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A Systematic Review of Game Technologies for Pediatric Patients

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A Systematic Review of Game Technologies for Pediatric Patients

Abstract

Children in hospital are subjected to multiple negative stimuli that may hinder their development and social interactions. Although game technologies are thought to improve children's experience in hospital, there is a lack of information on how they can be used effectively. This paper presents a systematic review of the literature on the existing approaches in this context to identify gaps for future research. A total of 1305 studies were identified, of which 75 were thoroughly analyzed according to our review protocol. The results show that the most common approach is to design mono-user games with traditional computers or monitor-based video consoles, which serve as a distractor or a motivator for physical rehabilitation for primary school children undergoing fearful procedures such as venipuncture, or those suffering chronic, neurological, or traumatic diseases/injures. We conclude that, on the one hand, game technologies seem to present physical and psychological benefits to pediatric patients, but more research is needed on this. On the other hand, future designers of games for pediatric hospitalization should consider: 1. the development for kindergarten patients and adolescents, 2. address the psychological impact caused by long-term hospitalization, 3. use collaboration as an effective game strategy to reduce patient isolation, 4. have purposes other than distraction, such as socialization, coping with emotions, or fostering physical mobility, 5. include parents/caregivers and hospital staff in the game activities; and 6. exploit new technological artifacts such as robots and tangible interactive elements to encourage intrinsic motivation.

Keywords

Videogames, game technologies, children, hospital

1 Introduction

A hospital stay or visit is usually an unwelcome event in the life of any person, especially if the person is still a child. It may hinder a child's play time, which is an essential part of childhood development [1], or cause a breach in the child's usual social interactions (especially in the case of long hospital stays). Further, the child may have to deal with boring and repetitive therapeutic procedures, or even be submitted to painful medical procedures. One way of dealing with these situations is adding an element of play to the hospital visit. With the help of technology, games can be created to help in a number of ways, be it to boost motivation during therapy, distract from a painful procedure, provide a window for social interactions, and so on. In this sense, an introduced game can serve several purposes, including that of allowing a child's play time to remain undisrupted.

The emergence of new technologies provides a wide variety of tools to be used as medium for creating patient-centric games. In some cases, certain technologies can even serve to offer a companionship role for hospitalized children (e.g., [2,3]). New technologies can also offer a higher degree of immersion, enhancing the effectiveness of the game and helping it serve its purpose. Furthermore, technology can be used to make the game itself become a measurement instrument serving both the patient as well as the medical staff (e.g., [4,5]).

Several previous authors have provided systematic reviews to study the relationship between games and health for children. However, not all of them have focused on technological approaches (e.g., [6]), and the ones who have usually targeted adults (e.g., [7,8]) or children outside hospitals (e.g., [9]). Therefore, there is a lack of information about how technology can be used to design games for pediatric patients in a hospital setting. In this respect, this work contributes with a systematic review of the literature, in which we present the different age ranges that are usually addressed, the circumstances surrounding the administration of the game (namely, during which procedures and/or to children with which pathologies), the technologies (i.e., devices and interactions) used, the type of company considered (i.e., whether the games are designed to be mono-user or multiuser, collaborative or competitive), the general purpose of the works, as well as their impact on the children. The results indicate that the most common age range considered is 6 to 12 years old; the most popular treatments, venipuncture procedures and chronic, neurological, or traumatic diseases/injures; the most used technologies, traditional computers or monitor-based video consoles; and that the games are usually designed with the purpose of serving as distractors or motivators for physical rehabilitation, and that they are normally played individually. The results also show that such technologies seem to have a positive impact on pediatric patients in terms of improving enjoyment, socialization, and motor functions; increasing emotional expressions; and reducing pain, anxiety, distress, and stress. However, there is not enough evidence supporting these benefits, and more research would be needed to confirm them.

2 Related Research

Several previous efforts have been made to provide a general view of technological games in healthcare, however, to our knowledge, no systematic review has specifically addressed games for children in hospitals.

Most of the reviews conducted to date on technology and healthcare have not focused on the effect of the technology on the patients. Yao et al.[10], for instance, explored the use of RFID technology in healthcare. They identified applications of this technology (e.g., tracking, identification and verification, and sensing) in different areas (e.g., equipment, administering procedures, and surgery). They also highlighted the barriers to adopting this technology in healthcare (e.g., interference, ineffectiveness, cost, and privacy), and its benefits (e.g., improved patient safety and reduced medical errors, real-time data access, and improved medical processes). Similarly, Fosso Wamba et al.[11] reviewed the literature to find applications and RFID issues in healthcare. They identified three main areas in which this technology could present benefits (namely, asset management, patient management, and staff management). Nevertheless, these two studies focus mainly on technical and business-related aspects of the implantation of RFID technology, and do not consider the potential of RFID to create game platforms for children (e.g., [12,13]).

Others have reviewed the literature to study the effect of serious games in the learning or practice of healthcare. In this respect, Ricciardi and De Paolis [14] conducted a review to assess whether games can be useful to health training, and whether they present benefits with respect to other approaches. Similarly, Lynch et al. [8] explored the MEDLINE database (accessible via PubMed) to study how videogames improve surgeons' performance. Kato [7] reported on several studies about the impact of video games on health, focusing on the pathologies treated or the medical unit in which the game is used. She included both games used to train medical practitioners as well as others aimed at improving the patients' health. However, her review is not systematic, which prevents us from getting a complete picture of the work conducted in the area.

Other works have focused on patients, but not necessarily on children, as in the case of Costa et al.[15], who conducted a systematic review to identify different technological games for healthcare and their benefits, with focus on recent studies (published from 2009 onwards). Their review classified the studies by game types (commercial, tailor-made, and adapted), by platform (console, desktop, and mobile), by interface (movement sensors, measurement sensors, controls, balance platforms, mouse and keyboard, microphone, and touchscreens), and by health areas (rehabilitation, self-care, treatment/therapy, clinical detection, monitoring, and health and wellness). However, they left out important databases in information technology such as the ACM Digital Library.

Other authors have focused on children, but not specifically on technology. For instance, Koller and Goldman [6] conducted a review on distraction techniques to alleviate pain and anxiety in children undergoing medical procedures. Even though they mentioned several technological approaches such as the use of interactive toys and virtual reality, the main scope of their work is not technological. Considering technology, LeBlanc et al.[9] reviewed fifty-one studies published up to 2012 on the effect of Active Video Games on physical activity in children and teenagers. However, these kinds of games are not suitable for some hospitalized children who are required to be bed-bound.

3 Research Questions

With the aim of analyzing previous research focused on developing technological games in hospital settings for children, six different research questions were defined, revolving around three main axes: the patients targeted, the technological game itself, and the study conducted. The ones concerning the patients are the following:

- RQ1: What age groups are considered?
- RQ2: In which procedures and/or with children of which pathologies are the technological games applied?

With respect to the technological game approach, the following research questions were considered:

- RQ3: What specific technologies are used and how are they related to RQ1 and RQ2?
- RQ4: What is the general purpose of each work? In addition, what purposes are addressed with each technology?

- RQ5: Do the proposed games involve more than one user in a collaborative or competitive activity, or do they focus on individual (mono-user) gameplay? In addition, what type of games (i.e., collaborative, competitive, or individual) are most used with each procedure/pathology and with each technology?

Finally, the following research question was defined with respect to the study conducted:

- RQ6: Have previous works studied the impact of technological games on patients? If so, what are the objects of study and the outcome of each work?

4 Methodology

The following describes the procedure followed to conduct the systematic review, i.e., where and how was the literature explored, which studies were considered fitting, and how were they analyzed to answer the above research questions.

4.1 Data Collection

4.1.1 Databases Searched

For the purpose of identifying studies for this review that are relevant to information technology, health, and social sciences, the following online databases were consulted: ACM Digital Library, IEEE Explore, Science Direct, and Scopus. The latter is in fact an abstract and citation database which in turn directs to other online databases including Springer, PubMed, Taylor & Francis, Wiley Online Library, Hindawi, IOS Press, SAGE Journals, JSTOR, Bentham Science, and The BMJ, as well as the previously mentioned databases.

4.1.2 Search Terms

The search terms that were used were made up of a combination of different keywords that included the main object under review (i.e., games, gamification approaches, etc.), the subjects considered (i.e., children visiting the hospital, hospitalized, or in the pediatrics unit), and the approach taken (i.e., technological). More specific terms were added for the approach to include videogames, or digital and computer-based solutions. The resulting search string was the following:

$$gam^* \wedge ((hospital^* \wedge children) \vee pediatric) \wedge (technol^* \vee video^* \vee digital \vee comput^*)$$

The search string was introduced into each database where the title, abstract, and keywords fields were searched. More specifically, in the ACM Digital Library and IEEE Explore it was entered as provided (replacing ∨ and ∧ symbols by “OR” and “AND” keywords, respectively), whereas the other two databases required the use of their corresponding advanced search forms, which resulted in the following queries:

(TITLE-ABS-KEY (gam*) AND ((TITLE-ABS-KEY (hospital*) AND TITLE-ABS-KEY (children)) OR TITLE-ABS-KEY(pediatric)) AND (TITLE-ABS-KEY (technol*) OR TITLE-ABS-KEY (video) OR TITLE-ABS-KEY (digital) OR TITLE-ABS-KEY (comput*))) [Scopus]

((TITLE-ABSTR-KEY(gam*) AND ((TITLE-ABSTR-KEY(hospital*) AND TITLE-ABSTR-KEY(children)) OR TITLE-ABSTR-KEY(pediatric)) AND (TITLE-ABSTR-KEY(technol*) OR TITLE-ABSTR-KEY(video*) OR TITLE-ABSTR-KEY(digital) OR TITLE-ABSTR-KEY(comput*))) [Science Direct]

4.1.3 Inclusion and Exclusion Criteria

The main inclusion criterion was that the work had to refer to technological games used in a hospital setting with pediatric patients. The only exclusion criterion was that the papers had to be in the English language.

4.2 Data Analysis

After obtaining an initial pool of papers by using the search terms described above, an initial screening of these papers was performed manually in which the title and abstract were read and the previously mentioned inclusion and exclusion criteria were used. The next step was to remove the repeated papers that were accessed through Scopus but are publications from one of the other three databases. Finally, an in-depth analysis of each remaining study was conducted with three purposes in mind. First, to identify and remove any work that may have seemed relevant from the title and abstract but was in fact not so (according to the defined inclusion and exclusion criteria). Second, to identify and remove duplicate works that are published as separate papers but present indeed the same technological game, purpose, and evaluation (or do not contain an evaluation with children). This situation usually consists of having a work describing the technology and another with an evaluation (in this case, the most complete work, i.e., the one with the evaluation, is the one that is kept). Finally, the third purpose is to extract all the information relevant to the research questions. The analysis procedure to answer them was also conducted manually as follows.

- RQ1 (*age ranges*). Each study was analyzed in order to obtain the age range that the authors recommended for their game. In the cases where no ages were mentioned, this question was simply ignored.
- RQ2 (*procedures and pathologies*). The situation of the patients in each work was taken into consideration. This refers to when, where, or to whom the technological-game interventions were applied, namely, children with specific pathologies or undergoing certain medical procedures. In the cases in which more than one situation was addressed, all were included and considered.
- RQ3 (*technologies*). All the technologies used in each publication were taken into consideration, with special emphasis on the hardware used as output peripheral and the interactions or input mechanisms supported.

