

Staying Motivated During Difficult Times: A State of The Art of Serious Games for Pediatrics Cancer Patient

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Abstract—Research on the use of digital games for cancer patients suggests positive impact in the form of the reduction of the depressive symptoms, anxiety, and the feeling of nausea after chemotherapy treatment, as well as making time moves quickly. The agency in digital games provides learning and self-development opportunities, while the experience of immersion, flow and presence allow patients to be less aware of their surroundings and the environment of a hospital ward. This can take the child's focus off their condition and their treatment process and direct it towards other aspects of their childhood. A comprehensive review of the current literature was conducted to assess how serious games could positively impact pediatric cancer patients. Searches were conducted in Scopus, Science Direct, IEEE Explorer, and ACM Digital Library. Inclusion criteria were used during data extraction to find the most relevant literature, including the need for a game prototype to have been developed and for the game to specifically target children with cancer as a target audience. Data were extracted including age ranges, treatment and procedure plan, time context, users, purpose, and technology. A total of twelve unique serious games from the literature were included in the review. This review demonstrates the positive use of serious games as an intervention for pediatric cancer patients that undergo treatment in hospital. The results suggest that the design of these serious games should consider (1) purpose of treatment design; (2) technology used as intervention with child cancer patients; and (2) social connection in game play.

Index Terms—Serious Games, Cancer, Children, Pediatric, Comprehensive Review.

I. INTRODUCTION

CANCER is a disease caused by abnormal cell growth in an uncontrolled way and can develop at any stage of life. Childhood cancer, also known as pediatric cancer, often affects children aged between 0-18 years. The number of pediatric cancer patients is dramatically increasing in both developing and developed countries. As an example, in Australia, about 750 children are diagnosed with cancer every year, and the number increased significantly by 35 between 1983 and 2014 [1]. Therefore, the need to support this number of cancer patients has become a concern for health providers and governments around the world.

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Pediatric cancer patients, in particular, require a different support system in comparison to adult patients. Their physiological and psychological needs are different, and a strategy is needed to ensure that they are being empowered to address their condition positively. There is extensive research on coping strategies for cancer patients focusing on either motivation, physical therapy or pharmacological therapy [2] [3] [4]. One of the strategies suggested by researchers is the use of serious games [4].

Serious games are games designed for non-recreational purposes only. Serious games have been widely used in different areas such as health, education, economics, industry, military and politics [5]. Serious games can be used for various specific purposes, the most common are education, training, and behavioural change [6]. Games for health have become popular especially for medical treatments as a means of making the user experience of a treatment more enjoyable and engaging or educating patient on their medical condition or treatment plan [7]. Many games for health are designed and deployed on well-established platforms such as personal computers, game consoles, web browsers and smartphones, making them accessible and easy to for the player.

The use of digital games amongst cancer patients has shown a significant reduction in the symptoms of depression as well as pain management [9]. Digital games research for cancer patients has also shown that playing digital games during a chemotherapy session can significantly reduce the feeling of nausea after receiving the treatment [10]. Games are believed to give enjoyment and engagement, to aid making choices, and to incentivise behaviour change [8]. Therefore, this approach has enormous potential in assisting pediatric cancer patients in coping with the condition by empowering them to fight the disease.

Several previous authors have provided systematic reviews to study the relationship between health games for pediatric . However, many of them focus on chronic diseases in general [11]. Therefore, there is little of research on serious games that focus on pediatric cancer patients specifically and the technology used in serious games for pediatric cancer patients in a hospital setting.

The purpose of this study is to study the literature in a manner to determine whether serious games can positively impact children with cancer and determine what additional variables may play a significant role in helping them progress through this illness. For this review, we focused on reviewing

literature that focused on children with cancer that were hospitalized or under treatment in pediatric wards, including before, during and after their treatment. The review also focuses on emotion change or psychosocial variables as past research suggests that perceptions of self-efficacy, adherence to a plan, and knowledge directly impact patient health outcomes [12]. We also assess the social connection between friends, family and clinician involvement in gameplay, as this social connection seems to play an important role in helping patients reduce feelings of isolation and provides emotional support to children undergoing long-term hospitalization [13].

The rest of the paper is structured as follows. The Related Work section presents a summary of similar work to review games for pediatric health care, including previous relevant classifications of this discipline. In the Methodology section, we describe our approach to the literature search and present our criteria for selection. The Results section contains our findings based on the selection criteria, while the Review of Games section contains a breakdown of the games that were found. Finally, the conceptual framework derived from this literature review process is found in the Discussion, followed by concluding remarks.

II. RELATED WORK

Several previous efforts have been made to provide a general view of serious games in healthcare. There has been a wide array of games for health that have been applied to specific outcomes such as patient rehabilitation therapy [14], motivational engagement [15] and symptom management of children with cancer [10]. Research has also found that digital games can be used to promote physical activities among hospitalised cancer patient [16], increasing a cancer patient's sense of empowerment over their condition [17].

