International Journal of Virtual Reality
Volume 24 Issue 1

Guingo, E., Paquin, D., Côtes-Turpin, C., Addab, S., Vézina, C., Côtes-Charlebois, F., & Le May, S. (2024)
Customized Avatars in a multiplatform Game on Mobile and Virtual Reality for Hospitalized Children in Hemato-Oncology: a Conceptual Design.
International Journal of Virtual Reality, 24(1), 23-45.
10.20870/IJVR.2024.24.1.7905

Published: 7/2024

ISSN: 2727-9979

Customized Avatars in a multiplatform Game on Mobile and Virtual Reality for Hospitalized Children in Hemato-Oncology: a Conceptual Design

Estelle Guingo[1,2], David Paquin[1], Casey Côtes-Turpin[1], Sofia Addab[3], Cathy Vézina[1], Félix Côtes-Charlebois[1], Sylvie Le May[2,4]

[1]Université du Québec en Abitibi-Témiscamingue

[2]Université de Montréal

[3] Centre de recherche des hôpitaux Shriners pour enfants(R)-Canada, Montréal, Canada

[4] Centre de recherche du centre hospitalier universitaire de Ste-Justine, Montréal, Canada

Corresponding author: Estelle Guingo, estelle.guingo@uqat.ca

Submission date: 05/12/2023

Publication date: 08/07/2024

Keywords: Virtual reality – Pain – Anxiety – Avatar – Transmedia storytelling

Abstract

The hospital is an environment that may induce both anxiety and pain in hospitalized children and their families. The use of games and distraction offers a solution to better manage anxiety and pain. The objective of the present paper is to introduce “A Friend for Life,” a multi-platform game based on the creation of customized avatars to help children hospitalized in the hematology-oncology unit cope with their everyday pain and anxiety. This smartphone and virtual reality application uses the IKEA Effect and transmedia storytelling to improve child engagement in the game.

This game was developed as part of AVATAR, a research project that combines collaborative action research with co-design. The project is led by our multidisciplinary team, including a former patient and his parent.

In this paper, we introduce our serious game, “A Friend for Life”, and the collaborative development method that was used in the prototyping phase. Additionally, we outline our hypothetical conceptual framework and its underlying concepts. Finally, we discuss the game's limitations and directions for future research.

1. Introduction

1.1. Healthcare gamification

Serious games are games that have a serious goal beyond mere entertainment. The incorporation of game-like elements and characteristics into serious procedures with the aim to create motivation, engagement, and/or a desire to change behavior is commonly referred to as, "gamification" (Deterding et al., 2011; Johnson et al., 2016). Unlike serious games, gamification is not always a game and can take on many forms. Our focus of study is the use of video games, particularly virtual reality (VR), in healthcare gamification.

Virtual reality is a technology that enables users to interact with a computer-generated, immersive environment. By using a VR head-mounted display and audio feedback, the player is isolated from the real world and can interact in the virtual environment. This technology has been gradually integrated into the healthcare field for a wide range of uses (Tao et al., 2021).

Gamification has numerous applications in the healthcare field. It may be used to educate and raise awareness among patients, families, and the general public on various health-related topics, such as, health-practices (Fijačko et al., 2020), sexual education (Haruna et al., 2018), and nutrition (Chow et al., 2020). Gamification may also serve as a potential tool for professional training, thereby decreasing the associated training costs and ethical challenges (Ferguson et al., 2015; Nevin et al., 2014; Suncksen et al., 2018). Many studies have used gamification, particularly serious videogames, and VR as a tool during diverse treatments (Udara & Alwis, 2019). Virtual reality-based treatments, such as the "In Virtuo" treatment, have shown potential for individuals with schizophrenia (du Sert et al., 2018), obsessive-compulsive disorder (Laforest et al., 2016), and phobias (Botella et al., 2017; Difede & Hoffman, 2002; Suso-Ribera et al., 2019). Additionally, VR and video games have shown benefits in rehabilitation (Hoffman et al., 2020), especially for stroke patients (Nolin et al., 2019).

Virtual reality is also a commonly used tool for therapeutic distraction to manage pain and anxiety. Studies have examined the feasibility, acceptability, and efficacy of VR during various medical procedures, including burn wound care and orthopedic bone pins removal in children (Le May et al., 2020, 2021).

1.2. The hospital: A painful and anxiety-inducing environment

Pain is defined as "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage" (International Association for the Study of Pain, 2020; Williams & Craig, 2016). Anxiety may increase pain perception, as is seen in patients during the preoperative period (Álvarez-García & Yaban, 2020; Tola et al., 2021). Stress and anxiety are two related, yet distinct concepts. Stress is a non-specific response to any event and can be triggered by many agents (Selye, 1956). In contrast, anxiety has two distinct concepts: state and trait anxiety (Spielberger, 1972). State anxiety fluctuates in time and intensity and is a response to a stressful situation. On the other hand, trait anxiety refers to a relatively stable disposition within the individual to judge a wide range of environmental events as potentially threatening (Mascarenhas & Smith, 2011).

The hospital environment may be anxiety-inducing for young individuals as well as their family. The fear of treatments, death and/or the separation from loved ones can lead to anxiety, particularly in the case of children with cancer undergoing painful treatments (Darcy et al., 2014; Dyekjær & Dreyer, 2019; Nazari et al., 2017). Although hospitals offer distractions such as therapeutic clowns (Lopes-Junior et al., 2020) and music therapy (Facchini & Ruini, 2021) to help children relax, anxiety and pain may persist. There are few resources available to help children and their family cope with pain and anxiety (Lazor et al., 2021; Tutelman et al., 2018). However, Thrane's (2013) systematic review shows the potential benefits of diverse pain and anxiety management interventions. Through the review of twelve studies about pain and anxiety management intervention from 1990 to 2010, Thrane (2013) highlighted the benefit of hypnosis, mind-body techniques, virtual reality, massage, music, and creative arts therapy. However, studies included in the review had small sample sizes.

Lopez-Rodriguez et al. (2020) reviewed the benefits of technologies in managing symptoms of depression, anxiety, and pain observed in children with cancer. This systematic review included eight studies that used smartphones, robotics, video games, and virtual reality. Recent technological improvements have led therapeutic distraction researchers to explore the use of virtual reality, serious gaming, and gamification as new tools for anxiety and pain management before or during procedures (Khadra et al., 2020; Le May et al., 2021).

1.3. Social agents in game contexts: Potentiality for serious games

Serious games have the potential to motivate users (Treviño-Guzmán & Pomales-García, 2014), while video games may be developed to evoke specific emotions in players (Villani et al., 2018). The use of certain colors or the design of specific atmospheres can generate emotions in players (Geslin et al., 2016; Roohi & Forouzandeh, 2019). Understanding cognitive psychology and cognitive biases can be a significant asset when creating video games (Hodent, 2017). Cognitive biases, when applied to video games, allow for a better understanding of the player and their reactions.