- RQ4 (*purpose*). The purpose of each study was established as the improvement or intervention that each approach was after. In other words, it was established as the goal that was intended for a game to accomplish.
- RQ5 (*number of users*). Each study was analyzed to establish whether the authors' proposal takes into consideration any form of collaborative or competitive gaming instead of focusing on individual gameplay.
- RQ6 (*study*). If a study was conducted to evaluate the impact of a certain game technology on the patients, the measures evaluated were extracted as well as the results and conclusions obtained.

5 Results

After obtaining 1305 papers identified by the search term, 108 were selected after the initial screening of title and abstract using the inclusion and exclusion criteria. After removing repeated papers, 95 studies were left. Finally, after the in-depth analysis of each of the remaining studies, 20 more papers were removed, hence obtaining a total of 75 relevant studies. The most frequent reason for removing papers after the in-depth analysis despite their having passed previous screenings was that the proposed game was meant to be played outside the hospital setting (e.g., at home). Another reason was discovering that the technological intervention used was in fact simply a measurement tool without any gamification applied. Out of these removed papers, four were essentially previous versions of others (i.e., the description of the same technology for the same target group, with no evaluation of hospitalized children). Table 1 summarizes the number of papers collected from the databases and the ones remaining after each screening step. Further details of the individual studies can be found in Appendix A.

Table 1. Search results summary.

Database	**Papers found**	**Papers after screening**	**Papers after removing repetitions**	**Papers after in-depth analysis**
ACM Digital Library	12	11	11	10
IEEE Explore	321	16	16	10
Science Direct	82	6	6	6
Scopus	890	75	62	49
Total	1305	108	95	75

Figure 1 shows the number of publications since 2001. As can be seen, the tendency of building videogames in the context at hand is increasing. The chart shows a leap in the number of publications since 2010. Up to this year, there are 1.56 (SD = 0.88) works/year on average, whereas from 2010 onwards the amount is 8.71 (SD = 3.15) works/year.

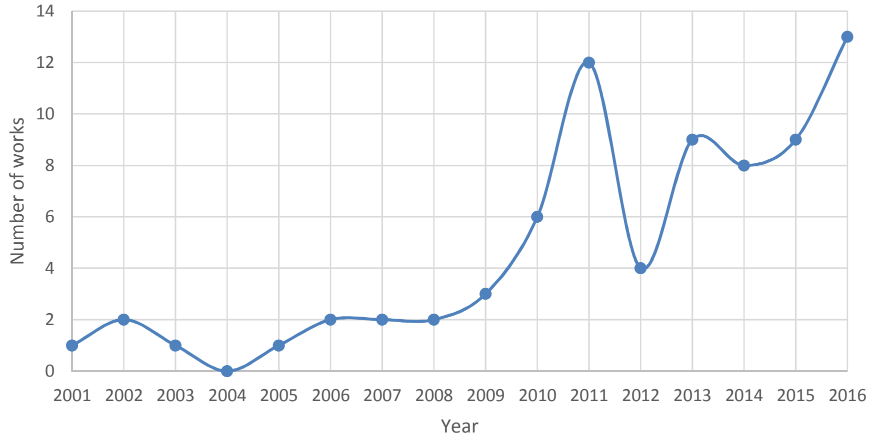

Figure 1. Number of publications over the years on the topic of interest.

5.1 Patient-Related Results

5.1.1 Age Ranges

Almost one third (32%) of the studies analyzed do not specify the age of the children they are aimed at. For the remaining 68%, Figure 2 depicts their distribution with respect to the age(s) considered, which are grouped into four stages of children's development: toddlers, preschoolers, school-age children, and adolescents [16]. The overall sum is greater than 100% because one work may target different age groups. As can be seen in the chart, most studies target children from 6 to 12 (i.e., schoolers, or children in primary school). Less attention has been paid to adolescents in middle- and high-school (between 27% and 48% of the papers), and to preschoolers (between 17% and 51%). Even fewer studies (4%) considered designing game technologies for nineteen-year-olds or for toddlers (only 1.96%).

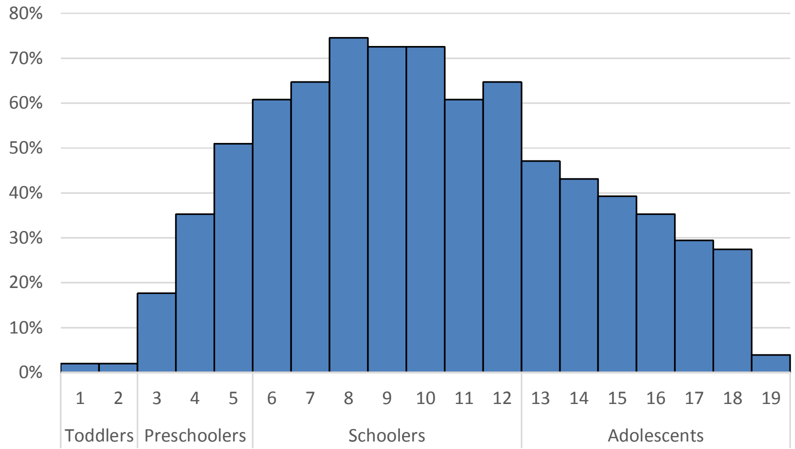

Figure 2: Percentage of publications considering children of each age.

5.1.2 Procedures and Pathologies

The analysis of the literature revealed that game technologies have been applied mainly to children suffering from different pathologies (69.33% of studies), followed by 17.33% that use them before, during, or after administering a certain medical procedure. 22.67% of the publications do not specify any procedure or pathology related to the intervention and only mention that the game is used in hospitals with children. The treatments considered to apply technological games are the following:

- Venipuncture: Refers to the process of puncturing a vein for surgical, therapeutic, or blood collecting purposes, in general. Venipuncture for hemodialysis or chemotherapy is also included in this category.
- Anesthesia: Refers to the process of administering anesthesia before a surgical procedure.
- Minor surgery: Refers to the moments before undergoing any type of surgery that does not require long periods of hospitalization before or afterwards.
- Cold pressor task: Refers to a procedure in which the patient's hand is immersed in ice water and used to measure changes in blood pressure and heart rate.
- Transplant: Refers to hospitalization after undergoing an organ transplant.

Figure 3 depicts the frequency of use of game technologies for each procedure identified. It reveals that the most common interventions are during venipuncture, followed by being administered anesthesia before surgery.

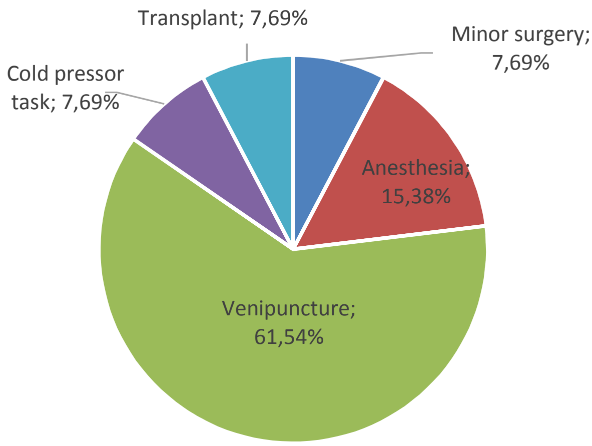

Figure 3. Frequency of use of technological games in each procedure.

The pathologies addressed have been classified into seven groups, some of which are composed of more specific pathologies, as explained below:

- Chronic: Includes diseases lasting three months or more.

  - General: Refers to any type of chronic illness, without specifying which one.
  - Cancer: Refers to a group of diseases involving abnormal cell growth that have the potential to spread through the body. All types of cancer in any possible stage are included.

- Diabetes: A chronic disease in which the body lacks insulin to control the amount of sugar in the blood.
- Renal disease: Refers to the chronic kidney disease in which this organ progressively loses its function.

- Traumatology: Includes treatments of wounds and injuries.
  - General physical disability: Any type of physical disability, temporary or otherwise. This could be a side effect of another illness, but in this case is taken into consideration individually.
  - Neck: Neck-related issues that require keeping the neck straight.
  - Burn: Refers to any type of burn injury that requires treatment, of any degree of severity.

- Neurological: Includes different diseases of the brain, spine, and the nerves connecting them.
  - General: Refers to any neurological disorder, without specifying which one.
  - Cerebral palsy: A specific neurological disorder that affects muscle movement and motor skills.

- Behavioral: A psychological disorder, sometimes also referred to as emotional disorder.

- Pulmonary: Includes any type of pulmonary disease (e.g., asthma).

- Ophthalmology: Refers to anything related to the anatomy, physiology, and diseases of the eye.

- Other severe illnesses: Refers to any type of critical or life-threatening illness in general, with no further specification.

Figure 4 shows that the most common pathologies considered (and with similar frequency) are chronic diseases, neurological, and trauma. The most frequently considered are cancer (21.15%) and cerebral palsy (17.31%).

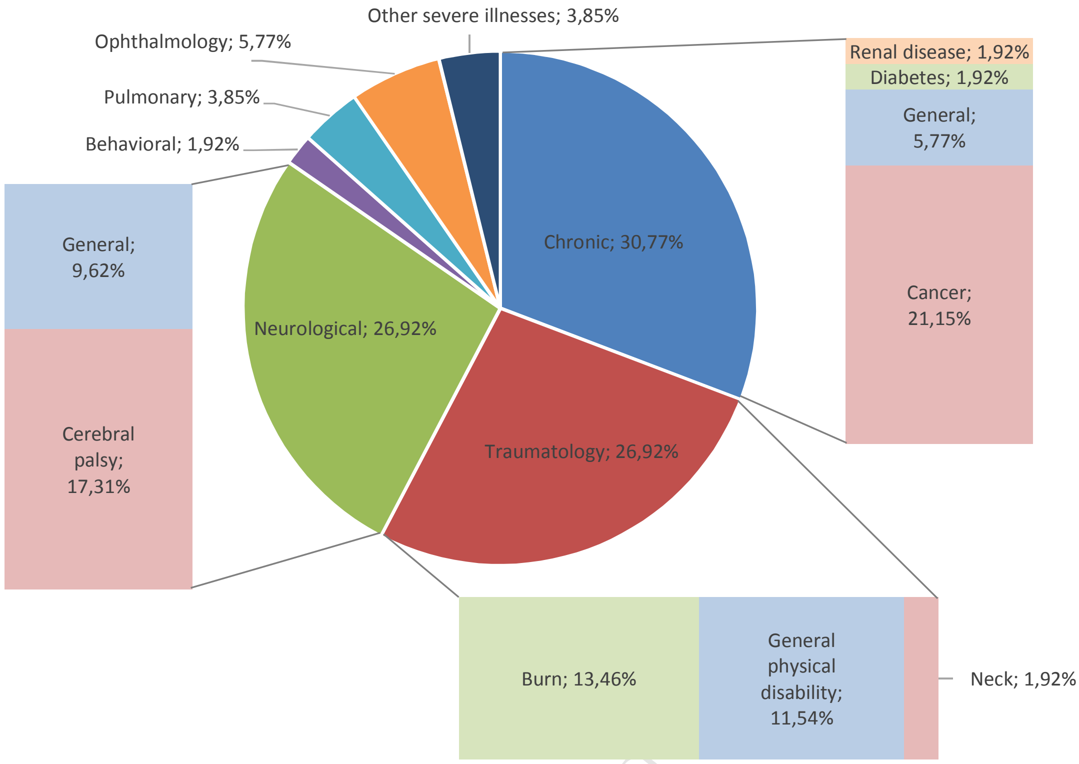

Figure 4. Details of each pathologies considered with their frequency.