However, to the authors' best knowledge, no review on serious games developed especially for children with cancer currently exists. Sandra Jurdi et al. [18] presented a compilation of games for general pediatric patients that serve as a distractor for children undergoing fearful procedures. They state that game technologies seem to offer physical and psychological benefits to pediatric patients, but further research is still needed. This review focuses on highlighting the key aspects that designers should consider when developing games for pediatric use, which include (1) child development, (2) impact of being in a ward on children, (3) collaboration game strategy for patients at home to reduce isolation, (4) social environment or physical mobility, (5) feedback with parents, specialist interaction with games, and (6) use of new technology to empower motivation and immersion.

Similarly, Holtz et al. [11], reviewed the literature to assess if serious games impact health outcomes for children with chronic diseases. They state that serious games have an impact on children that are hospitalized and suggest that game-based intervention development and study designs should consider (1) designing the interventions from a theoretical framework, (2) self-efficacy or measuring precursors to behaviour change such as disease-specific knowledge, (3) involve parent in game play, and (4) consider the impact of the dose of the game.

Others have reviewed the literature that focused on technology, such as virtual reality (VR) during cancer treatment, but not necessarily with regard to children. In this respect, [19] conducted a review to provide an overview of all the studies that used VR intervention on cancer patients. Their review classified the studies based on the treatment or condition where VR was applied in the time context of during chemotherapy, during painful procedures, and during hospitalization. Based on these studies, they found that VR improved patients' emotional well-being and reduced cancer related psychological symptoms in the different types of settings.

To establish the understanding of pediatric cancer patients being hospitalised, reviews have been done on the management of children with cancer. Hughes and Stark [20] presented a model of care for child cancer patients in oncology wards. The authors suggest that the ward environment in a hospital needs to be tailored specifically to the needs of child patients. Inpatient wards need to be colourful and have facilities for relaxation, such as a games room, to provide patients with an environment that they are happy to attend. They also suggested that child patients present treatment related challenges due to physiological state of their bodies during. For example, child patients receive lower doses of chemotherapy and the experience can be more disorienting for them, due to their emotional and cognitive development. Therefore, it is important to consider how psychological interventions, such as serious games, relate to the time context of the treatment procedure, such as before, during, or after cancer treatment.

The work presented in this paper extends and complements these previous studies by providing a systematic review where serious games were used for pediatric cancer patients, with a focus on the games technology involved, the social engagement of the game, and the time context of the game relative to the treatment. The next section sets out the methodology used for our classification and identifying the most relevant literature to review.

III. METHODOLOGY

In this section, we describe the procedure followed in conducting the systematic review. We explain how the literature was sourced, which studies were considered fitting and how they were analysed to in the context of this study.

A. Databases Searched

The most appropriate database and journals were reviewed in search of reliable data. A comprehensive literature search of peer-reviewed databases and journals relating to information technology, health and social science was conducted. This included Scopus, Science Direct, IEEE Explorer, and ACM Digital Library databases. The two former databases are abstract and citation databases, which in turn direct to other online databases including Springer, PubMed and Wiley Online Library, as well as the latter mentioned IEEE and ACM databases.

B. Search terms

The search string was a combination of different keywords that included the main object as serious games, the subjects considered for example children visiting the hospital, hospitalized or in the pediatric unit and cancer patients, and the approached taken (for example video games technology). More specific terms were added for the approach including videogames or digital or virtual, augmented reality and computer-based solutions. The resulting search string was the following:

Serious game* AND; ((hospital* AND; child*; cancer) OR; pediatric) AND; (technol* OR; reality* OR; video* OR; digital OR; compt*);

C. Inclusion Criteria

The main inclusion criteria were that the work had to refer to a specific serious game designed for a hospital setting with pediatric cancer patients and be a recent work, defined as been published from 2013 on-wards. Besides that, references were searched for the game technology used, the time context of the game (before, during and after treatment) and having an element of social connection between family, friends and clinicians.

D. Data Extraction

Attributes collected included (1) author and year, (2) age range, (3) name of game, (4) treatment and procedure plan, (5) time context (e.g before, during, or after); (6) users (7) purpose and (8) technology.