While the virtual environment can emotionally affect the player, the creation of social bonds, even with non-player characters (NPCs), can also evoke an emotional response and be a source of engagement (Isbister, 2016). Non-player characters are social agents that can play various roles within a video game. They can be present to guide the player, offer a service or interaction, accompany the player, or even pose an obstacle to overcome (Rogers et al., 2018). When integrated in VR, these social agents bring a sense of social presence, that is, the degree to which users feel that they are "together in the virtual world" when they are interacting with social entities (real-ones or not) (Kyrlitsias & Michael-Grigoriou, 2022).

Social agents with customized avatars and pet simulators have been used in the Pain Buddy project (Fortier et al., 2016; Hunter et al., 2020) and the virtual pet game created by Chai et al. (2020). These applications aim to keep children motivated in their treatments and to help them better manage their pain. These studies (Chai et al., 2020; Fortier et al., 2016; Hunter et al., 2020) have demonstrated promising results in using avatars for managing pain and anxiety in addition to improving staff/child communication. However, from a game design perspective, these applications lack a high level of customization as they only allow customization of a pre-existing character. Furthermore, none of these projects offer the possibility of meeting and interacting with a virtual friend through VR.

1.4. Objectives

While there have been many studies published on the effectiveness of VR and new technologies in healthcare, there remains a gap in research on game content and aesthetics for serious games in healthcare. In addition, there is no research, to our knowledge, on the potential benefits of customizable avatars and multi-platform applications in a healthcare context. Therefore, the main objectives of the present study are two-fold: (1) To present the conceptual design of our serious game "A Friend for Life," designed for hospitalized children in hemato-oncology based on highly customizable virtual-friend avatars and transmedia storytelling; (2) To present the key concepts that support our project and the collaborative development method used for the creation of our serious game.

2. Methods

2.1. Design

An action-research and art-based research design was conducted to develop a multiplatform game, "A Friend for Life.". The multidisciplinary research team comprised of a former cancer patient and his parent, and pediatric hemato-oncology experts, including a child psychologist, a physician, and a nurse. The involvement of relevant persons that are not necessarily familiar with research is a key characteristic of action-research. Iterative cycles of prototyping and optimizing were conducted based on qualitative feedback.

A design thinking approach was used to prototype the game, punctuated by prototype testing for game development (Figure 1). Design thinking is a process that works through iterative cycles of modifications until users are satisfied with the prototype (Hodent, 2017). Then, a co-design approach was used, which centers users in the game design process, to create characters with each patient participant (Hodent, 2017). This human-centered design ensures that user needs are met, and that the experience is both positive and enjoyable (Norman, 2013).

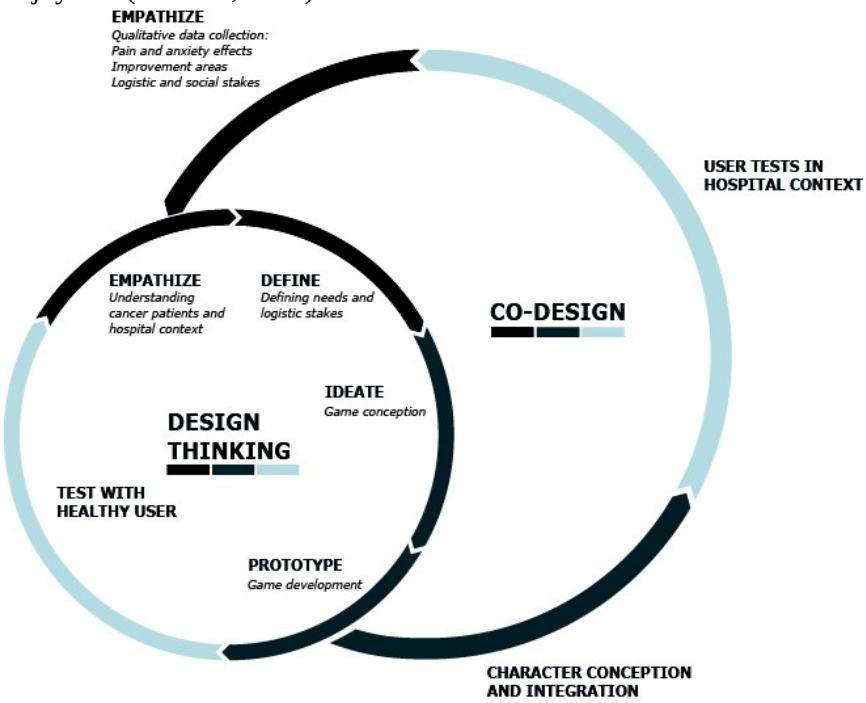

Figure 1 - Design thinking and co-design process

In the development of our game “A Friend for Life,” children were recruited in user testing to obtain feedback and to improve the prototype. Although not all members of the research team were experts in gamification and serious games, they all provided feedback and opinions about logistical stakes and intervention integration. Once the prototype was ready, a virtual friend was co-designed through a drawing activity with each child (figure 2).

Figure 2 - Children during character drawing activity

This development process allowed us to work effectively even with a small development team and to optimize game content with pertinent feedback from the research team and user testers.
Referring to methodological elements related to art-based, or creation-research, raised ideological debates in both French and English literature. While English literature employs different terms concerning “art-based research” allowing to specify the creation field (as research-creation, practice-led research, or others) (Paquin & Noury, 2018), methodological and epistemological debates persist. Some researchers argue that art research does not have to follow the same rules and methods as traditional research (Gosselin & Le Coguiec, 2006; Léchot Hirt, 2015). On the other hand, other researchers highlight the difference between scientific research and creative quests, as well as the lack of epistemology and methodology around research-creation (Findeli & Coste, 2007; Stévance, 2012; Vial, 2015). They also promote a multidisciplinary framework in which each research team member brings their own expertise.

2.2. Team members

To ensure that the project would benefit from diverse perspectives, a multidisciplinary team was convened, consisting of representatives from four key areas: healthcare, child psychology, lived-experience, and new technologies/videogame design. The team structure and the roles of each member are illustrated in Figure 3. Patient partners and pediatric hemato-oncology experts were integrated following the GRIPP2 reporting checklist for patient and public involvement in research (Staniszewska et al., 2017).