5.2 Results Related to Game Technologies

5.2.1 Technologies

The works analyzed were classified by the hardware they use as main output device (i.e., how users perceive the digital information in the game), and how children can interact with it (i.e., input mechanisms). With respect to the former, the following alternatives were identified after processing the publications:

- Monitor: A medium-large screen that is usually used with computers or consoles (in the form of a TV), and is situated at a distance from the user. Only one work (1.33%) made use of a tabletop display and was also included in this category.

- Head-Mounted Display (HMD): Screen in the form of a helmet or goggles worn by the user. In combination with virtual reality, it provides a sense of immersion since the virtual scene occupies the user's whole field of view. However, it can also be used with augmented reality, in which the user views the real world augmented with digital objects.

- Handheld: A small screen the users hold in their hands while playing. It includes portable consoles (e.g., Nintendo Game Boy), phones, smartphones, and tablets.

- Robot: Refers to playing with a robot companion. It enables mixed-reality experiences, in which the digital and physical worlds are combined in the same game activity. From the analysis, we observed that one work (1.33%) used humanoid robots, and two (2.67%) relied on robots of indeterminate shape.

- Other: Includes other types of hardware such as projections on walls and floors, or tiles mounted on the floor.

Regarding the input mechanisms, the children can use to interact with the previous hardware in order to play the game, the following were extracted:

- n/a: Refers to when the children can only sense the outputs of the system.
- Controller: The output hardware is coupled with a specific controller, and interactions are based mainly on pressing buttons and/or pulling handles (e.g., mouse and keyboard for computers, or joysticks for consoles).Three studies (4%) made use of the Lokomat[2] system, a commercial controller for physiological gait rehabilitation.
- Touch: The user enters input to the system by directly touching the output device.
- Tangible: Input comes in the form of physical objects the user can manipulate with a higher degree of freedom than is available with regular controllers. It includes both common and tailor-made objects, and enables mixed reality situations.
- Gesture: Refers to making gestures with hands, arms, or the whole body, which are captured by any type of motion sensor. It includes those interactions in which the user holds a controller (e.g., Nintendo Wii) but interaction is not based on pressing buttons or pulling handles.
- Voice: The system reacts to the user's voice.
- Gaze: By moving their eyes, users point to specific parts of the output device (usually a monitor) to make a selection.

Figure 5 depicts the tendency of the analyzed works over time to consider the previous output/input approaches, using a 2-period moving average.

[2] https://www.hocoma.com/solutions/lokomat/

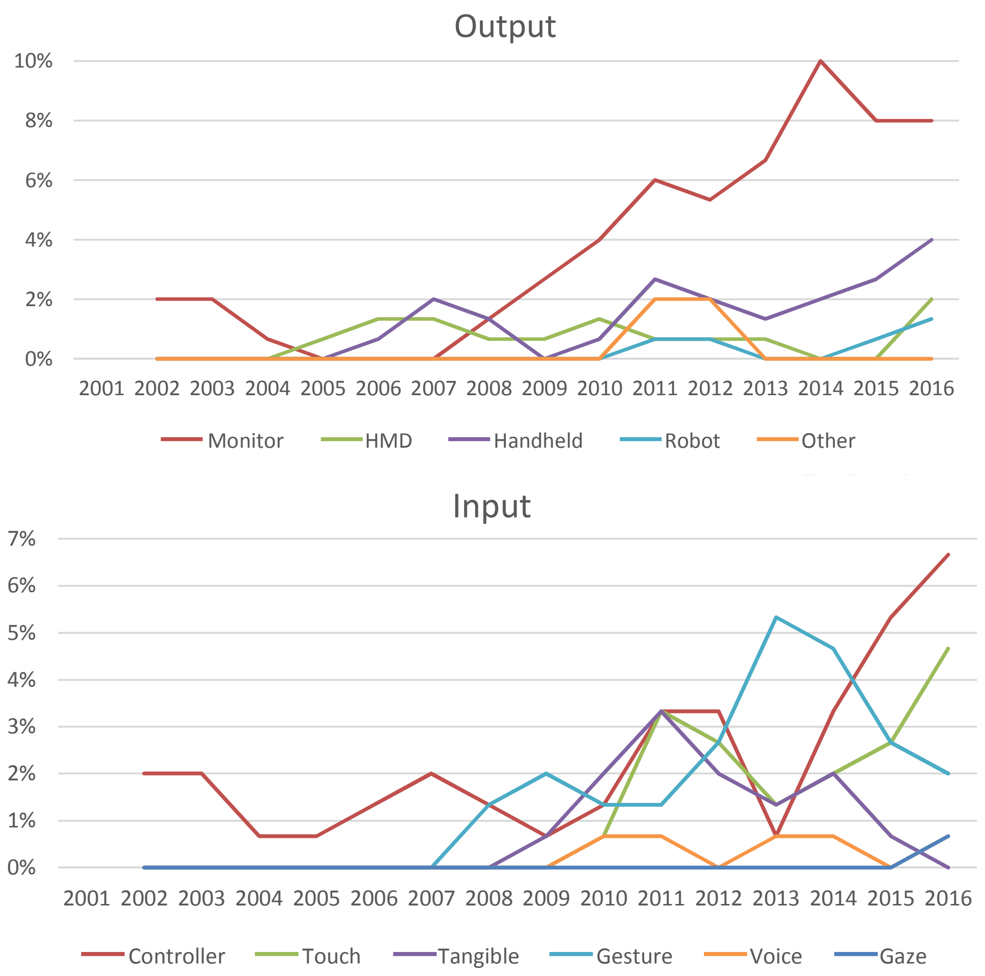

Figure 5. Tendency of works over time (2-period moving average) to rely on each output hardware (top) or input mechanism (bottom).

Figure 6 shows the proportion of publications that consider each output device or rely on each input mechanism (for further details, see Appendix A). It can be seen that the monitor is by far the most common output device, and the controller the most popular input peripheral (followed by gesture interactions).In turn, Figure 7 depicts, for each combination of output and input technologies, the proportion of studies that make use of commercial or customized approaches. Only combinations with a frequency greater than 3% are shown in the chart, the rest are grouped in the two bars on the right. As can be seen in the figure, the most frequent combination is monitor and controller, which corresponds mostly to commercial consoles or PCs. 14.67% of the works also rely on commercial games, whereas 20% opt for designing their own. Another popular trend is to use gesture-based consoles, as 14.67% of the studies rely on commercial platforms such as Nintendo Wii or PlayStation Move, whereas only 4% implement custom devices and games. The third most frequently used combination of output hardware and input mechanism is the use of touch-mediated handheld devices, in which customized solutions prevail with a proportion of 12%. Of these, 77.78% of the works implement games for Android tablets and iPads, whereas 22.22% take the customization process further and also design their own portable devices.It is worth mentioning that whenever tangible interactions are considered, regardless of whether the output device is a monitor, HMD, handheld, or robot, the approach is always customized, which might be due to a lack of generic tangible input hardware on the market. Going for commercial platforms is usually affordable, entails little development effort, and is interesting for studies that only want to assess the impact of videogames in general. However, the majority of the publications apply customization to some degree, making games tailored for the target children's age, pathology, or undergoing a certain procedure.

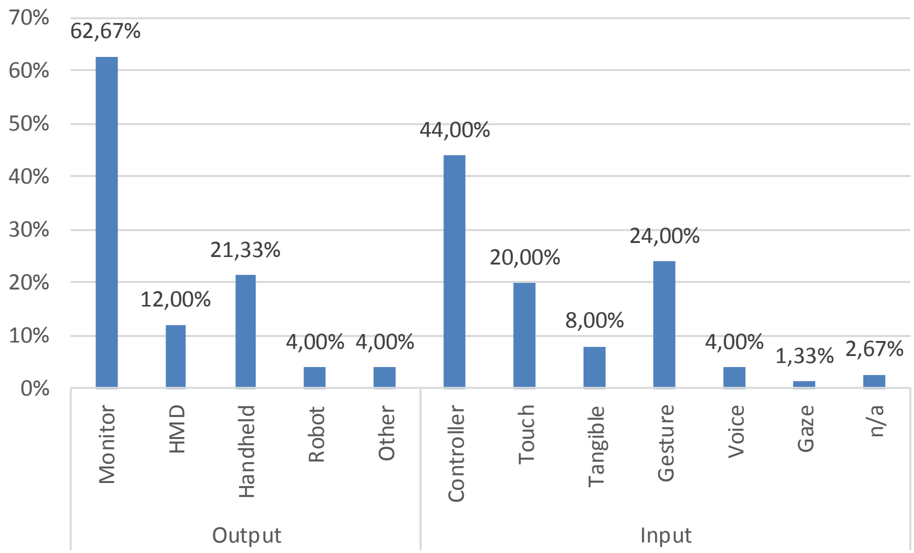

Figure 6. Proportion of publications that rely on each output device and input mechanism.

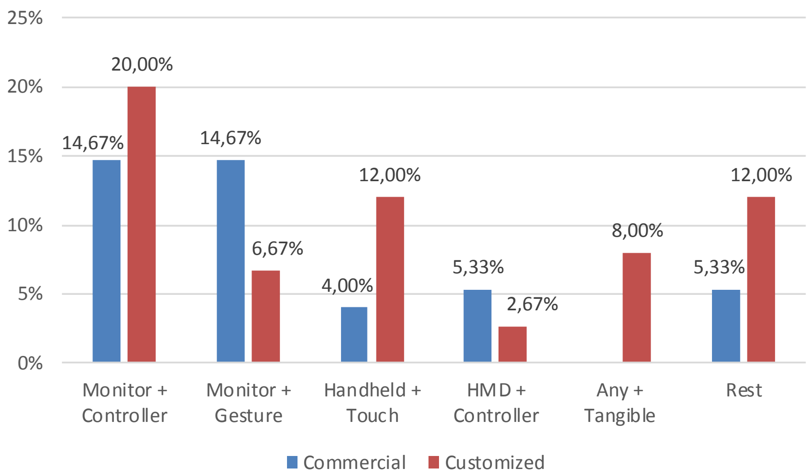

Figure 7. Proportion of publications that make use of commercial and customized combinations of output devices and input mechanisms.

The relationship between the technologies used in each work and the patient's age was also analyzed. Figure 8 shows the proportion of studies that consider each output device and input interaction for the four age stages identified above. The distribution for schoolers is similar to the one in Figure 6 because it is the majority group, i.e. the monitor being the most common output hardware, followed by handhelds and HMD; and controllers being the most common input mechanisms, followed by gesture and touch interactions. For adolescents, the distribution is similar except for HMD being slightly more used than handhelds, although this difference is due to only one work. Some differences can be found for other age groups. The only work targeting toddlers relies on tactile tablets. For children in kindergarten or preschoolers, even though the most frequent combination is monitors plus controllers, there is less difference between these and handhelds and other types of interaction, although it is still infrequent.

The analysis of the literature also suggests that the target age group does not have a significant impact on the choice of specific output/input technologies. Although the works that create their own games do consider this factor and adapt the graphical user interface to children, commercial platforms are mainly chosen because they are appealing and well known to the subjects, and customized ones have other hidden motivations. Only five studies (6.67%) make an explicit reference to the children's age in their motivation. Krebs, Michmizos, and colleagues [17,18] present the pediatric Anklebot, a custom controller specifically adapted to children aged 6-10; Akabane et al. [13] make use of toys for 5-to-10-year-olds as tangible manipulators; and Lu et al. [2] design a custom robot companion for children aged 3-7. Finally, Looije et al. [3] opt for using a friendly-looking commercial humanoid robot for bonding with children in primary school.

