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# Staying Motivated During Difficult Times: A Snapshot of Serious Games for Paediatric Cancer Patients

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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. 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 paediatric cancer patients. 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. The resulting serious games were grouped based on their purpose and were classified in three main categories; motivation, education and distraction. This review demonstrates the positive use of serious games as an intervention for paediatric cancer patients that undergo treatment in hospital. The results suggest that the design of these serious games should consider (1) the purpose of the game within the treatment plan of target audience; (2) the accessibility and suitability of the technology used for the game; and (3) social connection during play.

**Index Terms**—Serious Games, Cancer, Children, Paediatric, 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 paediatric cancer, often affects children aged between 0-18 years. The number of paediatric 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 this number increased 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.

Paediatric 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 and used outside of the context of pure entertainment [5]. Here, the serious game is a game designed for a primary purpose but explicitly emphasises the added pedagogical value of fun and competition [6]. Serious games have been widely used in different areas such as health, education, economics, industry, military and politics [7]. Serious games can be used for various specific purposes for improving an individual's quality of life, with the most common being education, training, and behavioural change [8]. 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 patients on their medical condition or treatment plan [9]. 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 use for the player [10].

The use of digital games amongst cancer patients has shown a significant reduction in the symptoms of depression and pain management [11]. 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 [12]. Games are believed to give enjoyment and engagement, to aid making choices, and to incentivise behaviour change [10]. Therefore, this approach has enormous potential in assisting paediatric cancer patients in coping with the condition by empowering them to stay motivated and think positively during their treatment.

Previous studies have explored the relationship between games for health and paediatric patient. However, many of these studies were generally focused on the use of digital games among children with chronic diseases [13]. Therefore, there is little of research on serious games that focus on paediatric cancer patients specifically and the technology used in serious games for paediatric cancer patients in a hospital setting.

The purpose of this study is to study the literature and 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 condition. For this review, we focused on reviewing literature on children with cancer that were hospitalized or under treatment in paediatric 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 [14]. 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 [15].

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

## 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 [16], motivational engagement [17] and symptom management of children with cancer [12]. Research has also found that digital games can be used to promote physical activities among hospitalised cancer patients [18], increasing a cancer patient's sense of empowerment over their condition [19].

However, to the authors' best knowledge, no review on serious games developed especially for children with cancer currently exists. Sandra Jurdi et al. [20] presented a compilation of games for general paediatric patients that serve as a distractor for children undergoing fearful procedures.

They suggest that with the latest advancement of game technologies, digital games are now able to offer both physical and psychological benefits to paediatric patients. This is however, is depending on further research. This review focuses on highlighting the key aspects that that need to be considered in developing games for paediatric use, which include (1) child development, (2) impact of being in a ward on children, (3) collaborative gameplay 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. [13], 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 parents in gameplay, 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, Chirico et al. [21] conducted a review to provide an overview of all the studies that used virtual reality (VR) interventions for 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 paediatric cancer patients being hospitalised, reviews have been done on the management of children with cancer. Hughes and Stark [22] 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 their physiological state. 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 session.

The work presented in this paper extends and complements these previous studies by providing a comprehensive review where serious games were used for paediatric cancer patients and, 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 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 paediatric 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; paediatric) AND; (technol\* OR; reality\* OR; video\* OR; digital OR; compt\*);

### C. Inclusion Criteria

The main inclusion criteria were that the studies had to refer to a specific serious game designed and develop for a hospitalised paediatric cancer patients and be a recent work, defined as been published from 2010 until 2020. In addition, 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 of target audience, (3) name of the game, (4) treatment and procedure plan that the game was designed to compliment, (5) time context (e.g before, during, or after) of when the game was to be played, (6) users involved in the gameplay, (7) purpose of the game in improving the child's wellbeing and (8) the technology used to present and interact with the game.