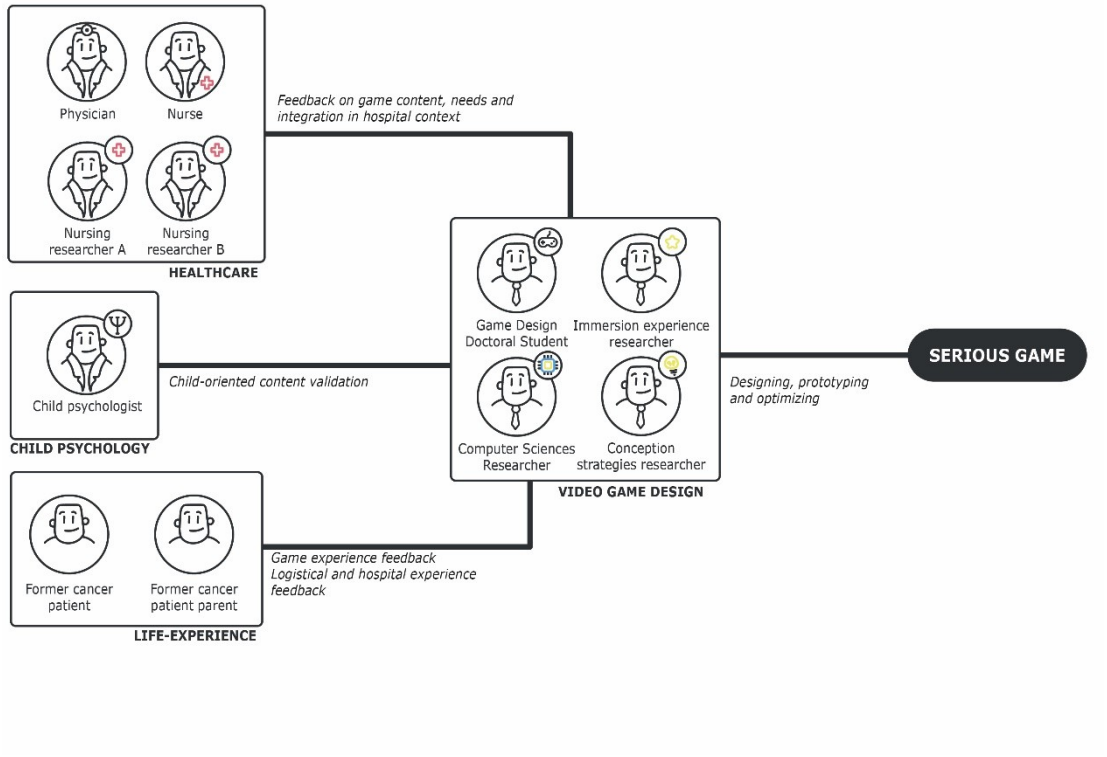

Figure 3 - AVATAR team composition and members' roles

The healthcare professional group included a nurse, a physician, and two nurse researchers, each bringing a crucial understanding of the needs and context of healthcare to the project, guiding the selection of the research methodology. Child psychology expertise was essential in ensuring that the virtual game was appropriate and engaging for the targeted population. Additionally, a former patient and their parent provided valuable insights into the logistical and social stakes involved in hospital stays and hemato-oncology treatments. Finally, experts in new technologies, game design, and creative workflows were responsible for application development, prototyping, and addressing and handling technical issues.

By convening a strong and complementary team with expertise from diverse fields, the game content was optimized for the hospital environment and its associated social and logistical challenges. This is an innovative approach because it recognizes the importance of aesthetics and game content, which are often neglected in research and serious game development as Isbister (2016) shares in her book:

“Another risk is placing high hopes on games designed for the public good – as many nonprofits, health organizations, and social enterprises are doing – without realizing that bad game design can undermine the most noble of ambition. It’s quite possible to make terrible, dull, and unappealing games for learning or training or health.”
(Isbister, 2016, p. xvii)

2.3. Smartphone application

The social aspect of the avatar-friend allowed the addition of a diary in the smartphone application which was recommended by the child life specialist team. In the digital diary the patient confided their feelings to their virtual friend through voice recordings. As well, children self-reported their anxiety and pain levels, using the Children Face Scale (McMurtry et al., 2011) and a 0-10 numerical rating scale (Breivik et al., 2008), respectively. The diary helped us better understand cancer patients and monitor their feelings, mood, anxiety, and pain during hospitalization. Each day and during 2-weeks, the child logged into the smartphone application, they were prompted to complete their diary by speaking to their virtual friend. The user interface (UI) chosen was very similar to a texting application. If negative moods persisted for three days, an email was sent to a designated staff member to check on the child and provide them with proper care as required.
After completing the daily diary, the patient visited their virtual friend’s house (figure 6). From there, they could take care of their virtual friend’s needs like hunger, hygiene, love, and sleep which were indicated by gauges. The child could have fun with their virtual friend by fulfilling their needs, such as feeding them their favorite food, bathing them, brushing their teeth, or even making them dance. The virtual friend’s needs were frustration-free as they could not suffer or be harmed in any way.

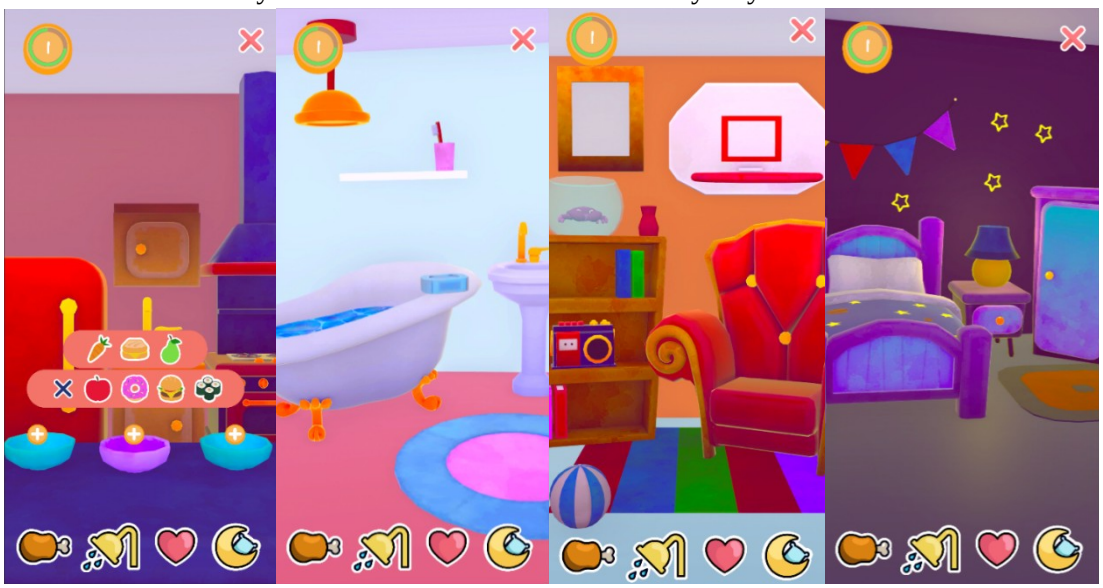

Figure 1 - Picture of each room

Furthermore, the child earned experience points by taking good care of their friend and could level up to unlock new types of food and accessories.
The accessories were inside the dresser within the virtual friend’s bedroom (figure 7). Selecting an accessory would put the item on the character and appear on both the smartphone and VR application.