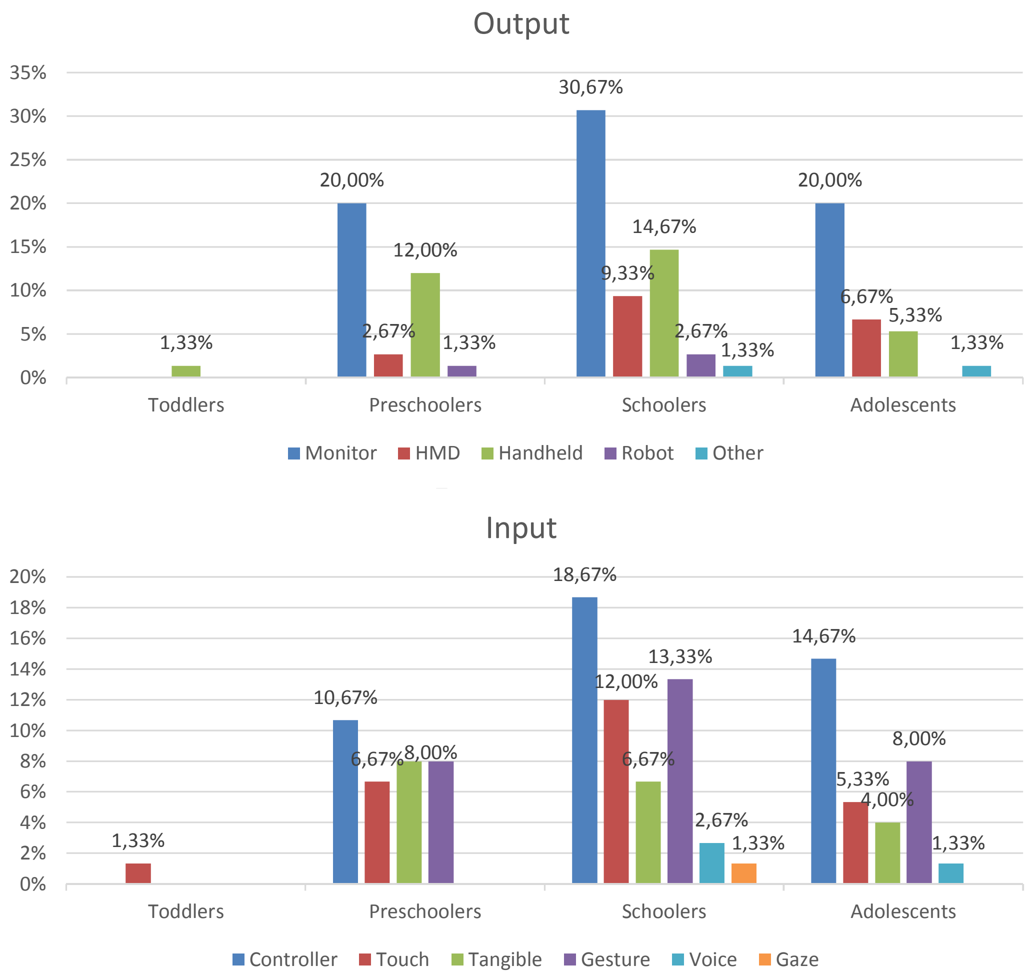

Figure 8. Proportion of works that consider the specified output (top) and input (bottom) approaches for each stage in childhood development.

The technologies were also analyzed in relation to the different procedures and pathologies. The proportion of publications considering each output hardware and input mechanism for each type of procedure and pathology is shown in Figure 9 and Figure 10, respectively. Even though only 33.33% of the works analyzed explicitly report having a specific reason to use a certain technology because of the child's pathology or procedure undergone, this dimension does seem to influence the choice of input/output technologies more than the patients' age range. Gaming activities must not interfere with procedures like administering anesthesia, venipuncture, or minor surgery, and thus benefit from a portable handheld device [19–21] or from a gesture-based input [22], since they remove the need for wired controllers. Similarly, Law et al. [23] report on the need for hands-free input mechanisms like voice for cold press or tasks, since this procedure would keep the patient's hand busy.

With respect to the pathologies that can affect the choice of technology, we identified two different groups with common requirements. First, patients with either neurological problems or general physical disabilities (traumatology) that are subjected to physical rehabilitation require the ability to physically exercise a specific body part [17,18,24–31], or to perform fine-grained movements [32,33]. For this, they rely on commercial gesture-based consoles such as Nintendo Wii [26,27,30], which has been proven to improve movement abilities in people with motor impairments [34,35]; the Lokomat system [31], which has been found successful at neurological movement rehabilitation [36]; or commercial tactile tablets, under the promise that direct touch capabilities will increase dexterity and muscle tone [33]; but most of the studies analyzed rely on tailor-made controllers, which can provide the most customization for the body part being rehabilitated. The second group corresponds to those patients with no specific pathology (pulmonary, chronic, burn-related, or other severe illness) but who must remain in hospital for long periods of time. The most frequently used technologies in this case are gesture-based commercial consoles that enable general physical exercise, such as Nintendo Wii [37,38], PlayStation EyeToy [39], or PlayStation Move [40]; and commercial handheld tablets or smartphones the children can carry with them as they move around the hospital [41] and are also able to provide disease-specific game contents to each patient [42].

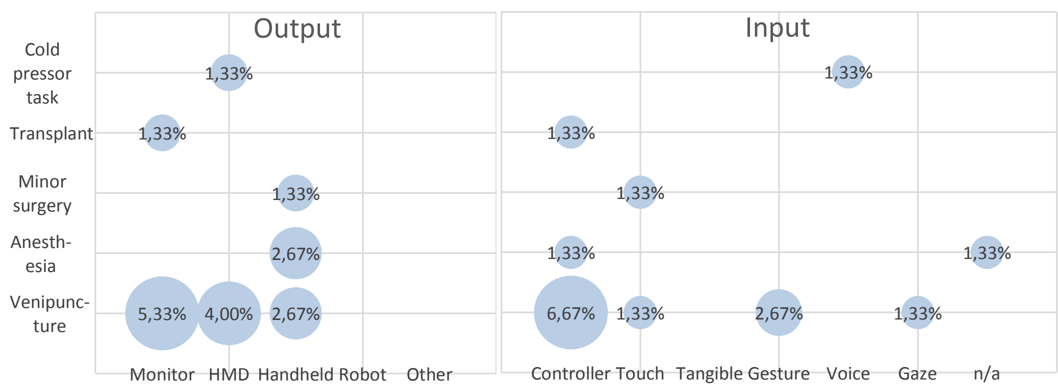

Figure 9. Proportion of works that consider the different output (left) and input (right) approaches for each type of procedure.

Figure 10. Proportion of works that consider the different output (left) and input (right) approaches for each type of pathology.

5.2.2 Purpose

The purpose, or intention, of each identified work was also analyzed. After the in-depth analysis of each study, the following ones were identified:

- Distraction: Refers to the purpose of providing a way of entertaining the child while in hospital or while undergoing a specific procedure, with the aim of reducing the stress they might experience.

- Motivation: Includes the works that use the game as a motivator for the children to perform any kind of rehabilitation activity (e.g., physical, mental). At the same time, the game serves therapists to keep track of the patients' progress.

- Socialization: Considers works that provide a space for communication or socialization with either other patients, the hospital staff, or the outside world.

- Education: Refers to when the purpose is either to offer information about hospital procedures or the patient's illness, or to offer educational courses or a way of connecting with the patient's classroom in order to avoid falling behind in their studies.

- Emotion coping: Refers to when the work aims to provide a way for the patients to face and regulate the negative emotions they feel during their stay in hospital.

Figure 11 depicts the proportion of publications that propose games for each purpose identified, showing that the two most common trends are to use game technologies as motivators in rehabilitation activities and to distract the patients from the situation they are in. In turn, Figure 12 shows, for each purpose, the proportion of works that have considered each output device and input mechanism. The relation between technologies and purposes does not reveal any major differences from the general cases: monitors and controllers lead the technologies used. This is mostly due to their availability, because, although the custom solutions that implement their own games do so with a purpose in mind, the hardware and interaction modalities used seldom have a motivation underneath. As counterexamples, gesture interactions are used 8% more than regular controllers in motivation games. This has to do with these games being used mostly for physical rehabilitation, in which the game helps the patients perform certain body movements. In addition, HMDs are used to distract the children from painful medical procedures in 77.78% of the cases (the rest being used as motivators). The reason behind this is the immersive experience these devices provide, which cognitively abstracts the children from their situation as well as preventing them from physically seeing the procedure they are undergoing. For the treatment of burn injuries, in particular [43–45], it represents a non-pharmacological approach that has been shown to reduce pain and anxiety [46].

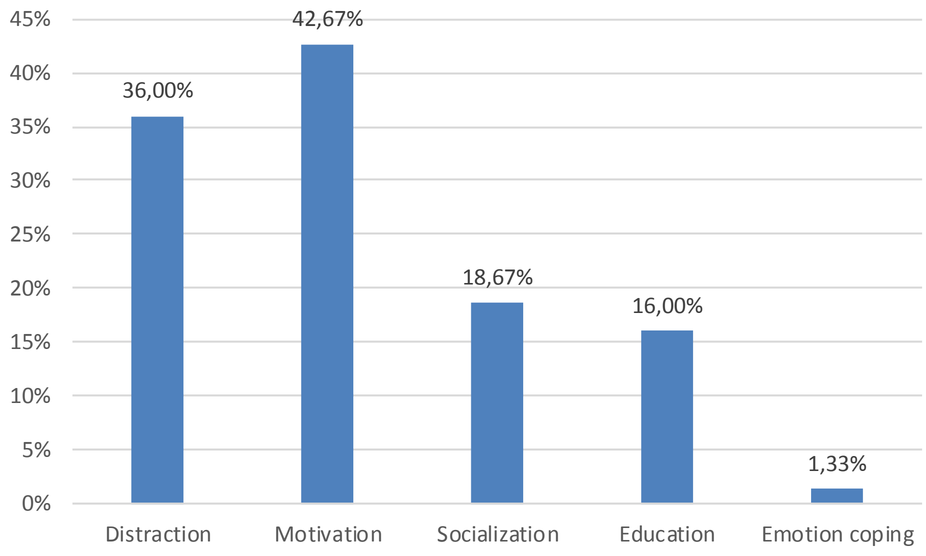

Figure 11. Proportion of works pursuing each identified purpose.