The analysis procedure of the extracted data was as follows:

- Age range – Each study was analysed to obtain the age range that the authors recommended for their game. The age classification of child and adolescent encompasses different age groups depending on purpose and the country of classification. However, for this review, in the cases where the age is above 20, or no ages were mentioned, the paper was ignored.
- Treatment and Procedure Plan – The procedure and situation of the patients in each cancer treatment were taken into consideration. This refers to when, where, or to whom the serious game interventions were applied.
- Time Context – Each study was analysed for the time of the treatment or procedure where the serious game interventions were applied. This refers to before, during, or after the treatment for patients.
- Users – Each study was analysed to establish whether the authors take into consideration any form of collaborative gaming versus focusing on individual gameplay.
- Purpose – The purpose of each study was established as the improvement or intervention that each approach was after. That is, the goal that was intended for a game to accomplish.
- Technology – All the technologies used in each publication were taken into consideration with special emphasis on serious games that used the platform of mobile games and virtual reality.

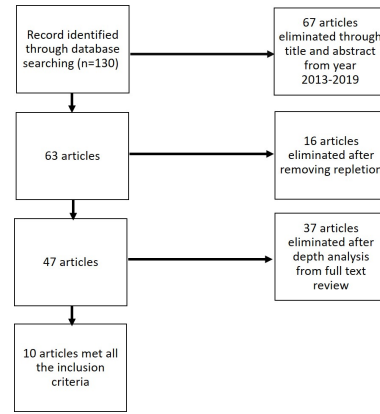


Fig. 1. Flow of information through the different phases of the systematic review.

E. Data Analysis

An initial screening of the pool of papers was performed manually in which the title and abstract were read, and the previously mentioned inclusion 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 it fact not so. Second, to identify and remove duplicate works that are published as separate papers but present the same game design, purpose and procedure plan. Finally, all the information relevant to the research aims was extracted.

TABLE I
SEARCH RESULT SUMMARY

Database	Paper Found	Papers 2013-2019	Papers after removing repetition	Papers after in depth analysis
ACM Digital Library	3	3	3	1
IEEE Explorer	4	2	2	2
Science Direct	102	37	35	2
Scopus	15	15	3	3
Other Sources	6	6	4	2
Total	130	63	47	10

IV. RESULT

After obtaining 130 papers identified by the search terms, 63 were selected after the initial screening of title and abstract and using the inclusion criteria of being published in or after 2013. After removing repeated papers, 47 studies were left. Finally, after the in-depth analysis of each of the remaining studies, only 12 papers were found to be relevant and are reviewed below. The most frequent reason for removing papers after the in-depth analysis despite them having passed previous screenings was that the proposed game was not a serious game for pediatric cancer patients. Table I summarizes the number

TABLE II
CHARACTERISTICS OF QUALIFYING ARTICLES

No	Work	Year	Age Range	Game Name	Treatment/ Procedure Plan	Time Context (Before, During, After)	Users	Purpose	Technology
1	[21]	2019	<18	HealthVoyager	Consultation/ Visits	Before & After	Collaborative-Patients & Physicians	Education & Engagement	Virtual Reality- Tablets and Smartphone
2	[22]	2018	<18	iManageCancer	Therapy	Before, During & After	Collaborative-Patients, Family & Friends	Motivation	Tablets and Smartphone
3	[23]	2018	<18	Farmooo	Chemotherapy	During & After	Individual	Distraction	Virtual Reality- Oculus Rift DK2 & Leap Motion sensor
4	[24]	2018	4-10	Proton U	Proton Therapy	Before & After	Collaborative-Patients & Family	Education	Tablets and Smartphone
5	[10]	2018	7-14	Empower Stars!	Chemotherapy	After	Individual	Physical & Motivation	Mobile Game -iPad
6	[25]	2014	8-18	INTERACCT	Stem Cell Transplant	After	Collaborative-Patients & Clinicians	Socialization, Motivation	Web browser game
7	[13]	2014	7-12	Presence App	Hospitalisation	During	Collaborative-Patients, Family & Friend(School)	Socialization	Tablets
8	[26]	2014	10-14	3D GIT	Therapy	Before & After	Individual	Emotion Coping & Motivation	Desktop Game
9	[27]	2011	7-19	Adventures in Sophoria	Treatment and Hospitalisation	During	Collaborative-Friends & Family	Socialization	Web browser game
10	[3]	2011	7-19	Cytarius	Therapy	After	Individual	Education	Console Game

of papers collected from the databases and the ones remaining after each screening step. Fig. 1 shows these values against a selection flowchart.

V. REVIEW OF GAMES

A. Serious Games for Pediatric Cancer Patient

This section focuses on providing a brief description of each serious game found that is designed for pediatric cancer patients who are hospitalized. All games are described based on treatment procedure involved, when the game was played, the range of technology used, and the social connection elements. Table II provides a summary of these games and the features that were extracted from them, as required by the selection criteria.