Figure 2 - Accessories menu

2.4. Virtual reality application

The VR experience took the player on a magical journey where they could play three games with their virtual friend by their side. To minimize motion sickness and simplify user interactions, players were restricted to a small area in the virtual world. However, they could collect flowers all around them in VR that would become available in the smartphone application.

Each VR game was embedded within a 5 to 8 minutes storyline. The characters made contextual comments that brought them to life and added to the rewarding and dynamic nature of the experience.

The first game included in the VR application was a “shoot’em all” game wherein the child used a water gun to shoot bubbles. Once a certain number of bubbles were shot, an animal would spawn among the bubbles. If the child caught the animal with the water gun, the animal would appear in their aquarium within the smartphone application (as shown in Figure 8).

Figure 3 - Bubble mini-game and animal rewards examples

The bubble game is adaptive and offers different difficulty levels based on the player's performance. The more the player scores points, the more challenging the game becomes as the bubble spawning rate increases. Conversely, the level of difficulty decreased with low scores (table 1).

Level	Previous score range	Bubbles per seconds
1	< 500	6
2	500 - 1000	9
3	> 1000	12

Table 1 - Adaptability of the bubble game

The second game was a carnival game where the child was instructed to hit five levels of stacked cans with a ball. Next to this carnival stand was also a hammer game where the child was instructed to hit a button with a certain intensity to launch a small rocket.

The last game was a relaxation game based on the pursed lip breathing exercise (Miller, 1954). A systematic review showed the potential of this exercise in post-surgical pain management for cancer survivor patients (Wang et al., 2022). Moreover, the pursed lip exercise also significantly decreases dyspnea and anxiety among patients with acute heart failure in the emergency department (Srimookda et al., 2021). Hence, this game aimed to help children with cancer manage their anxiety. The goal of the game is to blow on paper pinwheels to make them turn. At first, the paper mills are red, indicating the player must breathe in. Then, the paper mills turn green, signaling to the player to breathe out using the pursed lip breathing technique.

The VR headset posed challenges with the relaxation game because the headset could not natively detect whether the player was blowing due to the sound sensors being restricted to the side of the headset. Initially, we explored the use of small blowers, but we found they required too much precision on the blowing direction and target. We needed a system that could be adapted to all, or at least to most of the players. After considering different options, we decided to use a small fan attached to the headset via an adapted support (Figure 9). When the player blows on the fan, the noise produced by the spinning fan amplified the noise and vibrations so it could be detected by the sound sensors and transmitted as an input to the application, enabling blowing to be used as an interaction in the virtual world.

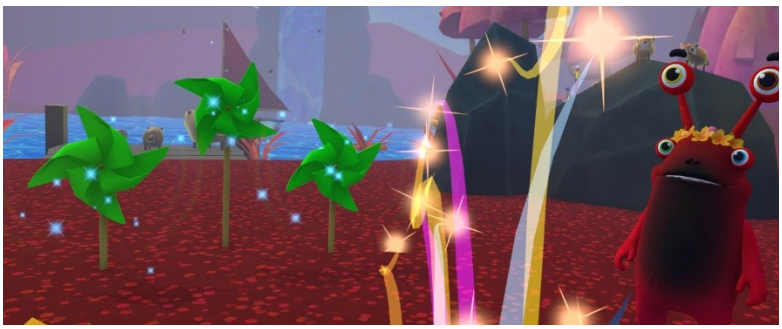

Figure 4 - Adapted fan and its use in the virtual reality game on a participant during data collection

2.5. Instruments and materials for the multiplatform

This multiplatform project needed various devices and software. First, a Google Pixel 4 was used as the smartphone due to its optimal performance and reasonable cost. The use of a smartphone VR rather than a computer-based VR was primarily to avoid logistical challenges and to easily bring the VR to children anywhere on the unit.

To connect the smartphone and VR application to a database, an external mobile 5G routers was used to avoid relying on hospital internet networks, which are often very restricted and provide inconsistent connection speeds from one hospital block to another. The database was designed to keep track of players' in-game habits and facilitate the transfer of rewards and accessories from one application to the next (figure 4).

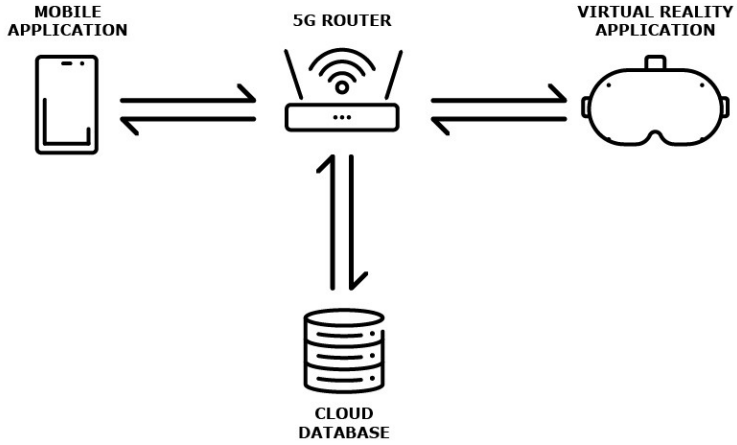

Figure 5 - Data synchronisation structure

The 3D environment of the game was optimized to reduce polygon counts and to draw calls to ensure a smooth and consistent frame rate of 60 frames per second (fps). Going below this threshold can cause the device to lag, slowing down the game and causing cybersickness (e.g. nausea, vomiting, dizziness, etc.) for the player (Zhang, 2020). Since the game was designed to be played on two portable devices, additional efforts were put to optimize both environments. This optimization was of top priority during the development process as the target users are hospitalized children with cancer. It was important for the game not to exacerbate any side effects of medical treatment.

2.6. Software for developments

The game was developed in Unity engine. Characters and environments were modeled with Autodesk Maya, Character rigging was accelerated with the use of Advanced Skeleton 5 allowing us to quickly rig humanoid characters. Blendshapes were added to characters to make emotional responses and automatic behaviours (happiness, sadness, blinking, smiling, etc.). Three-dimensional models were textured in Adobe Substance

Painter with smart materials made especially for the game to speed up the character modeling workflow. Most of the 3d environment content was created for the game, except for some packed decorations assets like flowers and animals bought on the Unity Asset Store. Character animation was made with motion capture downloaded from Mixamo website or recorded for the game with a Vicon system at the Université du Québec en Abitibi-Témiscamingue.