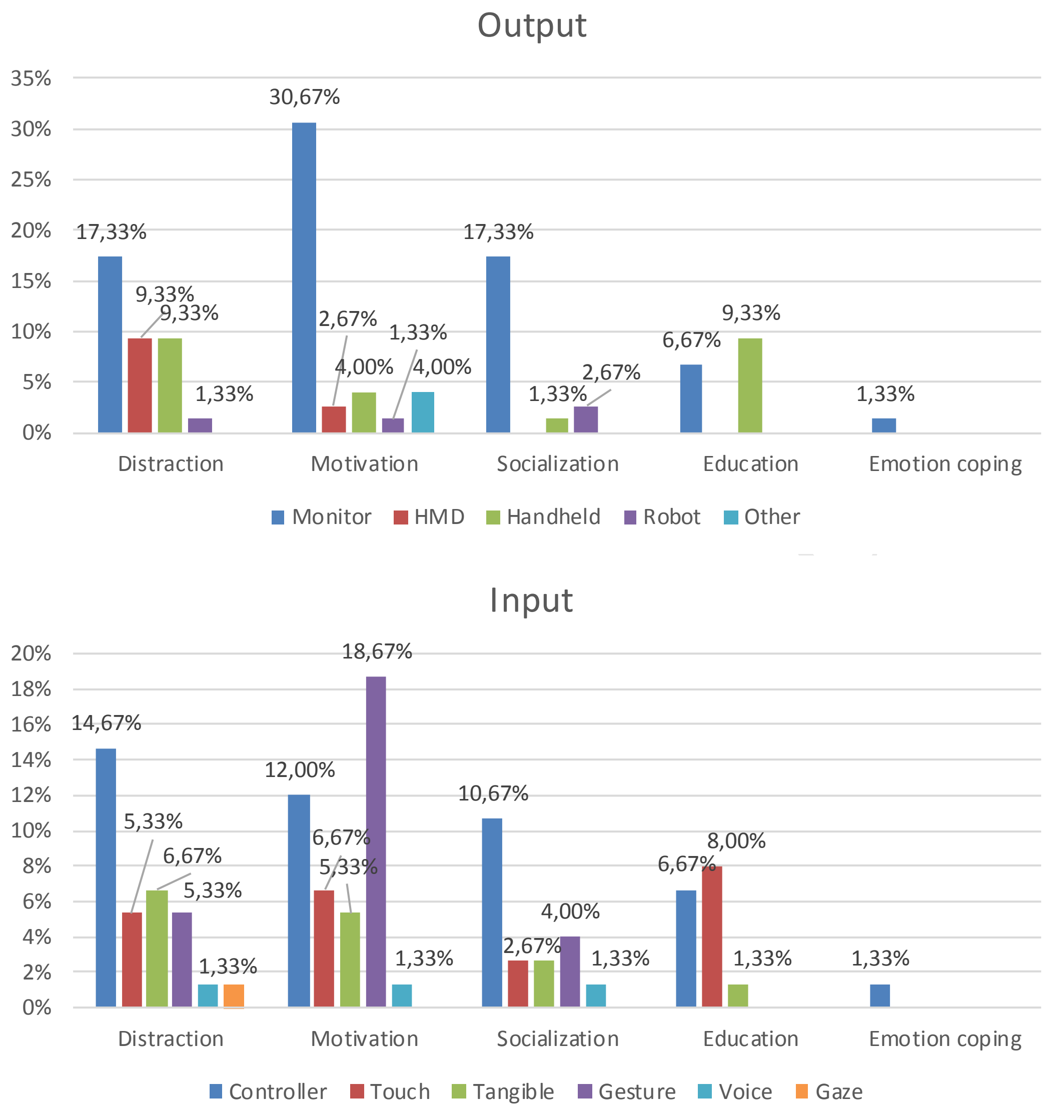

Figure 12. Proportion of works that consider the specified output (top) and input (bottom) approaches for each purpose identified.

5.2.3 Number of Users

With respect to the number of users supported, the different technological games explored were classified into four categories:

- Individual: Refers to when a proposed game can be played individually by a single player, or is not meant to be played in company at all.
- Collaborative (online): Refers to when the proposed gameplay includes collaborative activities that can be performed by players without requiring them to be in the same location at a given time.
- Collaborative (co-located): Refers to when the proposed gameplay by a study includes collaborative activities that a patient may perform with other patients, family members, or even hospital staff.

- Competitive (co-located): Refers to when gameplay may be competitive, where patients may play against other patients or family members or friends, in order to provide further incentive or create an environment in which the patient may feel more involved.

Figure 13 depicts the proportion of works that consider each user combination described above. It can be seen that individual games are used significantly more than multiplayer games. This can be related to the two main purposes pursued: using the games as simple distractors, or as motivators for different therapeutic tasks. With respect to the former, the game intervention is meant to be applied during a specific medical procedure, which is usually applied to each patient in private. As for the latter, different patients require different therapeutic routines, which would complicate any form of collaborative or competitive gameplay, especially if only one gaming device is available.

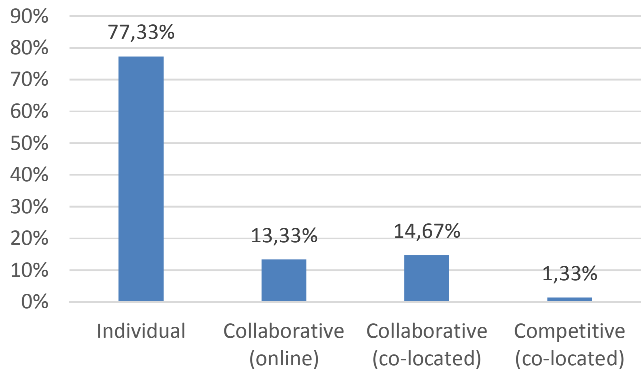

Figure 13. Proportion of works that consider each group of users during game play.

Since the vast majority of studies target only a single user, the distribution of pathologies/procedures as well as of input/output technologies for individual games is similar to those shown in Figure 3, Figure 4, and Figure 6. Figure 14 provides more detail on which procedures or pathologies have been considered for each type of multiplayer games, i.e., collaborative (online), collaborative (co-located), and competitive (co-located). As can be seen in the chart, there is no predominant procedure or pathology in which multiplayer games are applied. In fact, in most cases none is specified. The only pathology that seems to stand out is cancer, as this is the most prevalent in any multiplayer modality. This may be due to pediatric oncologic patients being especially prone to psychosocial issues [47] and the fact that social support can help these patients cope with the stress of the disease [48]. Competitive play is seldom explored, which can be explained by these types of games having a potential effect on aggression [49,50], which might not be desirable to foster in a hospital environment.

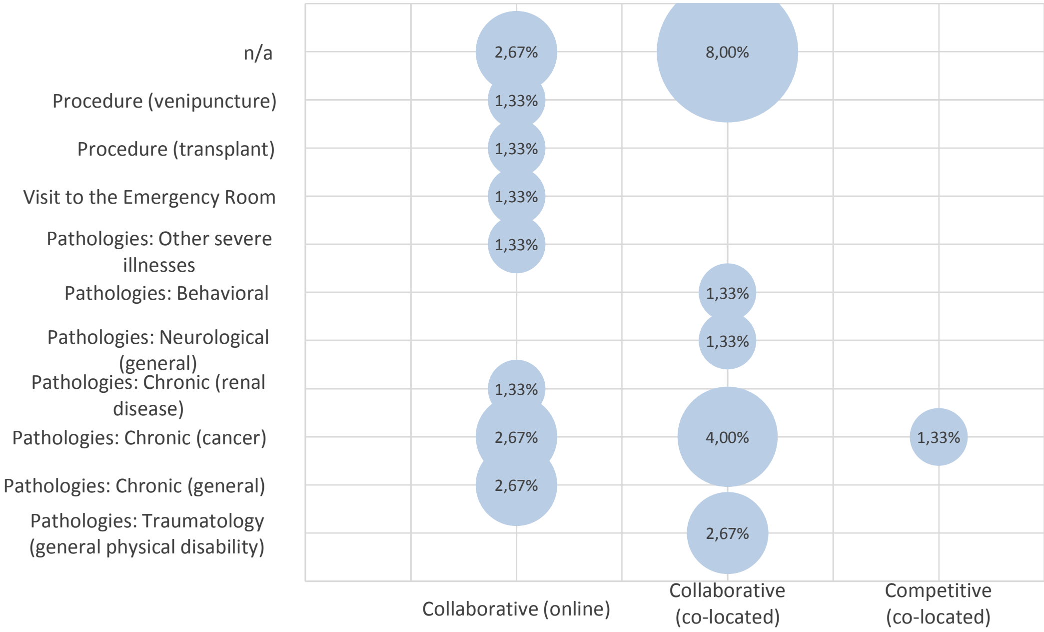

Figure 14. Proportion of each type of multiplayer game for each procedure or pathology considered.

The relationship between the different multiplayer game types and output and input technologies can be seen in Figure 15. As for the technologies used, the tendency for individual games is the same as in the general case discussed above. For online collaborative games, the combination of output hardware and input mechanism that stands out the most is also controller-based monitors, i.e., computers and consoles, since the only requirement is to have a network connection. For co-located (collaborative and competitive) games, the most common interaction is through gestures. This is achieved by means of motion sensor consoles such as Nintendo Wii or Xbox Kinect, which enable multi-user interactions and having a shared workspace, which enhances awareness, a key factor in this type of activity [51,52]. In addition, the fact that children can see each other moving around may provide a more fun experience, ensuring user acceptance. In contrast, handhelds are seldom used, even though they have been identified as potentially interesting for co-located activities through what has been called Multi-Display Environments, i.e., joining several devices together [53].

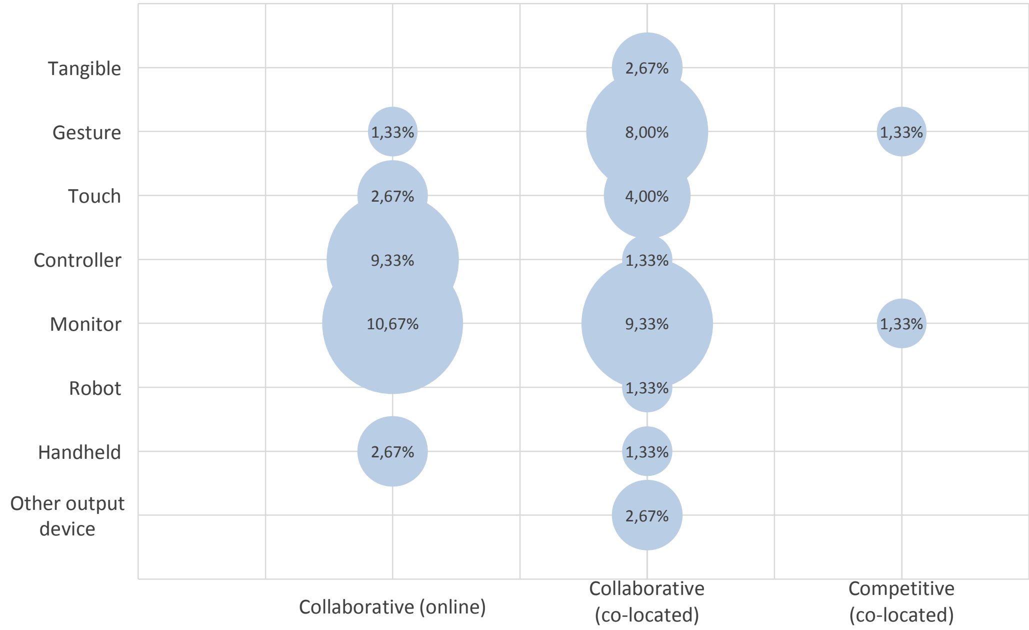

Figure 15. Proportion of each type of multiplayer game for each technology used (output hardware and input interaction mechanism).

5.3 Study-Related Results

26.67% of the publications selected only describe a system design or implementation, or discuss game requirements for pediatric settings. 6.67% of the total number of works analyzed study the feasibility of the approach in hospitals with children, 2.67% analyze how a specific game technology can help therapists create new activities and assess their patients, and only one work (1.33%) focuses on alleviating parents' anxiety. The remaining 64% of the publications selected present a study in which a game technology was evaluated with children in hospitals in order to measure one or many patient-related variables. Of this 64% of the studies, Figure 16 gives the proportion that considers each one of these variables. The most recurrent objects of study are enjoyment (39.58%), which consists mostly of informal assessments of users' acceptance and impressions, usually collected through observations or interviews; pain reduction (31.25%); improvement in motor functions (20.83%); and, to a lesser extent, reduction of anxiety, distress, or stress (14.58%), improvement in socialization (12.50%), and increased emotional expressions (8.33%). The rest, which can be consulted in Appendix A, were studied in less than 5% of the works.

