health professions backgrounds	Educational table-top game Note: Only non-computer-based serious games were included.	5 studies (This article did not clearly describe study designs of included studies)	**Knowledge improvement** There was an increase in student cognition illustrated by higher test scores or encouraged students to use other references as sources of learning. Educational games create a beneficial learning environment by requiring students to take part in question and answer scenarios that reinforce students to retain information.	Gaming has a positive impact on the teaching/learning process. However, existing assessment methodologies have been not fully captured the learning that may occur in these games. Robust research is needed to address the use of games that have been assessed objectively.	Low
Wang et al. (2016)	To aggregate the available articles on serious games designed for health care professionals, investigate the developmental processes implemented, identify a number of effective games, and assess the evaluation methodologies used	Physicians, nurses, paramedics, physical therapists, and others involved with patient care, at all levels of training (students to advanced level practitioners) Note: This review included quiz games designed for the pathology courses of medical education. However, the participants in the study were both	Serious games created for the purpose of training health care professionals Note: Only computer-based serious games were included.	42 serious games from 48 publications were identified (37 journal articles and 11 conference abstracts or proceedings).	**Knowledge and skills improvement** Of the 19 studies that attempted to evaluate their games for improving skill or knowledge gains, only 2 (11%) did not find significant differences between the intervention and comparison groups upon assessment or significant improvement after serious game use in one group pretest-posttest studies.	Serious gaming is a growing health care training platform that serves a range of learning objectives and specialties via numerous game genres. The assessment of serious games as training tools is an essential but currently heterogeneous process, with varying degrees of methodological quality are in need of improvement.	Moderate

Author (Year)	Aims of studies reviewed	Populations included in studies reviewed	Type of interventions	Methods of studies included	Results	Authors' conclusion	Quality
		medical and dental students.					

Author (Year)	Subject	Serious games and learning objectives	Research objectives	Study design/data collection methods	Participants (n)	Results	Authors' conclusion	Quality
Amer et al. (2011)	Operative dentistry	An interactive dental video game (IDVG) **Objective** To teach the sequencing steps of applying a three-step resin bonding system in operative dentistry	To compare performance on both written and practical skill evaluation of first year dental students receiving a conventional passive clinical video instruction versus an interactive learning module	Randomized controlled trial, using: 1. Pre- and post-test questionnaires 2. Attitudinal questionnaire (5-point Likert scale) towards for IDVG group 3. Bonding exercise, which required the students to bond a composite resin button to the dentin	1st year dental students **n (Total)** = 80 **n (Test)** = 42 **n (Control)** = 38	**Knowledge improvement** There was no difference between two groups in the distribution difference score of pre- and post-knowledge tests. **Practical examination** There was no difference between two groups in the shear bond strength testing. **Satisfaction** Responses tended to be very favorable to the use of the interactive video game, with most falling in the agree zone of the Likert scale, except a question that asked students if they thought of an interactive module completely replacing the lecture in this topic.	Results using an interactive dental video game are as good as a passive, non-interactive way of teaching. They also show dental students preferring this method of teaching to a lecture.	Moderate
Hannig et al. (2013)	Alginate mixing	Skills-O-Mat (a linear, single-player, 2D, reusable, and interactive serious game) **Objective** To train rhythmic and	To present Skills-O-Mat and to compare the effectiveness of the use of the game in learning to learning in a traditional workshop	Parallel-group randomized controlled trial, using: 1. a usability questionnaire for the quality of the game 2. the pre- and post- self-report	2nd year dental students **n (Total)** = 55 **n (Test)** = 30 **n (Control)** = 25	**Knowledge improvement** There was a significant difference between the pre- and post-assessments within both groups. **Satisfaction** An analysis of the usability questionnaire revealed a high overall usability of Skills-O-Mat (5.33 points on average on a 1-6 scale).	An analysis of the results of the evaluation gives indications of the positive learning effect of the game. The game was rated a valuable instrument for teaching and	Moderate

Author (Year)	Subject	Serious games and learning objectives	Research objectives	Study design/data collection methods	Participants (n)	Results	Authors' conclusion	Quality
		period motor skills in alginate mixing		evaluation sheets (both groups)			developing practical skills.	