3. “A Friend for Life”: a transmedia application for virtual reality and smartphones featuring unique avatars

3.1. Game aesthetic

The game aesthetic for “A Friend for Life,” was designed after reviewing various child-oriented content. One of the main challenges was to create a world that would appeal to a wide range of ages from 6 to 17 years old. To achieve this, the team drew inspiration from popular sources such as Pixar movies and original Nintendo content, both of which have a broad audience (Black, 2022; T. J., 2016). We also gathered inspiration from independent games such as, “Last Day of June,” and animation films with unique visual designs like, “Mitchell’s Vs the Machine,” “Le Petit Prince,” and “Pokemon: Mewtwo Strikes Back – Evolution.” We also reviewed several popular pet simulation games, meaning applications with more than 5M downloads on the app store, including “Clumsy Ninja,” “My Tamagotchi Forever,” “Pou, My Talking Tom,” and “Axolochi,” to better understand the user interface and experience of these kinds of games. These games brought us to focus on simplifying the game mechanics and the importance of character reaction. For VR, the pet simulation game “Bogo” was our main inspiration as a lot of activities are available in a single virtual environment where the player does not have to move around. Figure 5 contains pictures that inspired the game aesthetics.

Figure 6 - Some videogames inspirations for the game aesthetics
Animal Crossing New Horizon – Nintendo (2020), My Sims Kingdom – Electronics Arts (2007), Yoshi's Crafted World – Nintendo (2019), Bogo – Oculus (2019), My Tamagotchi Forever – Bandai Namco Entertainment Europe (2018), Clumsy Ninja – Natural Motion Games Ltd (2013)

From a 3D modeling perspective, we aimed for a low-poly aesthetic to accommodate the maximum performance levels of the two devices used in our project. We also wanted a recognizable aesthetic, achieved through a hand-crafted texturing environment that allows us to create harmony between research workflow (avatar conception) and visual aesthetic. Our watercolor and clay textures made with procedural conception software convey an aspect of DIY (Do It Yourself), which aligns with our highly customizable avatars.
To make the environment engaging for children, we opted for a colorful and stylized look, using everyday objects to furnish the character's house in the smartphone application. The narrative connection between the two applications is straightforward: the VR game takes place in the character's courtyard, while the smartphone games invite the child to enter the character's house.

3.2. Game mechanics

From a user interface perspective, the major constraint was the wide age gap of our targeted population (6 to 17 yo). This gap forced us to create simple and logical interactions for the user such that even the younger children could quickly understand the game mechanics. We focused on creating simple interactions based on design affordances, allowing children to intuitively understand how to interact with the objects. Design affordance refers to the action possibilities that are easily inferred by the user based on their perception or

experience with similar objects or interfaces (Norman, 1988, 2013). For example, by tapping on the bathtub in the bathroom of the smartphone application, a child would expect to wash their character. After tapping, the character teleports into the bathtub and can be washed with the soap and rinsed with the shower head by dragging them over the character. In the VR application, we created an imaginary land, with relaxing sound effects and music. If the environment has more of a magical feel, interactive objects remain familiar to the children (a water gun, a pinata stick, flowers, a ball, a hammer) so the affordance remains logical and easy to understand. Also, classical VR interaction mechanics has been used, as the use of the back trigger to take objects and the upper-back trigger to shoot with the water gun. These were the only interactions allowed with VR controllers as we wanted children to have a quick learning curve for VR game mechanics.

3.3. Character preparation

Character creation was the main challenge of this creative project. As it is a time-consuming workflow, we needed to prepare tools to accelerate the character creation and integration. Character modeling and UV-unwrap was made with Autodesk Maya. Our modeling process was accelerated by the prior creation of smart procedural materials that adapt to 3D models. Through a baking process, the software (Adobe Substance 3D Painter) generates textures that detect the contours of objects. The visuals of these materials are inspired by classic artistic textures like grainy paper and watercolor paintings, with easily interchangeable colors through layering. This allowed us to speed up the modeling process and establish a solid artistic direction. Modifications could then be made by hand on top of these textures. As for the characters, they were dressed in a gradient texture of modeling clay, a unique visual in the game that highlights them.

One of the challenges of integration was the transfer of animation from one character to another. This transfer was made possible through the prior creation of a rigging structure that was consistent across all characters. The body rigging was done using a plugin called Advanced Skeleton, which allows for the rapid creation of a skeleton and the controllers needed to animate it. Facial animations were created using predefined blendshapes modeled by hand. Some plugins like Advanced Skeleton6 also allow for the automatic generation of blendshapes. This automatic generation generally allows for the creation of numerous blendshapes for each emotion and phoneme, which then need to be adjusted to achieve the desired shapes. However, in this case, the character only required a limited number of blendshapes (eight). Therefore, it was faster to create them manually than to use procedural generation. Once the skeleton was created, it was then possible to apply retargeting to the animations recorded through motion capture.

Then, when the character was ready, it was integrated into the game in the Unity game engine by creating a new prefab and connecting the scripts responsible for interaction, scenario management, and character animation.

3.4. Characters

We invited each child to create their own virtual friend through a design process using visual aids such as color charts, shape sheets, and mood boards. Our animator, Estelle Guingo, worked with each child to create a character with details that matched the child’s wishes. Children could create their own character by drawing. The goal was to create a unique character concept for each child based on their interests and preferences. The only constraint in creating the character was that it had to be bipedal, with two arms and a mouth to ease the two-day modeling /integration workflow. Children were also free to add a small object in one hand of the character if they wished, as it did not disrupt the workflow.

Once the virtual friend avatar concept was created with the child, their character was then brought to life through 3D modeling (Figure 10). We respected all the main shapes to create a friendly character that was true to the original concept, while also adhering to visual aesthetics. The character was then integrated into the 3D environment using our character integration checklist to speed up the workflow. Once integration was complete, the character was ready to meet the child on both smartphone and VR applications. This multi-platform storytelling approach is called transmedia storytelling.

Figure 7 - Characters and their 3D versions - From left to right: Cookie, Lapin, Kaï, Arianna, Bobross

4. Discussion: Conceptual design and framework

4.1. Creating emotion with game design strategy

Videogames can be a source of vivid emotions and it is up to the game designer to enable players to feel these emotions through game design strategies (Hemenover & Bowman, 2018; Isbister, 2016). Therefore, we carefully designed an atmosphere for our VR game that created and optimized emotional responses in players. We selected colorful environments and wide-open spaces to elicit positive moods such as joy, as suggested by the circumplex model for color scripting model in video games (Geslin et al., 2016; Roohi & Forouzandeh, 2019). Additionally, we used stylized characters, as Scott McCloud (1994) suggested that abstract and stylized characters allow comics viewers to project more of themselves onto the characters without being distracted by details. Furthermore, other research found that amongAamerican sign language participants, stylized signing avatars were more appealing than realistic ones (Adamo-Villani et al., 2016). While Isbister (2016) highlights the capacity of a videogame to create emotions in players through the relationship with a non-player character, she also emphasizes the potential emotional impact of allowing players to control their character's appearance and actions. Hence, we enabled children to customize the design of their virtual friend in its entirety. We hoped this would evoke emotions and use the cognitive bias known as the "IKEA Effect."