Palancica et al. [21] proposed an immersive VR game for pediatric gastrointestinal cancer patients to increase their engagement, education and understanding of their own disease to enhance patient satisfaction and adherence to the treatment. This application uses VR for mobile platforms to visually captivate patients and their families with an animated digital representation of the clinical workflow of an endoscopic procedure. This application, named HealthVoyager, consists of three core components; an interface between clinician and patient to generate a procedure report, the utilization of the individualized data for each patient, and an interactive VR experience for the patient to navigate a virtual endoscopy

or colonoscopy. HealthVoyager works on web interface with drag and drop interactivity. The authors expect that the more patients and their families can visualize and understand their disease, the more satisfied they will become, and the more likely they will be to communicate their symptoms and adhere to their therapies.

Hoffmann and Wilson [22] developed a serious game to support young child cancer patients. They created the iManageCancer app and aim is to motivate patient to stay positive and to participate in social life. The authors believed that child patients have emotional problems while they are hospitalized because of their isolated situation. To improve this, social aspects were included, allowing family and friends to interact via game mechanics with the children. Games were developed for mobile gaming platforms like tablets and smartphones. This project covers all time contexts in the treatment procedure. Before treatment, this game tries to transfer knowledge about the procedure that is about to be performed. During treatment, the design aims to improve self-efficacy by showing children that fighting against cancer is an active process; for example, the players travel in a virtual vessel through a human body and fight virtual cancer cells with different weapons that represent the therapeutic clinical tools against cancer. After the treatment, the design was to lower the child's resistance to returning for another round of treatment, thus providing children with a positive and active attitude in their fight against cancer.

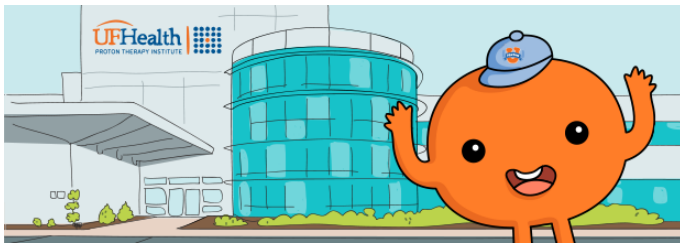


Fig. 2. Conceptual framework for designing effective serious games for pediatric cancer patients.

Ng et al. [23] developed an immersive VR game called Farmoo that has been used as a form of pain distraction for teenage cancer patients while undergoing chemotherapy treatments. The game was developed for children 18 years and below. Farmoo was designed to work on the Oculus Rift head mounted display with a leap motion or Wii Controller for input. The game is played individually and enables players to feel immersed in the tailored virtual world. In Farmoo, designers used metaphors for the life of teen cancer patients. The idea was to implement distracting gameplay elements while also offering a way for patients to look forward for the future by growing and harvesting plants in virtual farms. To demonstrate Farmoo as a medium of distraction, the authors tested the game with cancer patients, with a post-test questionnaire and discussion circle.

Florida Proton Therapy Institute [24] developed the a mobile games application for pediatric cancer patients called Proton U. The game aims to teach patients about proton therapy for the purposes of education, motivation, and engagement. The Proton U system educates patients before the treatment with a description on the coming procedure, while after the treatment it is used more for therapy for increased motivation of the patients. In Proton U, the narrative invites patients to attend a virtual preparatory school where they learn about proton therapy. The main character includes a specialist (the narrator and teacher) and the patient (Jefferson) as shown in Fig. 2. Proton U provides social connection and interaction between patients and family for preparing them on proton therapy treatments and the games aims to increase patient empowerment between patients and family with knowledge about their upcoming medical procedure. Finally, the system is intended to be used both in a home setting after the treatment as well as at a hospital before the treatment.

Bruggers et al. [10] developed a game named Empower Stars. This games purpose was to directly couple physical exercise with promoting personal empowerment over cancer. The game requires 20 minutes of exercise within a 30 minute, once a day gameplay session involving superheroes, space exploration, metaphorical cancer challenges, life restoration on planets, and star rewards. In the game, players also never die, giving a sense of resilience against the challenges that are faced. Empower Stars uses a mobile platform and was created for children ages 7-14 years with cancer that are undergoing chemotherapy treatments. Promoting exercise and motivation using video games technology facilitates usability and widespread dissemination for children with cancer, with

the game being portable and easy to play. Additionally, the author conducted a series of usability assessments centered on a multilevel user approach between children with cancer, their parents and clinicians. This approach reduces stress and increases motivation by promoting personal empowerment over cancer using mobile platform.

INTERACCT (Integrating Entertainment and Reaction Assessment into Child Cancer Therapy) is a serious game developed by [25]. This online game aims at providing a child-friendly communication channel between outpatients and their clinicians. This project seeks to increase motivation for stem cell transplant treatment patients after they have been discharged from hospital and help them communicate directly with clinicians. The game involves preparing patients for their life after treatment by encouraging patients to give feedback to their clinicians regarding their current health status. This maintains social connection between patients and physicians for developing effective values-based interventions for cancer survivors. The authors present an explorative design approach with the stakeholders and conducted a quantitative survey to compare the gaming habits and preferences of the patients. The author also used a participatory design approach to create a suitable character, stories and game mechanics which are interesting to child players. It was found that the use of user centred and participatory design methods at early stages of project helps to develop an effective gamified communication tools for children after their cancer treatment.