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 discarded.
- Treatment and Procedure Plan – The procedure and situation of the patients in each cancer treatment were taken into consideration. This refers the conditions under which the serious game interventions were applied.
- Time Context – Each study was analysed for the time of the treatment where the serious game interventions were applied. This refers to before, during, or after the treatment.
- Users – Each study was analysed to establish whether the authors take into consideration any form of social gameplay 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 platforms of mobile games and virtual reality.

### E. Data Analysis

A starting screening of the pool of papers was performed manually in which the title and abstract were read, and the

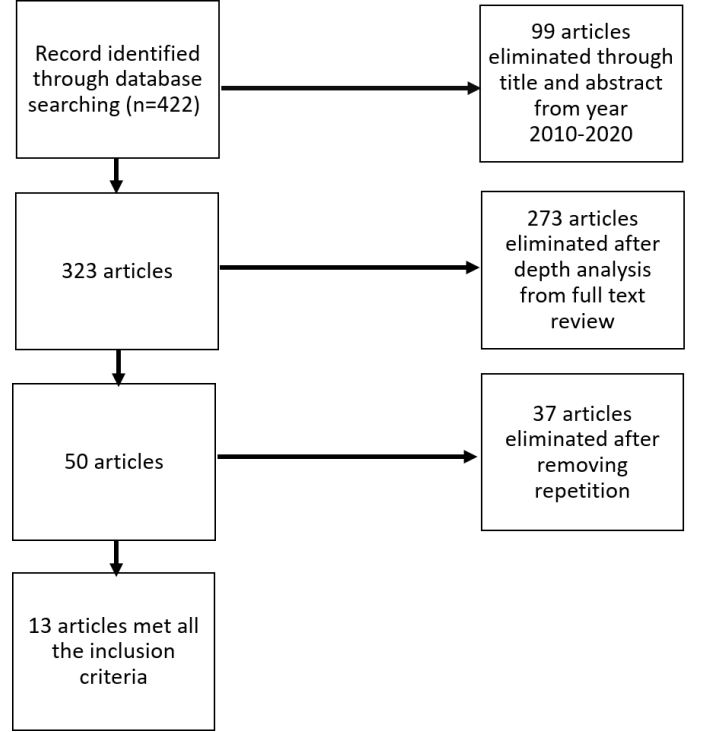


Fig. 1. Flow of information through the different phases of the systematic review.

previously mentioned inclusion criteria were used. The next step was to remove the repeated papers. Finally, an in-depth analysis of each remaining study was conducted of which it started with identifying and removal of any work that may have seemed relevant from the title and abstract but was in fact not applicable. Next, redundancy is identified through removal or works containing the same game design that were published as separate papers. Finally, all the information relevant to the research aims was extracted.

TABLE I  
SEARCH RESULT SUMMARY

Database	Paper Found	Papers 2010-2020	Papers after removing repetition	Papers after in depth analysis
ACM Digital Library	65	59	3	1
IEEE Explorer	4	2	2	2
Science Direct	263	209	35	2
Scopus	74	41	3	3
Other Sources	16	12	7	5
<b>Total</b>	<b>422</b>	<b>323</b>	<b>50</b>	<b>13</b>

## IV. RESULT

Based on the search results, 422 papers were identified and 323 were selected based on screening of title, abstract and inclusion criteria. Subsequently, any repeated paper is removed with 50 papers left for in-depth analysis. However, only 13 papers were found to be relevant for further review. The main

reason for removal of these papers despite them passing the previous screening process was that the proposed game was not related to serious games for paediatric cancer patients. Table I summarizes the number of papers collected from the databases and the number of remaining papers after each screening step. Fig. 1 shows these values against a selection flowchart.

## V. REVIEW OF GAMES

### A. Serious Games for paediatric Cancer Patient

This section focuses on providing a brief description of the serious games found in the literature that are mindfully designed for pediatric cancer patients in a hospital setting. The resulting games were grouped based on their purpose and were classified in three main categories: motivation, education, and distraction. Table II provides a summary of these games and their key features.