4.2. IKEA Effect: Creating a customizable, loving avatar-friend

Our multiplatform game features highly customizable avatars based on child participants' drawings of their own avatar-friend. One constraint was imposed to make the 3D integration workflow easier: characters had to be humanoid, have two arms and two legs, and be standing upright.

With this participative creation workflow, we aimed to tap into a cognitive bias called the IKEA Effect. This bias is defined by Norton et al. (2012) as the higher valuation of one's own work. Participants in the study by Norton et al. (2012) were asked to build an object and to rate it against another similar object. Participants

often valued their own object more, even if the second one was very similar. A second study with children aged between 3 and 6 years old concluded that the IKEA Effect is a cognitive bias observable from the age of 5 years old (Marsh et al., 2018). The IKEA Effect is sometimes associated with a negative connotation in marketing, because customers tend to over evaluate objects if they participated in their creation, leading them to overspend (Patyal, 2022). We believe this cognitive bias can be useful in creating interest and engagement in many activities, such as video games. If the created videogames are used for a serious purpose, such as healthcare gamification, the IKEA Effect could be a key factor in motivating children through difficult treatments and medical procedures.

Moreover, Hodent (2017) highlighted the relevance of the IKEA Effect in satisfying players' need for autonomy, improving intrinsic motivation and increasing engagement in video games. Therefore, we decided to offer children the opportunity to customize their therapeutic distraction intervention to call upon this cognitive bias and try to promote engagement and motivation.

4.3. Transmedia storytelling: From paper to smartphone to VR, the story continues

Transmedia storytelling is a technique used to tell a story through multiple platforms. Each platform adds a unique dimension to the story (Jenkins, 2017). This approach is often used in marketing and entertainment strategies to appeal and engage new audiences (Schiller, 2018). A typical example of transmedia storytelling is the "Star Wars" film franchise. "Star Wars" lore transcends the movies by including comics, books, video games, and other media, that provide fans with additional storylines and deeper insight into the "Star Wars" universe (Guynes & Hassler-Forest, 2017). Other movie franchises, like "Lord of the Rings" and "The Matrix," have also embraced transmedia storytelling (Brown & Waterhouse-Watson, 2016; Jenkins, 2010). The main goal of transmedia storytelling is to appeal and engage audiences by encouraging their participation across multiple platforms. It also introduces possibilities for storytellers to offer more storylines that are not necessarily first-plan stories, but rather are complementary stories adding more depth to the franchise. The evolution of new technologies has improved and transformed the way transmedia storytelling can engage and communicate with their audience (Schiller, 2018). In our case, we aimed to use transmedia storytelling to create engagement, interest, and motivation in the therapeutic intervention and medical treatment.

Each device had its own benefits for the project. One of the main characteristics of VR is its ability to transport the player to a different world through visual and auditory cues. This allows game designers to create immersive environments, where players can interact with virtual objects and non-player avatars. Immersion has been a topic of discussion among researchers for years, with some seeing it as a device's capacity (Slater et al., 2018), while others view it as a state of mind (Jennett et al., 2008; Murray, 1997; Tekinbas & Zimmerman, 2003). Calleja (2011) noted that while there is an agreement on the importance of immersion in the player's experience, confusion remains over the meaning of "immersion," and its close relative, "presence." To clarify the concept, he divided the definition of immersion into two sub-definitions: immersion as absorption and immersion as transportation, emphasizing the importance of specifying which definition is used in a study (Calleja, 2011). For the present study we chose to adopt Jennett's et al. (2008) view of immersion as a state of mind and Calleja's immersion as an absorption state (2011).

In the same vein, Mutterlein (2018) brings a fresh perspective on the immersion/presence debate, which complements the definition. In his study, he presented immersion as a subjective psychological experience that is provided by and limited by the capacity of a technological system but must be measured on a subjective level. This definition links immersion to the capacity of the device, but also acknowledges the idea of a state of mind and a subjective experience (Mütterlein, 2018). This is similar to Jenett's definition of immersion as "the subjective experience of feeling totally involved in and absorbed by the activities conducted in a place or environment, even when one is physically situated in another." He differentiates the concept of presence from immersion, seeing presence as the feeling of being in another place in VR. He also positively links both concepts to interaction, stating that interactivity positively affects presence and immersion, and presence positively affects immersion. Finally, he suggests that immersion positively

influences satisfaction. These concepts are fundamental in using VR as a tool to help manage both pain and anxiety.

Virtual reality also offers a high-level multisensorial stimulation allowing players to interact with objects and characters and receive virtual feedback in the virtual environment. These are crucial components of a player's experience, contributing to satisfaction and engagement (Hudson et al., 2019). Hudson et al. (2019) confirmed that Belk's social concept (Belk, 1988) is applicable in virtual environments. Belk and Hudson identified three key concepts that support a satisfying virtual experience: things, surroundings, and other people. The first concept, things, refers to the interaction made possible by VR controllers and an interactive environment. The second concept, surroundings, relies on the sense of immersion that VR provides. The third concept, other people, refers to the social interactions that can take place within the game.

Inspired by the third concept, we provided each child with a virtual friend to interact with, empowered by IKEA Effect (Norton et al., 2012) to enhance the social aspect of our VR experience.

The use of VR comes with benefits, but it also has some drawbacks. One significant issue is the potential for side effects, such as headaches, nausea, and/or dizziness, commonly referred to as, "cyber sickness" (Caserman et al., 2021; Zhang, 2020). There is no consensus on the maximum duration of VR gameplay, but some studies have found high rates of early drop out due to VR side effects. For example, Merhi et al. (2007) showed that 59% of subjects (10 of 17) stopped playing a VR action game after only an average play time of 14 minutes (Merhi et al., 2007).Moreover, Davis et al. (2015) found that 42% (10 of 24) of participants stopped playing a rollercoaster game after an average of 5 minutes due to motion sickness, which is most likely due to the player moving around in the virtual world while their body remained stationary, creating a sensory (visio-vestibular) conflict (Davis et al., 2015).

To address cybersickness, we created scenarios that lasted between five and eight minutes and disabled the player's ability to move around in the virtual world. As this reduced the level of interactivity, we added many activities accessible from the player's location. Additionally, we developed a transmedia storytelling approach that allows the patient to continue the experience on a smartphone application and reduce the likelihood of side effects. Transmedia storytelling enables the patient to bring their virtual friend anywhere, even in places that are not VR friendly. Patients could also choose from a variety of different games and activities depending on their mood.

Furthermore, our transmedia storytelling approach synchronized the two devices and tracked players' habits and story details across both applications. For example, players could customize their character's appearance in the smartphone application and view those changes when they met their virtual friend in VR. These possible customizations offered players more autonomy and control over their character, which may increase their engagement and motivation as Hodent (2017) has argued.