Children who are hospitalised and are isolated for significant periods of time will face big challenges to their wellbeing. In response to this, Wardley et al. [13], designed Presence App, a tablet game application that combined an ambient presence with photo-sharing to connect hospitalised children with schools and families. The objective of the game is to increase motivation while reducing loneliness and a sense of isolation. Based on this study, it shows that communication technology, a good design, and being sensitive to the context can reduce isolation and improve the emotional wellbeing of children undergoing long-term hospitalization.

Sajjad et al. [26] studied the used of fixed imagery psychotherapy incorporated into game design. The authors developed a 3D game with cognitive behavioural effects on children suffering from brain tumours. The game's name is 3D GIT; the main theme of the game is that the patient hits an enemy character through the use of weapons. The enemy character is represented as a brain tumour and in destroying it, the health bar of the player is increased. The gameplay includes the consumption of medicine and fruit pick-ups that increase the health of player to encourage healthy living and adherence to medication consumption. This game is only played by individual patients and does not have collaborative in social connection. In the evaluation of the game, the authors assessed psychological symptoms through the Beck Youth Inventories [27] using pre and post assessment to measure the level of anxiety of patients. The game was effective for brain tumour patients to alleviate anxiety, depression, anger and disruptive behaviour related to this illness and to improve their self-concept. The 3D GIT game showed a significant difference in the psychological illness of children with brain tumours as



Fig. 3. Conceptual framework for designing effective serious games for pediatric cancer patients.

compared to the patients only on medical treatments.

Fuchslocher et al. [28] present a prototype named *Adventures in Sophoria*, as seen in Fig. 3. This online game prototype aims at facilitating the social communication of teenagers during their cancer treatment. In *Sophoria*, the player needs to enter into a fantasy world that has been attacked by an alien force. The game starts with a short tutorial, in which the player is accompanied by a personalized pet, which carries the player’s inventory and is designed to support the player throughout their journey. The game equips pediatric cancer patients with communication tools like bulletin boards, sending messages to friends from within the game, and keeping a diary for staying in touch with classmates and friends during their treatment period, while also providing a form of entertainment. The authors conducted an evaluation in order to explore possible differences between the implicit and explicit health game versions in regard to acceptance and enjoyment. By this means, communication beyond in-game collaboration is encouraged. Based on this study, parents suggested that the need for an online environment specifically designed for children with cancer and thus revealing a positive attitude towards an explicit health game.

Finally, Gerling et al. [3] present a casual game with a focus on the integration of serious game elements. The authors develop a game prototype called *Cytarius* which aims to illustrate cancer treatment and to convey information about the disease through the games story and mechanics, with the overall purpose to increase knowledge of child cancer patients. In *Cytarius*, the player is offered the role of a strategic commander. To master the game, it is crucial to coordinate the activities of *Cytowarriors* are equipped with different weapons which were designed based on different cancer treatments. This game is useful in hospital settings and for patients at home. The authors did a usability and accessibility assessment of the game with cancer patients through the *Game Experience Questionnaires (GEQ)* [29]. Interviews were also conducted to get players’ perceptions and opinions of parents and medical staff. The results showed that the game is suited to be played in a hospital setting and that it is widely accessible to its players

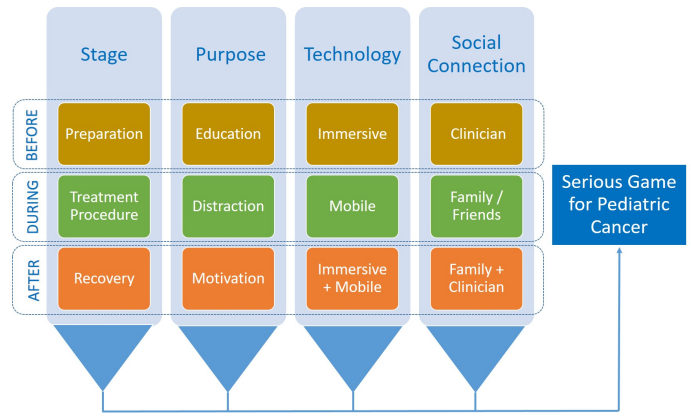


Fig. 4. Conceptual framework for designing effective serious games for pediatric cancer patients.

despite cognitive and physical consequences of the disease.