**Motivation:** Serious games have the potential to be used to promote motivation and engagement of the cancer patients during and after the treatment. During the cancer treatment procedure, pediatric cancer patients can experience long periods of hospitalization that trigger emotions such as loneliness, sadness and fear. For example, HabitApp [23] puts the users in contact with each other, with permanently present external contact between patients and caregivers being the main target. HabitApp is an effective motivation and engagement tool that improves patients' and caregivers experiences while warded. Triumf [24] was also developed to reduce the negative psychological changes for pediatric cancer patients through a serious game. The game was designed in cooperation with patients, parents and care teams to determine illness-related burdening factors during the treatment and develop a solution for the patients. This game provides psychological support that is dependent on the individual emotional state of the patient.

These types of serious games for motivation can also be used after a treatment session has been completed. For example, Kayali et al. [25] provide a child-friendly communication channel to patients after the treatment and promote personal empowerment over cancer called INTERACCT (Integrating Entertainment and Reaction Assessment into Child Cancer Therapy). 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 clinicians for developing effective values-based interventions for cancer survivors. Bruggers et al. [12] developed a game named Empower Stars, which promotes exercise and motivation using video game technology to facilitate usability and widespread dissemination for children with cancer, with the game being portable and easy to play. This approach reduces stress and increases motivation by promoting personal empowerment over cancer using mobile platform after the treatment.

Taking a holistic approach, Hoffmann and Wilson [26] developed a serious game to support young child cancer patients during the entire treatment lifecycle, acknowledging that

the children can be psychologically impacted before, during and after the treatment. The game is named iMangeCancer and the aim is to motivate patients to stay positive and to participate in social life. Before treatment, this game tries to transfer knowledge about the procedure that is about to be performed with the aim of making patients more at ease and less surprised with what is going to happen. During the 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 goals were 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. Similarly, Sajjad et al. [27] studied the use of fixed imagery psychotherapy incorporated into game design. The authors developed a 3D game with cognitive behavioural effects on children suffering from brain tumours after the treatment. 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 throughout the disease and treatment lifecycles.

Social interaction also appears to be a core theme in supporting children's emotional health while hospitalised. Wadley et al. [15] designed the Presence app, a tablet game that was combined with photo sharing to connect hospitalised children with schools and families. This game focuses on improving the emotional wellbeing of children undergoing long-term hospitalisation and isolated for significant periods of time while reducing loneliness and sense of isolation. Fuchslocher et al. [28] present a prototype named Adventures in Sophoria, a game to facilitating the social communication using bulletin boards, sending a message to friends from within the game and keeping a diary for staying touch with classmates and friends during their treatment period. 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. Both of these paper papers provide social connection-oriented health games as a communication tool for staying in touch with friends and family during treatment and hospitalisation. However, based on all the serious games that have been analysed in this study, most include a social aspect that allows family, friends and in some cases the clinicians to interact with the child using game mechanics. For that reason, we have not categorised social connection as a separate category of one of the primary purposes of serious games. Instead, later in our resulting framework, social connection is a feature that permeates across all stages of the treatment process in one way or another.

**Education:** Papers [29] [30] [31] [3] focus on increasing knowledge and understanding of their own disease. This educates patients before the treatment on the coming procedure, while after the treatment it is used more to understand the recovery process. For example, the application named HealthVoyager [29] uses VR for mobile platforms to captivate patients and their families with an animated digital representation of the clinical workflow of an endoscopic procedure. The