4.4. Gamification strategies to improve children's engagement and motivation

To enhance gamification, we aimed to improve what Hodent (2017) referred to as, "engage-ability," which consists of three key pillars: motivation, emotion, and game flow. Of these pillars, motivation appears to be at the core, with support from emotion and game flow. Motivation can be divided in two types: intrinsic and extrinsic.

Intrinsic motivation is driven by the inherent satisfaction of the activity itself (Hodent, 2017). To consider motivation, we used the Self-Determination Theory, which posits that intrinsic motivation is based on three needs: autonomy, relatedness, and competence (Ryan & Deci, 2020). Autonomy is all about choices, self-expression, and free will. As was previously mentioned, we provided autonomy by enabling players to create their own virtual friend, have access to accessories, play minigames, and through the IKEA Effect cognitive bias. Relatedness is associated with the possibility of social interaction which we aimed to provide through our virtual character. Although there are differences in social benefits between real players and non-player characters (Isbister, 2016), we aimed to create a meaningful social connection with our virtual friend by letting children create their own friend and watch them cheering them up during VR games. Competence refers to the ability of controlling the environment, which is achievable in VR when it presents a high level of interactivity, many control opportunities, and feedback.

On the other hand, extrinsic motivation is purely related to rewards (Hodent, 2017). In our game design process, one of the main focuses was developing strategies to improve child engagement and motivation through transmedia storytelling and minigames. With this in mind, we created games that offered useful rewards to the player. Additionally, we designed an experience and level system in the application where the more the player took care of their character, the more they unlocked new foods and accessories.

Although motivation appeared to be the core pillar for game engage-ability (Hodent, 2017), it was supported by both emotions and game flow. Game flow is a psychological state where the player is entirely focused on the game, providing them feelings of fulfillment and joy (Isbister, 2016). This state is very similar to immersion, where players lose track of time and external stakes (Chen, 2007). We believe that optimizing immersion can lead to a game flow state for players, thereby increasing engage-ability, engagement, and motivation. Finally, all these concepts combine to form our hypothetical healthcare gamification framework, which aims to reduce pain and anxiety management.

4.5. Hypothetical healthcare gamification framework

Given the current lack of healthcare gamification frameworks for pain and anxiety management through transmedia serious games, we developed a hypothetical framework that aims to link all the concepts we have discussed in the previous section (figure 11). By implementing the game strategies described above, our goal was to reduce the pain and anxiety that are experienced by children with cancer daily, while also optimizing healthcare satisfaction.

The first step in our framework was to create an immersive environment that optimized immersion through interactivity and the sense of presence to bring the player into a state of flow. Our avatar conception allowed us to use the IKEA Effect cognitive bias to create engagement and motivation, while also allowing the player to develop a special relationship with their character, evoking emotions. Our prototype was also based on transmedia storytelling and rewards to create engagement and motivation, thereby increasing patients' well-being by reducing pain and anxiety, as well as increasing satisfaction.

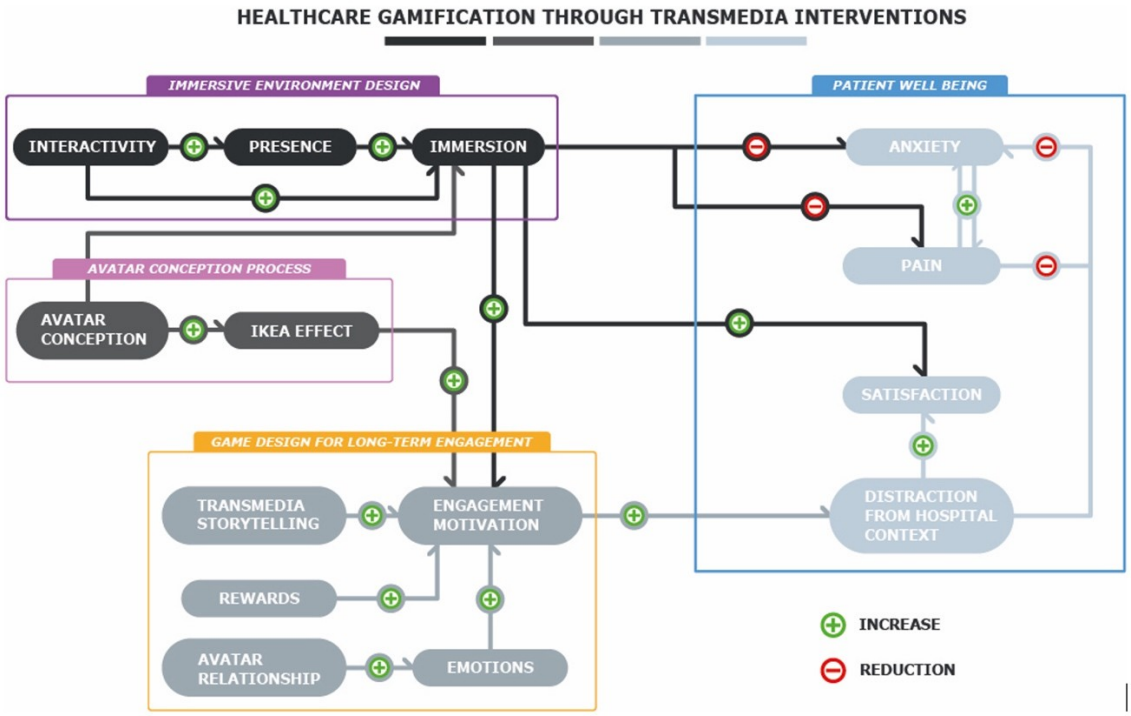

Figure 11 - Healthcare gamification through transmedia intervention hypothetical conceptual framework

4.6 Future research and limitations

Our study is the first to address the use of avatars in multiplatform virtual environments for pain and anxiety management for hospitalized children in hemato-oncology. However, research remains to be done to support our conceptual framework, which provides a new perspective on the link between immersion interactivity and presence. It would also be an opportunity to target areas of improvements on user experience.

On one hand, a preliminary qualitative data collection trial was conducted at the Ste-Justine Hospital Research Center in Montreal, Canada, during the fall of 2022 and winter of 2023. This trial aimed to gather user feedback about the applications, while also assessing the impact of our solution on anxiety and pain. This first cycle of data collection only was conducted with five participants only, hence scalability remains one of our most important challenges for future research and practical applications. Indeed, as character creation is a time-consuming process (48 hours), this workflow will have to be modified to adapt our solution to larger samples. Potential solutions allowing the child to choose premade clothes, accessories, and avatar shapes should be considered. Another solution could be using automatic coloring book texturing such that each child may choose an avatar shape and draw patterns on a coloring book to decorate them (Magnenat et al., 2015). These kinds of solutions would reduce the customization level that was at the center of the conceptual design. As artificial intelligence is still evolving, we could potentially use artificial intelligence model to create a 3D model from children's drawings. This technology remains, at the moment, not accurate enough to be used in video game development.