VI. DISCUSSION

Based on the review that has been conducted, we concluded that attributes such as the purpose of serious games, the stage of treatment, the technology used, and the social connection resulting from the game would have a relationship with each other to produce an effective serious game for this target audience. As most cancer treatments require unpleasant hospitalisation, each of the attributes can be further divided into the time context that is before, during, and after treatment while in hospital. Thus, we suggested the conceptual framework is Fig. 4 that outlines the attributes and the time contexts that were commonly seen in the literature that was found. This framework can be used as guide when beginning to design and develop a serious game for hospitalized in order to develop serious games for pediatric cancer patients.

A. Stage

Each stage of the treatment process, defined by the time context, has a different set of health objectives associated with it, along with related patient and physician activities. At the early stage of treatment, preparation of the emotional and physical resilience of patients is essential. The medical staff are preparing the treatment and attempting to make the patient comfortable with the environment they are in and process they are about to undergo. Next, the treatment will begin. The games that were reviewed each typically targeted specific set of treatment procedures. This is because, when designing a game to be played during the treatment, it is important to consider what mobility and attentional focus patients will be able to afford without disrupting the treatment procedure. Finally, after the treatment is completed, the patient enters a recovery stage where their own actions have the most impact on their health. Encouraging patients to perform low-exertion physical activity, engage with peers and family, and possess positive thought patterns can have a significant effect on the physical and mental health of the patient.

B. Purpose

From the analysis of the games in this review, we found a relationship between the stage of treatment and the purpose of the serious game that was designed. Before the treatment begins, a common approach found in the literature to prepare patients was to educate them on their condition and the treatment procedure or to provide a tool for personal coaching [21]. This encourages the patient to come to terms with what is happening and to give them encouragement to withstand any pain they may feel during the treatment. Serious games are used here to provide this education in a more engaging and enjoyable way [24]. During the game, a common purpose for many of the games was to distract the patients from the treatment itself through entertainment [23], as well as to provide motivation and opportunities to socialize during the treatment. This distraction may allow children to remain calm and stay still during lengthy or reasonably delicate procedures. There are also opportunities at this stage to use games to increase communication between the patient and the physician and for the game to gather data on the patient in subtle or indirect ways regarding their current state, such as the level of pain they are currently feeling. Finally, during the recovery stage after a procedure, a patient may need remain within the hospital ward for extended period of time, potentially between multiple treatment sessions. During this time, these children may have negative physiological effects such as fatigue, nausea, muscle weakness, and ongoing pain. They may also experience negative emotional effects, such as anxiety, fear, anger, and depression [29] resulting from the memory of the procedure, divergences from their typical daily routine, dietary restrictions, interruptions to normal education, and their isolation from their social connections [13] (other than selected family members). Thus, serious games should aim to reduce one of these negative physical [16] or emotional [30] effects by motivating patients to re-engage with healthy living practices and giving a sense of agency and self-efficacy over their own well-being. In this way, the ability of the games to act on neural mechanism which activate positive emotions, such as feedback reward systems in the game, help to improve pediatric cancer patients' world view as they face the daily challenges of their illness [31].

C. Technology

From the review of serious games, we observed that mobile games, web browser games and virtual reality are the most commonly used technology to deliver the game experience. Using mobile games implies a variety of gaming styles. For example, mobile games using iPad are easy to carry and allow for more active play styles for physical rehabilitation purposes but are also good for co-located social games where children can see each other moving around. The use of mobile games seems to be more suitable over traditional desktop and console games because they are easy to setup and adapt better to the user's posture when, for example, they are restricted to a bed. If the children have their own device, it also allows them to easily carry the device between areas in the hospital as well as to easily continue to play when they are at home. The

interaction with these devices via direct touch is well accepted and usable by children [32] but Jurdi et al. [18] state that the potential of touch interactions with mobile devices has and their benefits has not yet been explored deeply in hospital settings.

Recently, Head-Mounted Displays (HMDs) for virtual reality have become popular and more commercially accessible. Devices such as the Oculus Rift, HTC Vive and PlayStation VR enable immersive virtual reality environments, while mobile VR headsets, such as the Google Cardboard and Samsung Gear VR, are affordable and easy to set up. This technology, cognitively abstracts the children from their situation and is an effective medium of distraction for their pain [23] and engagement in education [21]. Palanica et al [21] suggest that VR is suitable as a viable solution to enhance patient satisfaction and knowledge comprehension due to the large amount of literature supporting its effectiveness in healthcare education. However, VR technology should be used with caution, because it can produce motion sickness symptoms [33] and should be suitable for treatment and procedure plan for the patients. There should also be enough of these potentially expensive devices to support the number of inpatients at the hospital and procedures for sterilization between use to prevent the spread of secondary diseases and infections between children with weakened immune systems.