TABLE II  
SEARCH RESULT SUMMARY

Purpose	Work	Year	Age Range	Game Name	Treatment/ Procedure Plan	Time Context (Before, During, and After)	Users	Technology
Motivation	[23]	2020	1-16	HabitApp	Therapy	During	Collaborative -Patients and Parents	Tablet
	[24]	2019	7-14	Triumf	Therapy	During	Collaborative - Patients, Parents and Clinicians	Mobile Game
	[26]	2018	<18	iManageCancer	Therapy	Before, During and After	Collaborative - Patients, Parents and Friends	Tablets and Smartphone
	[12]	2018	7-14	Empower Star!	Chemotherapy	After	Individual	Mobile Game -iPad
	[27]	2014	10-14	3D GIT	Therapy	Before and After	Individual	Desktop Game
	[25]	2014	8-18	INTERACCT	Stem Cell Transplant	After	Collaborative - Patients and Clinicians	Web browser game
	[15]	2014	7-12	Presence App	Hospitalisation	During	Collaborative - Patients, Parents and Friends(School)	Tablets
	[28]	2011	7-19	Adventures in Sophoria	Treatment and Hospitalisation	During	Collaborative - Parents and Friends	Web browser game
Education	[29]	2019	<18	HealthVoyager	Consultation/ Visits	Before and After	Collaborative - Patients and Clinicians	Virtual Reality- Tablets and Smartphone
	[30]	2018	4-10	Proton U	Proton Therapy	Before and After	Collaborative - Patients and Parents	Tablets and Smartphone
	[31]	2017	8-12	The City of Dreams	Chemotherapy	During	Individual	Desktop Game
	[3]	2011	7-18	Cytarius	Therapy	After	Individual	Console Game
Distraction	[32]	2018	<18	Farmooo	Chemotherapy	During and After	Individual	VR Oculus RiftDK2 and Leap Motion Sensor

Proton U [30] 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. Proton U, as shown in Fig. 2, provides social connection and interaction between patients and family for preparing them on proton therapy treatments and the game aims to increase empowerment for patients and families with knowledge about their upcoming medical procedure.

With many cancer patients also needing to go through the chemotherapy protocol, education about the treatment, side effects, and self-care behaviors of this protocol should be conducted in a specific and limited period surrounding the treatment. The City of Dreams [31] was developed to give information on the process of chemotherapy during the procedure and suitable for educating the patients and their families and providing emotional support. Finally, Gerling et al. [3] 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. Therefore, the use of serious games as a purpose of education were effective as a tool in influencing health-related behavior and improving the quality of life of children undergoing chemotherapy.

**Distraction:** Serious games can be used as a tool to divert attention from the often reported painful medical procedures. Adding elements of distraction allow patients to better cope with their treatments. For example: Ng et al. [32] developed an immersive VR game called Farmooo that was used as a form

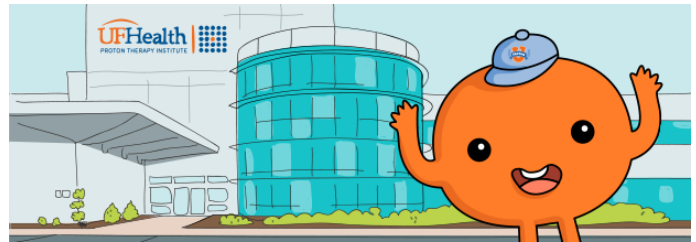


Fig. 2. Proton U screenshots of main menu. Color images available at <https://www.floridaproton.org/newsletter/2017/january/customized-app-proton-u-will-aid-children-cancer-treatment>

of pain distraction for teenage cancer patients while undergoing chemotherapy treatments. The game was developed for children 18 years and below. Farmooo 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 Farmooo, 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 to the future by growing and harvesting plants in virtual farms. To demonstrate Farmooo as a medium of distraction, the authors tested the game with cancer patients, with a post-test questionnaire and discussion circle. Based on this study, only this game developed as a medium of distraction and it is believed that there have a lot of commercial games available that can be used as a tools for distraction.

## 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 shown in Fig. 3 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 paediatric cancer patients.