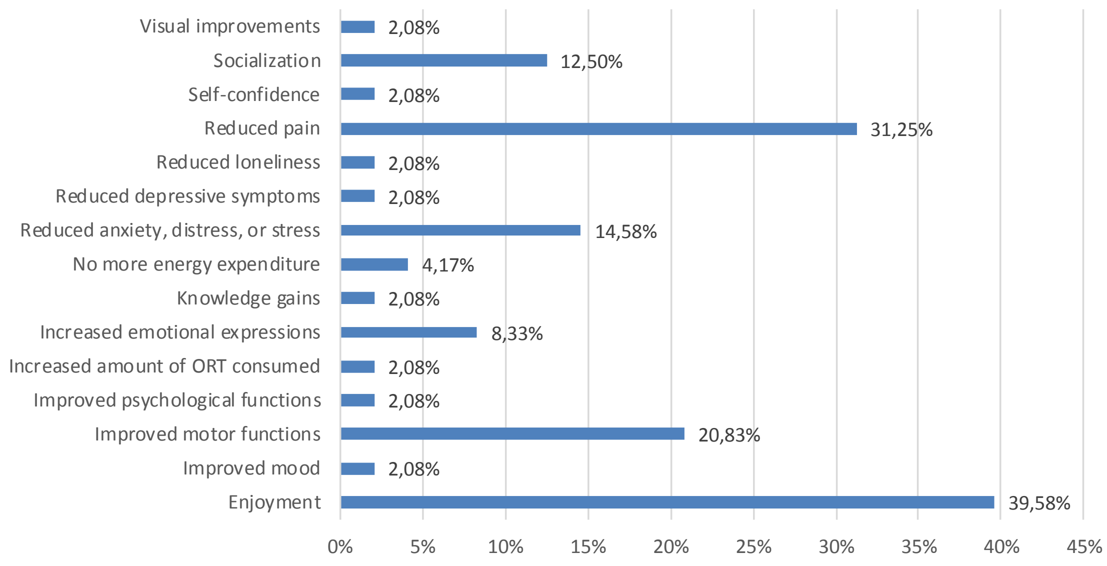

Figure 16. Proportion of works that evaluate each patient-related variable.

In turn, Figure 17depicts the success rate of each variable. Extreme values should be taken with caution due to the small sample of studies in which they were evaluated (see Figure 16). However, for those variables with more than 5 evaluations (which would represent 6.67% of the publications analyzed), it can be seen that game technologies for children in hospitals provide enjoyment, socialization, and increased emotional expressions in more than 90% of the cases; are able to improve motor functions in 80% of the studies; and reduce pain as well as anxiety, distress, or stress with a success rate greater than 70%.

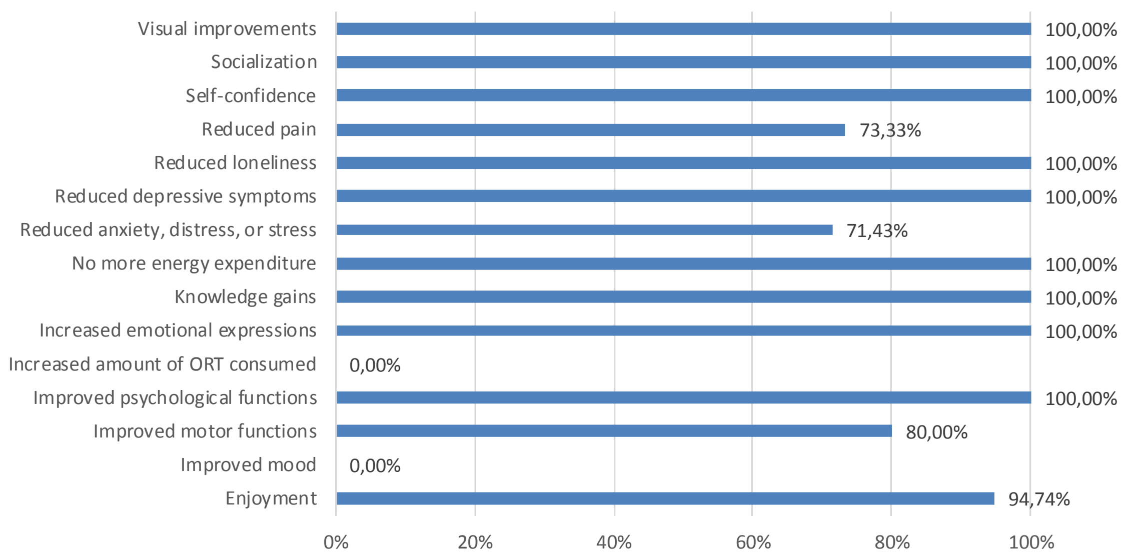

Figure 17. Success rate of the studies that consider each patient-related variable.

6 Discussion

6.1 Target Users

From the analysis of the literature, we found that the most common target group is primary school children. This is probably due not only to their being more likely to accept a given game, but also to their capacity for understanding it. Younger children might encounter difficulties in understanding both the dynamics and interactions of videogames. This complicates their design, which, in turn, can discourage researchers from creating games for these patients. On the other hand, adolescents may be more easily bored with a game that is not in their usual style, and more mature approaches may simply work better, which would explain the fewer monotonic studies for this group of patients. In our opinion, these groups of users should not be disregarded, as they experience a huge number of hospitalizations per year. For example, in 2015, each country in the European Union experienced, on average, 11,120 and 7,688 hospitalizations of children aged 1-4 and adolescents aged 15-19, respectively, for each 100k inhabitants [54].

We found that nearly 70% and nearly 20% of the studies consider using game technologies with children suffering from a specific pathology or undergoing a given medical procedure, respectively. With respect to the latter, the usual approach is to tackle potentially fearful treatments such as venipuncture. As for the former, the most common is cancer, a chronic disease that affects approximately 300,000 new children (less than 19 years old) each year, sometimes with fatal consequences [55]. General neurological and physical disabilities are also relatively common pathologies to be addressed, along with burn injuries and cerebral palsy. Most of these pathologies are very physical, observable pathologies. On the other hand, psychological disabilities, such as behavioral disorders, which include multiple diseases, are often neglected in this regard. This could be due to their harder-to-treat nature and the fact that they are often treated in specialized hospitals instead of general ones, but it presents an interesting topic that could be tackled though game technologies, as several studies with adults have pointed out. For example, a review by Horne-Moyer et al. [56] concludes that technological games often present the same benefits in psychotherapy as traditional methods, but they are in some cases more accepted, enjoyable, and engaging. Fernández-Aranda et al. [57] argue that some characteristics of videogames such as the capacity for immersion, low resistance to their use, and their demonstrated effects on brain activity make them very suitable for treating mental disorders.

Even though this review focuses on game technologies for pediatric patients, and therefore the publications analyzed focus on children, some of them [33,58] reveal that they can also be useful for therapists, as they can serve as measurement tools and help to create therapeutic activities. Also, as Fernandes et al. [21] observe, games can help not only the patients but also their parents. This is particularly interesting as a hospitalized child causes high loads of stress to their parents. In fact, some researchers propose the need to include parental care in these situations [59,60].

6.2 Technologies

We observed that videogame consoles and traditional computers are the most commonly used technology. Input via controllers was practically the only mechanism considered up to 2008, and from this year on its use and the use of monitors present strong growth. This could be due to the wide variety of gaming consoles on the market, as well as their generally affordable prices. Using a gaming console or pre-made games also simplifies the work by removing any implementation aspect. Further, the variety of consoles also means a variety of gaming styles, which enables other interaction mechanisms such as gestures. For example, some come with motion sensor accessories like the PlayStation EyeToy, Xbox Kinect, or Nintendo Wii, which offer a more active play style, mostly for physical rehabilitation purposes, but also for co-located games, which enable socialization, as children can see each other moving around. Nevertheless, as previous studies have pointed out [53,61], these kinds of technologies are fixed to a specific location, which would make them unsuitable for bed-bound patients. Neither would they be suitable for very young users, for whom they are known to present tracking problems. The use of handhelds seems to be more suitable in these situations because they are very easy to set up and adapt better to the user's posture. Their use is gaining momentum since 2010 along with touch interactions, which would correspond to the increasing popularization of smartphones and tablets, commonly used in other areas such as education [61,62]. The interaction with these devices via direct touch is intuitive and well accepted and usable by children [63,64]. According to Shneiderman et al. [65], it enables natural interactions for three reasons: a) the visibility of objects and actions of interest; b) the replacement of typed commands by pointing actions on the objects of interest; and c) the rapid, reversible, and incremental actions which help children to keep engaged and give them control over the technology, avoiding complex instructions that complicate the interaction. In spite of this, the potential of touch interactions with handheld devices has not yet been explored deeply in hospital settings. This would be interesting not only because good technology acceptance is key for the success of the game intervention, but because handhelds can be carried around with the patients, and are less obtrusive in certain procedures and situations as they are wireless. By joining several of these devices together one could devise co-located games to foster socialization [53,66], which has been mostly unexplored in children in hospital.

HMD, on the other hand, have been around for many years, but not until very recently have they become popular and made available commercially. Devices such as HTC Vive, PlayStation VR, or Oculus Rift enable immersive virtual reality environments that, as explained above, cognitively abstract the children from their situation, making them especially interesting as pain distractors. However, they should be used with caution, as they are known to produce symptoms similar to motion sickness [67], and even though this can be reduced by playing seated instead of standing [68], they present too big of a risk to expose hospitalized children to them.

Other emerging technologies such as robots, tangible user interfaces, and voice interactions are still little used. Furthermore, tangible interactions seem to decrease year after year since 2011. This is surprising, as recent research tends to praise the benefits of tangible user interfaces over traditional devices or even tactile handhelds. These include increasing children's interest, engagement, and understanding of the activity [69], and having a positive effect on socialization [70]. In addition, incorporating interactions with the physical space in a technological game is perceived as easier and more fun than screen-based activities [66]. Tangibles can be represented as toys, which are already familiar to children (e.g., plush toys [71]). These, alongside robots, will enable new experiences in the near future with the recent advances in Artificial Intelligence and robotics. Robots are very interesting technologies to be used with children because, as argued by Li et al. [72], they capture their imagination. They hold special promise in situations in which parents are not always present [73], as in the case of hospitals. Robots could accompany the child physically during game play as a companion, and be interacted via natural user interfaces such as voice and tangible objects. Breazeal et al. [74] proved that young children accept robots as interlocutors and informants, and others like Leite et al. [75] reveal that they can provide social support to a similar extent as other children.

6.3 Purpose

It was observed that most works focused on game technologies as motivators for rehabilitation activities or as distractors. One can assume that these two purposes are the most popular in game technology design for children in hospital because they are simpler to devise and implement. With respect to the latter, the topics of the game do not really matter, since the only goal is to abstract the child from his situation. As for the former, it is easier to build on therapeutic activities that already exist and simply provide extra aid instead of creating completely new activities for purposes that are not usually tackled in a hospital. This in turn leads to a lack of studies that have other interesting purposes as their main objective, such as fostering socialization, working on the children's emotional wellbeing, or promoting physical mobility.