From this review, we found none of the studies were concerned about technology availability and restriction in hospital setting for example internet infrastructure, socio-economic status of the patient's family and hospital conditions. Most papers assume that the technology is available to the hospital and family. However, pediatric cancer is global issue and games may need to be designed to target certain disadvantaged patient groups and hospitals with limited infrastructure and funding.

D. Social Connection

A significant problem for children with cancer, especially while they are hospitalised, is their isolation from family, friends and school peers. To improve this, most of the serious games include a social aspect. This allows family and friends, and in some cases the clinicians, to interact with the child using game mechanics. This allowed the family members to support the ill children and include them as an important part of the treatment. Patients expressed the desire to have more contact with their regular friends, preferring this interaction over the option of playing with other hospitalized children and games such as Mission Possible [34] allow for interaction with family and friends after completing the treatment in the hospital. These types of games allow family and friends to play and contribute to the child's sense of achievement, allowing the child to witness their support structure in action and giving others the opportunity to provide motivation to the child.

Hospitalised patients also receive less schooling, resulting in gaps in their education as well as missing valuable social experiences. Based on [33], pediatric cancer patients report wishing they could attend their school more and often repeat grades. This forces patients to be isolated from their social

environment and therefore affects their psycho-emotional development. Serious games can be used as a communication technology to reduce isolation and improve the emotional wellbeing of children undergoing long-term hospitalization.

Finally, social connection between patients and clinicians is also important. Open channels of communication between patients and clinicians can help in determining the patients current health status and clarify any concerns or misunderstandings regarding the patients condition and procedure plan [25].

VII. CONCLUSION

We conducted a comprehensive review with the goal of identifying the current state of studies focusing on serious games for pediatric cancer patients that undergo treatment in hospital, with the aim of finding areas of future study. We identified 10 relevant current studies, which were analysed to extract information regarding the target audience for the game, the technology used, the purpose of the game, and the time context of the game. This review demonstrates that using serious games for pediatric cancer patients has many positive effects and we have provided some key guidelines which will help future game design processes for this audience. We suggested that these serious games should consider (1) the objectives of the designed solutions need to relate with procedure or treatment of patients and whether the game is to be played before, during or after the treatment; (2) the technology that will be used during gameplay, its appropriateness to the hospital and treatment setting, its accessibility for various socio-economic groups, and how it will improve enjoyment, socialization, increase emotional expression and reduce stress and anxiety; and (3) how the game will involve families, friends and clinicians as social connections during the treatment for child patients. Yet, more work is needed in order to know to what extent serious games can benefit child cancer patients for the purpose of motivation, distraction, emotional well-being, and fostering physical activity and how immersing human-computer interaction technologies in robotics and mixed reality can contribute to these benefits.