However, it should also be noted that, because this is a reflection of the current literature, there are opportunities to more deeply explore various combinations of these features. For example, how could immersive virtual and augmented reality technology be used appropriately during the procedure. Alternatively, how could education be included at all stages of the treatment and can this go beyond increasing knowledge about the disease and treatment plan and extend to ensuring that children are not falling behind in their normal schooling due to their situation. While these are only some hypothetical potential future avenues, more may exist and may open new opportunities to improve the quality of life of children and families dealing with cancer.

### 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 [29]. 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 [30]. During the game, a common purpose for many of the games was to distract the patients from the treatment itself through entertainment [32], 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 an 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 [33] 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 [15]. Thus, serious games should aim to reduce one of these negative physical [18] or emotional [34] 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 paediatric cancer patients' world view as they face the daily challenges of their illness [35].

### 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 [36] but Jurdi et al. [20] state that the potential of touch interactions with mobile devices 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

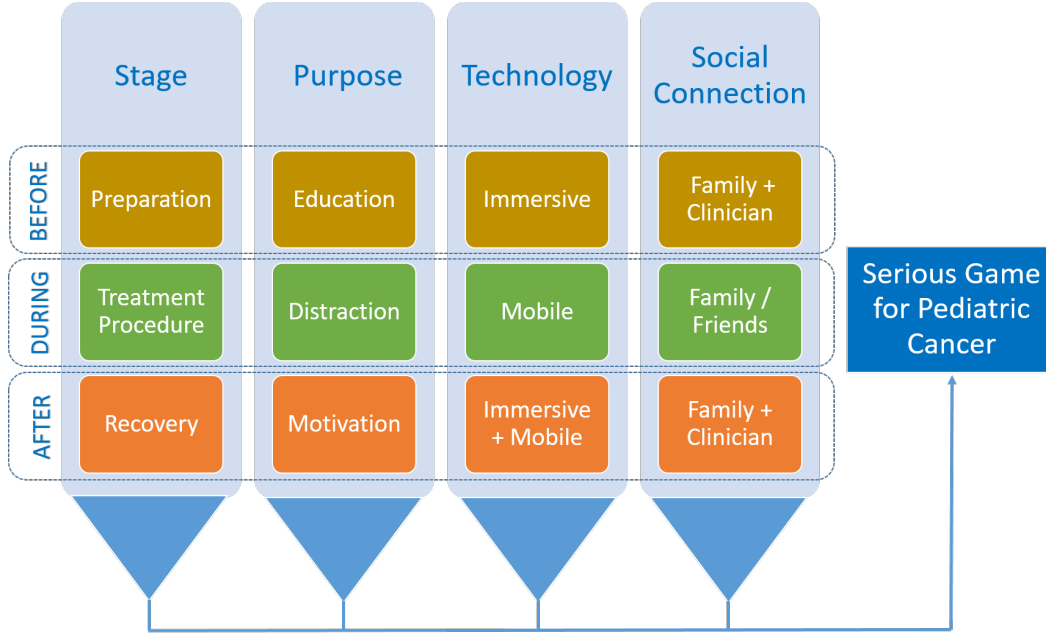


Fig. 3. Conceptual framework for designing effective serious games for paediatric cancer patients.

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 [32] and engagement in education [29]. Palanica et al [29] suggest that VR is a suitable tool to enhance patient's contentment and to assist patient to comprehend new knowledge about the illness, treatment and medication amongst others. This is supported to the huge measure of literature supporting its effectiveness in healthcare education. However, VR technology should be used with caution, because it can produce motion sickness symptoms [37] 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 that none of the studies were concerned about technology availability and restriction in hospital setting, for examples, internet infrastructure, socio-economic status of the patient's family, and hospital conditions and funding status. Most papers assume that the technology is available to the hospital and family. However, paediatric cancer is a 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. Games such as Mission Possible [38] 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 causing them to miss valuable social experiences. Based on LaViola Jr [37], paediatric cancer patients report wishing they could attend their school more and, as a consequence of their hospitalization, 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 paediatric cancer patients that undergo treatment in hospital, with the aim of finding areas of future study. We



identified 13 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 paediatric 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.

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