Children who spend long stays in hospital or make frequent visits to it due to chronic diseases suffer large amounts of stress that can result in many social and emotional issues [76–79]. These are caused not only by their physical symptoms but also by feelings of loneliness or isolation [80] that arise from being separated from their parents and friends. In fact, authors like Ceribelli et al. [81] underline the importance of communication with the child in these environments. Building socializing experiences could benefit children's emotional intelligence [82], which could in turn help them regulate the negative emotions they feel, for emotional intelligence is mainly of social nature [83]. Collaborative gameplay can encourage a sense of camaraderie between patients and add to their social circle. Online collaborative games in particular open the window for socialization outside the hospital, and can provide some sort of abstraction since the workspace is in a virtual world. On the other hand, collaborative co-located games can enable bonding between the patients and others in hospital, with whom they will have to spend a lot of time, namely caregivers, hospital staff, and fellow patients. This bonding is sometimes essential, as in the patient-nurse relationship, for the delivery of quality care [84].

Physical mobility is usually considered for patients in rehabilitation, but often neglected in game interventions for other children. Leaving aside those that are physically unable to move, physical exercise could be an interesting addition to game-based therapies, as it presents a plethora of health benefits, both physical and mental [85]. On the one hand, it helps prevent several chronic diseases like cardiovascular disease, diabetes, cancer, hypertension, obesity, and osteoporosis [86]. On the other, it can alleviate some depressive symptoms than can emerge during hospitalization, improve self-image, social skills, and cognitive functioning, as well as reduce the symptoms of anxiety [87,88]. Exercise has also been found to reduce fatigue, somatic complaints, obsessive-compulsive traits, fear, interpersonal sensitivity, and phobic anxiety in cancer patients [89]. With respect to children in particular, the effects are similar: reduction of low density lipoproteins while increasing high density lipoprotein; improvement of glucose metabolism in patients with type II diabetes; improved strength, self-esteem, and body image; reduction in the occurrence of back injuries; and stress reduction, which may also improve the immune system [90]. However, it is worth mentioning that some research reveals that to achieve substantial health benefits, the exercise should be at least of moderate intensity [91], which some patients might not be able to perform. In any case, additional studies should be conducted to properly assess the impact of exercise-enabler games for pediatric hospitalization.

7 Limitations

As is the case with systematic reviews in general, this review does not claim to be comprehensive or include every single existing relevant study. We summarize only the results we obtained through our search terms from the databases mentioned. Our research questions also leave out details that could also be extracted from the identified studies and which may contain information of interest, but we decided to focus on general questions that could shed light on the current state of the literature in this matter and on missing areas of study.

8 Conclusions

We conducted a systematic review with the goal of identifying the current state of works focusing on technological or video games for children in hospital settings and of finding areas of future study. We identified 75 relevant studies, which were analyzed to extract information about the patients they are directed at (their ages and whether the games are applied to children with specific pathologies or undergoing certain medical procedures), the approaches themselves (the technologies used, their purpose, and the number of users considered in a specific game), and the studies conducted to evaluate the solutions.

The results indicate that this topic is of increasing popularity (with more studies being published year after year). Also, that the most common trends in this area are focusing on primary-school children (aged 6-12) undergoing venipuncture treatments or suffering from chronic diseases (mostly cancer), neurological (especially cerebral palsy), or from physical injuries (mostly burns or physical disabilities). The purpose of the solutions designed is mainly to provide a means of distraction or to serve as a motivator to help with physical rehabilitation. The games proposed are usually devised to be played individually, and the most frequently used technologies are, by far, traditional computers or video consoles composed of monitors as output hardware and button-based controllers as input. Finally, we observed that game technologies in pediatric hospital settings seem to improve enjoyment, socialization, and motor functions; increase emotional expressions; and reduce pain, anxiety, distress, and stress. However, there are not many evaluations available on these issues, and more should be carried out to confirm these benefits.

Several lines of future work can be derived from the results. First, designers could also focus on (pre-) kindergarten children (under 6) and teenagers (over 12), and try to find the most suitable game topics and technological devices and interactions for them when in hospital, since each age group presents entirely different needs. Second, psychological (behavioral) pathologies have been mostly neglected when designing games for pediatrics, and, as stated by Horne-Moyer et al. [56], more work is needed in order to know to what extent games can benefit these illnesses. Third, new studies could have purposes other than motivation or distraction, such as socialization, emotion coping, or fostering physical activity. Additionally, other stakeholders like parents/caregivers or hospital staff could benefit from being included in the games. Finally, recent but well-established technologies such as digital tablets should be further explored, and their capabilities (e.g., portability, direct touch) further exploited to better accommodate these goals. The same could be argued for emerging technologies such as companion robots, as well as other interaction mechanisms such as voice or tangible.

A Publications' Details

Work	Year	Age ranges	Procedures and pathologies	Number of users	Purpose	Output device	Input mechanism	Object of study	Outcome
[92]	2001	n/a	Pathologies: Traumatology (neck)	Individual	Motivation	Monitor	Controller	Increased self-confidence	The activity decreased the demand for individual interventions and provided opportunities for improving self-confidence.
[93]	2002	n/a	n/a	Collaborative (online)	Education, socialization	Monitor	Controller	System description and discussion about technology	The use of online collaborative games in e-learning in hospital can enable socialization, which would prevent the loss of humanization that would occur if teachers were replaced by technological devices.
[94]	2002	8-19	Pathologies: Other severe illness	Collaborative (online)	Education, socialization	Monitor	Controller	Reduced pain and loneliness, improved mood, and increased enjoyment	Children reported significantly less loneliness and were significantly more willing to return to the hospital for treatment. They were also marginally less worried and experienced significantly less withdrawn behavior.

[95]	2003	n/a	Pathologies: Chronic (renal disease). Procedure: Venipuncture	Collaborative (online)	Socialization	Monitor	Controller	Feasibility	Results support the premise that computational environments may offer an opportunity for patients to participate in virtual communities that promote coping with chronic physical illnesses.
[96]	2005	5-18	Pathologies: Traumatology (burn)	Individual	Distraction	HMD	Controller	Reduced pain	Strong evidence supporting VR-based games in providing analgesia with minimal side effects and little impact on the physical hospital environment.
[19]	2006	4-12	Procedure: Anesthesia	Individual	Distraction	Handheld	n/a	Reduced anxiety	Patients demonstrated a decrease in anxiety in the preoperative area in the video game group compared to control group.
[97]	2006	8-12	Procedure: Venipuncture	Individual	Distraction	HMD	Controller	Reduced pain	Results show a decrease in affective pain for children in the VR group compared to children in the control group.
[20]	2007	3-9	Procedure: Anesthesia	Individual	Distraction	Handheld	Controller	Feasibility	Most of the children evaluated were able to tolerate the PediSedate

									device and achieved an adequate degree of sedation.
[98]	2007	5-18	Pathologies: Chronic (cancer). Procedure: Venipuncture	Individual	Distraction	HMD, handheld	Controller	Reduced pain and distress	Fear and distress were reduced, but not pain.
[24]	2008	5-18	Pathologies: Neurological (general)	Individual	Motivation	Monitor	Gesture	Increased enjoyment	All participating patients accepted the system and trained in reaching and grasping tasks at a far higher rate than in conventional occupational therapy.
[99]	2008	7-10	Pathologies: Behavioral	Collaborative (co-located)	Motivation	Monitor	Gesture	Increased enjoyment	Analysis shows that patients were strongly motivated and that their behaviors and verbal expressions had rich psychodynamic content.
[25]	2009	n/a	Pathologies: Neurological (cerebral palsy)	Individual	Motivation	HMD	Tangible	Improved motor functions	Participants showed improvements in overall performance on the functional aspects, in upper extremity active range of motion, and in kinematic measures of reaching movements.

[100]	2009	11-15	Procedure: Transplant	Collaborative (online)	Socialization	Monitor	Controller	Improved socialization	Results support the idea that innovative technologies can help adolescent patients to create a support network of peers when face-to-face interactions are impossible.
[22]	2009	5-18	Pathologies: Chronic (cancer). Procedure: Venipuncture	Individual	Distraction	Monitor	Gesture	Increased enjoyment, reduced pain and distress	Results failed to confirm a reduction of pain or distress but did show that non-immersive VR is a positive experience for children undergoing a minor procedure.
[30]	2010	7-12	Pathologies: Traumatology (general physical disability)	Individual	Motivation	Monitor	Gesture	Improved motor functions	The specific game being played had an impact on the quantity and quality of movements. Quantity of movement was significantly higher in experienced players, but there were no differences in movement quality between novice and experienced ones. Also, motivation did not have an effect on movement characteristics.
[43]	2010	3-10	Pathologies: Traumatology	Individual	Education,	Handheld	Touch	Reduced pain	Results show that multi-modal distraction offers superior pain

			(burn)		distraction				reduction when compared to standard practices or hand held video games.
[23]	2010	6-15	Procedure: Cold pressor task	Individual	Distraction	HMD	Voice	Reduced pain	Children demonstrated significant improvement in pain tolerance during distraction relative to baseline.
[101]	2010	n/a	n/a	Collaborative (co-located)	Distraction, socialization	Monitor	Tangible	System description	Zootopia is an RFID-based tangible game to see animals in live streaming videos through collaborative play.
[102]	2010	4-6	n/a	Individual	Emotion coping	Monitor	Controller	System description	CPgame is a game to help children cope with their emotional reactions to medical treatments as well as to self-report their emotional status.
[103]	2010	4-18	Pathologies: Traumatology (general physical disability), neurological (general)	Individual	Motivation	Monitor	Controller	Improved motor functions	The VR scenario induces an immediate effect on motor output to a similar degree as the effect resulting from verbal instructions by therapists.

[104]	2011	3-5	n/a	Individual	Education, distraction	Handheld	Tangible	Increased enjoyment and emotional expressions	Field observation found that children enjoyed naming and decorating the device, and they formed emotional bonds with it. Post-test interviews revealed that all the children felt emotionally attached to the device and expressed their desire to carry it with them next time.
[42]	2011	12	Pathologies: Chronic (general)	Individual	Education	Handheld	Touch	System description	C^3 is a game to provide disease-specific educational content to each patient in their own environment.
[32]	2011	n/a	Pathologies: Neurological (cerebral palsy)	Individual	Motivation	Monitor	Controller	System description	Description of a game for the rehabilitation of the pronation and supination movements.
[105]	2011	n/a	Pathologies: Chronic (cancer)	Collaborative (online)	Distraction, socialization	Monitor	Controller	Increased enjoyment	Results suggest that referring to the pathology implicitly yields higher enjoyment than a game that refers to it explicitly.
[58]	2011	n/a	n/a	Individual	Motivation	Other	Touch	Help to therapists	Results suggest that the platform provides therapists an easy-to-use

									and flexible way of creating new activities for different patients.
[29]	2011	n/a	Pathologies: Traumatology (general physical disability)	Individual, collaborative (co-located)	Motivation	Other	Touch	System description	Presentation of a virtual reality game that uses a hybrid human motion tracking system for gait and dynamic balance, which is able to both track the lower limbs of the user and identify them.
[106]	2011	7-19	Pathologies: Chronic (cancer)	Individual	Education	Monitor	Controller	Increased enjoyment	Results suggest that participants generally enjoyed playing the game.
[107]	2011	8-16	Pathologies: Chronic (cancer)	Collaborative (co-located)	Motivation	Other	Gesture	Reduced depressive symptoms and anxiety	Results show that children in the experimental group reported statistically significant fewer depressive symptoms than children in the control group. However, there were no differences in children's anxiety scores.
[2]	2011	3-7	n/a	Individual	Distraction	Robot	Tangible	System description	MediRobbi is a robot companion that aims to transform an intimidating medical situation into a joyful adventure game by