REFERENCES

- [1] "Cancer council and childhood cancers," <https://www.cancer.org.au/about-cancer/types-of-cancer/childhood-cancers/cancer-council-and-childhood-cancers.html>, accessed: 2019-01-23.
- [2] M. Prensky, "Digital game-based learning computers in entertainment (cie)," *Listen to the natives Educational Leadership*, 2003.
- [3] K. Gerling, A. Fuchslocher, R. Schmidt, N. Krämer, and M. Masuch, "Designing and evaluating casual health games for children and teenagers with cancer," in *International Conference on Entertainment Computing*. Springer, 2011, pp. 198–209.
- [4] M. Ghazisaeidi, R. Safdari, A. Goodini, M. Mirzaiee, and J. Farzi, "Digital games as an effective approach for cancer management: Opportunities and challenges," *Journal of education and health promotion*, vol. 6, 2017.
- [5] S. de Sousa Borges, V. H. Durelli, H. M. Reis, and S. Isotani, "A systematic mapping on gamification applied to education," in *Proceedings of the 29th annual ACM symposium on applied computing*. ACM, 2014, pp. 216–222.
- [6] B. Stokes, "Videogames have changed: time to consider serious games??" *Development Education Journal*, vol. 11, no. 3, p. 12, 2005.
- [7] I. L. Beale, P. M. Kato, V. M. Marin-Bowling, N. Guthrie, and S. W. Cole, "Improvement in cancer-related knowledge following use of a psychoeducational video game for adolescents and young adults with cancer," *Journal of Adolescent Health*, vol. 41, no. 3, pp. 263–270, 2007.
- [8] I. of Digital Media, C. D. W. G. on Games for Health, T. Baranowski, F. Blumberg, R. Buday, A. DeSmet, L. E. Fiellin, C. S. Green, P. M. Kato, A. S. Lu, A. E. Maloney *et al.*, "Games for health for children—current status and needed research," *Games for health journal*, vol. 5, no. 1, pp. 1–12, 2016.
- [9] C. G. Brown-Johnson, B. Berrean, and J. K. Cataldo, "Development and usability evaluation of the mhealth tool for lung cancer (mhealth tlc): a virtual world health game for lung cancer patients," *Patient education and counseling*, vol. 98, no. 4, pp. 506–511, 2015.
- [10] C. S. Bruggers, S. Baranowski, M. Besisis, R. Leonard, D. Long, E. Schulte, A. Shorter, R. Stigner, C. C. Mason, A. Bedrov *et al.*, "A prototype exercise-empowerment mobile video game for children with cancer, and its usability assessment: developing digital empowerment interventions for pediatric diseases," *Frontiers in pediatrics*, vol. 6, p. 69, 2018.
- [11] B. E. Holtz, K. Murray, and T. Park, "Serious games for children with chronic diseases: A systematic review," *Games for health journal*, vol. 7, no. 5, pp. 291–301, 2018.
- [12] P. M. Kato, S. W. Cole, A. S. Bradlyn, and B. H. Pollock, "A video game improves behavioral outcomes in adolescents and young adults with cancer: a randomized trial," *Pediatrics*, vol. 122, no. 2, pp. e305–e317, 2008.
- [13] G. Wadley, F. Vetere, L. Hopkins, J. Green, and L. Kulik, "Exploring ambient technology for connecting hospitalised children with school and home," *International Journal of Human-Computer Studies*, vol. 72, no. 8–9, pp. 640–653, 2014.
- [14] B. Lange, S. Koenig, E. McConnell, C.-Y. Chang, R. Juang, E. Suma, M. Bolas, and A. Rizzo, "Interactive game-based rehabilitation using the microsoft kinect," in *2012 IEEE Virtual Reality Workshops (VRW)*. IEEE, 2012, pp. 171–172.
- [15] Y. Huh, J. Klaus, and M. El Zarki, "ixercise: An immersive platform for exercise intervention for special needs populations," in *2016 IEEE/ACS 13th International Conference of Computer Systems and Applications (AICCSA)*. IEEE, 2016, pp. 1–7.
- [16] P. Jahn, N. Lakowa, M. Landenberger, D. Vordermark, and O. Stoll, "Interactiv: an exploratory study of the use of a game console to promote physical activation of hospitalized adult patients with cancer," in *Oncology nursing forum*, vol. 39, no. 2, 2012.
- [17] C. Caldwell, C. Bruggers, R. Altizer, G. Bulaj, T. D'Ambrosio, R. Kessler, and B. Christiansen, "The intersection of video games and patient empowerment: case study of a real world application," in *Proceedings of The 9th Australasian Conference on Interactive Entertainment: Matters of Life and Death*. ACM, 2013, p. 12.
- [18] S. Jurdi, J. Montaner, F. Garcia-Sanjuan, J. Jaen, and V. Nacher, "A systematic review of game technologies for pediatric patients," *Computers in biology and medicine*, vol. 97, pp. 89–112, 2018.
- [19] A. Chirico, F. Lucidi, M. De Laurentiis, C. Milanese, A. Napoli, and A. Giordano, "Virtual reality in health system: beyond entertainment. a mini-review on the efficacy of vr during cancer treatment," *Journal of cellular physiology*, vol. 231, no. 2, pp. 275–287, 2016.
- [20] N. Hughes and D. Stark, "The management of adolescents and young adults with cancer," *Cancer treatment reviews*, vol. 67, pp. 45–53, 2018.
- [21] A. Palanica, M. J. Docktor, A. Lee, and Y. Fossat, "Using mobile virtual reality to enhance medical comprehension and satisfaction in patients and their families," *Perspectives on medical education*, vol. 8, no. 2, pp. 123–127, 2019.
- [22] S. Hoffmann and S. Wilson, "The role of serious games in the imangeancer project," *ecancermedicalscience*, vol. 12, 2018.
- [23] J. Ng, H. Lo, X. Tong, D. Gromala, and W. Jin, "Farmoo, a virtual reality farm simulation game designed for cancer pediatric patients to distract their pain during chemotherapy treatment," *Electronic Imaging*, vol. 2018, no. 3, pp. 432–1, 2018.
- [24] N. W. Stephenson, K. E. Todd, D. J. Indelicato, and S. H. Arce, "Designing and developing a mobile application to prepare paediatric cancer patients for proton therapy," *Design for Health*, vol. 2, no. 1, pp. 77–88, 2018.
- [25] F. Kayali, K. Peters, A. Reithofer, R. Mateus-Berr, Z. Lehner, D. Martinek, M. Sprung, M. Silbernagl, R. Woelfle, A. Lawitschka *et al.*, "A participatory game design approach for children after cancer treatment," in *Proceedings of the 2014 Workshops on Advances in Computer Entertainment Conference*. ACM, 2014, p. 16.
- [26] S. Sajjad, A. Hanan Abdullah, M. Sharif, and S. Mohsin, "Psychotherapy through video game to target illness related problematic behaviors of