									accompanying the patient through their procedures.
[108]	2011	4-14	Pathologies: Ophthalmology	Individual	Motivation	Monitor	Controller	Feasibility	It is possible to develop a game-based system to measure fields in children in a noninvasive, affordable, and entertaining way.
[13]	2011	5-10	n/a	Collaborative (co-located)	Distraction, socialization	Monitor	Tangible	Increased enjoyment and improved socialization	Feasible way of encouraging children to communicate with others more while having fun in a hospital setting.
[44]	2011	3-10	Pathologies: Traumatology (burn)	Individual	Distraction	Handheld	Touch	Reduced pain and distress	A combined multi-modal distraction protocol reduced pain and distress experiences for young children during burn care procedures with respect to standard distraction protocols. It also reduced treatment length and pain adverse effects.
[26]	2012	n/a	Pathologies: Neurological (cerebral palsy)	Individual	Motivation	Monitor	Gesture	No more energy expenditure, increased enjoyment, and	Moderate levels of activity achieved in half the games evaluated. Muscle activations did not exceed maximum voluntary exertions. Angular

								improved motor functions	velocities and accelerations were significantly larger in the dominant arm than in the hemiplegic arm. A high level of enjoyment was reported.
[45]	2012	11-17	Pathologies: Traumatology (burn)	Individual	Distraction	HMD	Controller	Reduced pain	Statistically significant reduction in pain scores during dressing removal, and significantly less rescue doses of Entonox given.
[109]	2012	n/a	Pathologies: Chronic (general)	Collaborative (online)	Motivation, socialization	Monitor	Gesture	System description	The work explores the idea of improving communication between medical practitioners and patients using avatars in games to guide and encourage patients to comply with treatments, provide support, and elicit information about their wellbeing.
[110]	2012	4-10	Procedure: Venipuncture	Individual	Distraction	Monitor	Gesture	Reduced pain	Active distraction did not reduce perceived pain more than an EMLA-cream analgesic during iv cannulation and venipuncture.

[40]	2013	4-12	Pathologies: Chronic (cancer)	Individual, collaborative (co-located), competitive (co-located)	Motivation	Monitor	Gesture	System description	Presentation of a game to enhance patients' resilience via mechanisms that stimulate coupling between the brain reward systems and physical actions.
[33]	2013	n/a	Pathologies: Neurological (cerebral palsy)	Individual	Motivation	Handheld	Touch	Help to therapists	The study demonstrates the ability to eliminate factors like distraction from the assessment of patients' motor abilities and progress over time.
[111]	2013	1-3	n/a	Collaborative (co-located)	Education	Handheld	Touch	System description and discussion about best practices	A discussion with experts yields several design guidelines around four categories: preparation of the child, motivation, distraction, and rewarding.
[5]	2013	n/a	Pathologies: Neurological (cerebral palsy)	Individual	Motivation	Monitor	Gesture, voice	System description	Presentation of a multimedia game that can capture kinematic data from live gestures of a child and generate live analytical results.
[112]	2013	5-18	Pathologies: Neurological	Individual	Motivation	Monitor	Controller	Improved motor functions	Children with neurological gait disorders were able to modify their

			(general)						activity to the demands of the VR-scenario, but cognitive function and motor impairment determined to which extent.
[113]	2013	n/a	n/a	Individual, collaborative (co-located)	Distraction	Monitor	Gesture	System discussion	The work proposes a set of themes for games that aim to reframe bodily perception to a more positive self-image full of creative potential.
[114]	2013	n/a	n/a	Individual	Distraction	Monitor	Tangible	Increased enjoyment	Positive reactions.
[27]	2013	n/a	Pathologies: Neurological (cerebral palsy)	Individual	Motivation	Monitor	Gesture	Increased enjoyment and improved motor functions	Most children preferred the game, and balance was significantly improved. However, results did not carry over to functional tasks, hence the need for further research.
[37]	2013	3-18	Pathologies: Other severe illness	Individual	Motivation	Monitor	Gesture	Feasibility	VR exercise may be safely applied in a subset of critically ill children, but several threats to its feasibility in this population were observed.
[115]	2014	8-18	Pathologies:	Individual	Socialization	Monitor	Controller	System description	Participatory design of a game to

			Chronic (cancer)						foster communication.
[116]	2014	n/a	Pathologies: Traumatology (general physical disability)	Individual	Motivation	Monitor	Gesture	System description	Presentation of a web-based 3D game that uses non-invasive methods to recognize body movements.
[38]	2014	n/a	Pathologies: Pulmonary	Individual	Motivation	Monitor	Gesture	No more energy expenditure	One game resulted in light intensity activity and another in moderate intensity activity. No significant difference was seen between patients and healthy control group in the energy cost of playing.
[117]	2014	9-16	n/a	Collaborative (online)	Socialization	Monitor	Controller	Improved socialization and increased emotional expressions	The game was reported to have high playability values, and high amount of interactions and positive emotions were observed during gameplay.
[118]	2014	12	n/a	Collaborative (co-located)	Distraction	Monitor	Controller	Improved socialization and increased emotional expressions	Analysis shows how multiple human and non-human bodies become entangled in gameplace events and potentially generate affective atmospheres.

[31]	2014	5-18	Pathologies: Traumatology (general physical disability), neurological (general)	Individual	Motivation	Monitor	Controller	System description	Presentation of a project that connects rehabilitation games to various therapy devices for upper and lower extremities.
[119]	2014	8	Pathologies: Chronic (general)	Collaborative (online)	Education, socialization	Monitor	Controller	Improved socialization	Results support that multi-modal digital game-based learning provides social interactive processes and learning motivation.
[120]	2014	10-14	Pathologies: Chronic (cancer)	Individual	Motivation	Monitor	Controller	Improved psychological functions	Results show that 3D Graphical Imagery Therapy game is effective in recovering from psychological illness related to brain tumor.
[41]	2014	8-16	Pathologies: Chronic (cancer)	Collaborative (online)	Education	Handheld	Touch	Increased enjoyment	Observations of participants being very receptive, even young ones who sometimes were not aware of the complexity of the games' challenges.
[17]	2015	6-10	Pathologies: Neurological	Individual	Motivation	Monitor	Controller	Improved motor functions	Results demonstrate a statistically significant improvement in the

			(cerebral palsy)						performance metrics assessing explicit and implicit motor learning.
[121]	2015	n/a	n/a	Individual, collaborative (co-located)	Motivation, socialization	Robot	Gesture	System discussion	Discussion about the use of spatial augmented reality techniques on mobile robots for better enabling interactions with children.
[28]	2015	n/a	Pathologies: Neurological (cerebral palsy)	Individual	Motivation	Monitor	Controller	Improved motor functions	Increase in forearm supination/pronation movement precision and smoothness was observed, as well as a reduction in the movement duration.
[122]	2015	4-8	n/a	Individual	Education	Handheld	Touch	System description	Presentation of an educational game to help children prepare for medical procedures.
[39]	2015	5-18	Pathologies: Traumatology (burn)	Individual	Motivation	Monitor	Gesture	Improved motor functions, reduced pain, and increased enjoyment	Results show that interactive videogames are equally effective as traditional therapy for overall range of motion gains and result in quicker recovery of motion with less pain experienced. No differences were found in compliance and enjoyment.

[123]	2015	6-12	Pathologies: Chronic (cancer)	Individual	Distraction	Monitor	Controller	Increased enjoyment and improved socialization	The activities, which range from watching television, to using computers, games, and toys, to drawing, to a clown, provide fun, feelings of joy, distractions, and interactions with other people.
[21]	2015	8-12	Procedure: Minor surgery	Individual	Education	Handheld	Touch	Reduced children's and parents' anxiety	Children who received the educational multimedia intervention reported lower level of worries about hospitalization, medical procedures, illness, and negative consequences than those in the control (no intervention) and in the comparison (entertainment video game intervention) groups. Parents experienced less anxiety when the educational and entertainment interventions were applied.
[124]	2015	4-18	n/a	Collaborative (online)	Motivation	Handheld	Touch	Reduced pain, increased enjoyment, and increased amount of Oral	Results show improvement in pain control and patient satisfaction, but no effect on ORT.

								Rehydration Therapy (ORT) consumed	
[125]	2016	n/a	Pathologies: Pulmonary	Individual	Distraction	HMD	Controller	Increased enjoyment	Users were very immersed in their environments. Seemed to gravitate towards goal-oriented experiences. They were enthralled, and were able to use the device without feeling uncomfortable.
[126]	2016	6-12	Procedure: Venipuncture	Individual	Distraction	HMD	Gaze	System description	User-centered design of a virtual reality game to offer distraction from pain and anxiety that may arise during medical procedures.
[127]	2016	7-18	Pathologies: Traumatology (burn)	Individual	Distraction	HMD	Controller	System description	The DREAM game intends to be an efficient distraction tool to reduce pain and anxiety in children receiving medical treatments.
[18]	2016	6-10	Pathologies: Neurological (cerebral palsy)	Individual	Motivation	Monitor	Controller	Improved motor functions	Feasibility study indicates an improvement in motor functions.

[4]	2016	n/a	Pathologies: Ophthalmology	Individual	Motivation	Handheld	Touch	Feasibility	The game can effectively be used for automated testing of visual acuity.
[128]	2016	7-13	Pathologies: Chronic (cancer), traumatology (general physical disability), neurological (general)	Collaborative (co-located)	Distraction, socialization	Monitor	Touch, gesture	Increased enjoyment	Participants answered they felt creative, happy, "normal" again and had fun.
[129]	2016	4-7	Pathologies: Ophthalmology	Individual	Motivation	Monitor	Controller	Visual improvements	Improvement shown in both control and study group, but improvement in best corrected visual acuity, near visual acuity, and stereoacuity in study group was significantly better.
[130]	2016	4-13	Procedure: Venipuncture	Individual	Distraction	Handheld	Touch	Reduced pain	No improvement was found between being distracted by a hand-held game and by nurses.
[3]	2016	6-10	Pathologies: Chronic (diabetes)	Individual	Socialization	Monitor, handheld, robot	Touch, voice	Increased enjoyment, emotional	Overall positive experience. Children enjoyed the activities, built a relationship with the robot, and

								expressions, and knowledge gains	had a small knowledge gain. Parents and hospital staff pointed to positive effects on child's mood and openness.
[131]	2016	3-6	Procedure: Venipuncture	Individual	Distraction	Monitor	Controller	Reduced pain	Pain intensity in the interventional group was significantly lower than in the control group.
[132]	2016	3-6	Pathologies: Traumatology (burn)	Individual	Distraction	Monitor	Controller	Reduced pain	Pain intensity in the interventional group was significantly lower than in the control group.
[133]	2016	n/a	n/a	Individual	Education	Monitor	Controller	System description	Participatory design of three 3D virtual environments based on games.
[134]	2016	n/a	n/a	Individual	Distraction	Monitor	n/a	Reduced stress and increased enjoyment	High satisfaction and low stress, but informative content was not very clear.

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Highlights

- It is unclear how game technologies can improve children's experience in hospital
- Current trends and gaps were analyzed through 75 out of 1305 studies
- Game technologies present physical and psychological benefits to pediatric patients

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