On the other hand, future research should focus on conducting experimental studies to validate the applicability of the Ikea Effect in the virtual world. More specifically, there is a need to investigate if the effort and engagement involved in avatar creation can induce the Ikea Effect.

5. Conclusion

In the field of healthcare gamification, research often focuses on the efficacy (Xiang et al., 2021) or acceptability and feasibility (Osmanlliu et al., 2021) of digital interventions, with little attention paid to the game content itself. However, studying game content is crucial as these games are tools in research projects and should be evaluated in the same way as measurement scales. For example, if a patient is not immersed enough or if the content is not age-appropriate, this could explain mixed results or insignificant effects. Furthermore, integrating content study in qualitative research can help identify areas for improvement to optimize the efficacy of serious games. This article aimed to provide a content study of the game used in the AVATAR research project. AVATAR is a research project aiming to study pain and anxiety management through unique avatar conception for children with cancer. For this purpose, we developed a multiplatform game: "A Friend for Life."

"A Friend for Life" is a multiplatform game in smartphone and VR based on unique avatar conception for each player. This serious game has been developed through both design thinking and a co-design creative process to help children in hemato-oncology manage their everyday pain and anxiety. Applications have been optimized to fit performance constraints and stay synchronized through cloud database connection, which allows transmedia storytelling.

From a game design perspective, optimizing immersion is crucial in increasing player motivation. A high sense of presence and interactivity are key factors in achieving a state of flow. The game's conceptual design also focused on evoking emotions through various game design strategies and creating a strong player-character relationship to increase engagement. The co-design of the avatar aims to create a sense of attachment between the child and their character using the IKEA Effect cognitive bias and to engage the player even further. Motivation strategies such as rewards and transmedia storytelling are used to increase player engagement and create a desire to continue playing. Immersion optimization and distraction from the

hospital environment also contribute to the management of pain and anxiety, as well as increase satisfaction in both the child and their parents.

Acknowledgements

We would like to thank Christine Genest, Pascal Bernier, Alexandra Desjardins, Leon Dupuis, Marie-France Langlet and Dr. Michel Duval for their involvement in the development process. Also, we would like to acknowledge the work of Marie Galopin and Annie Lahaye in the recruitment of participants at the Sainte-Justine Hospital in Montreal, Canada.

References

Adamo-Villani, N., Lestina, J., & Anasingaraju, S. (2016). Does Character's Visual Style Affect Viewer's Perception of Signing Avatars? In G. Vincenti, A. Bucciero, & C. Vaz de Carvalho (Eds.), *E-Learning, E-Education, and Online Training* (Vol. 160, pp. 1–8). Springer International Publishing. doi: 10.1007/978-3-319-28883-3_1

Álvarez-García, C., & Yaban, Z. Ş. (2020). The Effects of Preoperative Guided Imagery Interventions on Preoperative Anxiety and Postoperative Pain: A Meta-Analysis. *Complementary Therapies in Clinical Practice*, *38*, 101077. doi: 10.1016/j.ctcp.2019.101077

Arvidsson, S., Gilljam, B.-M., Nygren, J., Ruland, C. M., Nordby-Bøe, T., & Svedberg, P. (2016). Redesign and Validation of Sisom, an Interactive Assessment and Communication Tool for Children With Cancer. *JMIR mHealth and uHealth*, *4*(2), e76. doi: 10.2196/mhealth.5715

Belk, R. W. (1988). Possessions and the Extended Self. *Journal of Consumer Research*, *15*(2), 139. doi: 10.1086/209154

Black, T. (2022). *Average Nintendo Switch Owner Age Revealed—Gameranx*. Gameranx.Com. https://gameranx.com/updates/id/397258/article/average-nintendo-switch-owner-age-revealed/

Botella, C., Fernández-Álvarez, J., Guillén, V., García-Palacios, A., & Baños, R. (2017). Recent Progress in Virtual Reality Exposure Therapy for Phobias: A Systematic Review. *Current Psychiatry Reports*, *19*(7), 42. doi: 10.1007/s11920-017-0788-4

Breivik, H., Borchgrevink, P. C., Allen, S. M., Rosseland, L. A., Romundstad, L., Breivik Hals, E. K., Kvarstein, G., & Stubhaug, A. (2008). Assessment of Pain. *British Journal of Anaesthesia*, *101*(1), 17–24. doi: 10.1093/bja/aen103

Brown, A., & Waterhouse-Watson, D. (2016). Playing with the History of Middle Earth: Board Games, Transmedia Storytelling, and The Lord of the Rings. *Journal of Tolkien Research*, *3*.

Calleja, G. (2011). *In-Game: From Immersion to Incorporation*. MIT Press.

Caserman, P., Garcia-Agundez, A., Gámez Zerban, A., & Göbel, S. (2021). Cybersickness in Current-Generation Virtual Reality Head-Mounted Displays: Systematic Review and Outlook. *Virtual Reality*, *25*, 1153–1170. doi: 10.1007/s10055-021-00513-6

Chai, C., Wang Er, Lau, B. T., Al Mahmud, A., & Kit Tsun, M. T. (2020). A Virtual Pet Serious Game in Motivating Children with Cancer in Treatment and Self-Care: A Conceptual Design. *Malaysian Journal of Paediatrics and Child Health*, *26*(2), 6–19. doi: 10.51407/mjpch.v26i2.101

Chen, J. (2007). Flow in Games (and Everything Else). *Communications of the ACM*, *50*(4), 31–34. doi: 10.1145/1232743.1232769

Chow, C. Y., Riantiningtyas, R. R., Kanstrup, M. B., Papavasileiou, M., Liem, G. D., & Olsen, A. (2020). Can Games Change Children's Eating Behaviour? A Review of Gamification and Serious Games. *Food Quality and Preference*, *80*, 103823. doi: 10.1016/j.foodqual.2019.103823

Darcy, L., Knutsson, S., Huus, K., & Enskar, K. (2014). The Everyday Life of the Young Child Shortly After Receiving a Cancer Diagnosis, From Both Children's and Parent's Perspectives. *Cancer Nursing*, *37*(6), 445–456. doi: 10.1097/NCC.0000000000000114

Davis, S., Nesbitt, K., & Nalivaiko, E. (2015). Comparing the Onset of Cybersickness Using the Oculus Rift and Two Virtual Roller Coasters. *Proceedings of the 11th Australasian Conference on Interactive Entertainment (IE 2015)*, *167*, 3–14.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From Game Design Elements to Gamefulness: Defining "Gamification." *Proceedings of the 15th International Academic MindTrek Conference on Envisioning Future Media Environments - MindTrek '11*, 9. doi: 10.1145/2181037.2181040

Difede, J., & Hoffman, H. G. (2002). Virtual Reality Exposure Therapy for World Trade Center Post-traumatic Stress Disorder: A Case Report. *CyberPsychology & Behavior*, *5*(6), 529–535. doi: 10.1089/109493102321018169

du Sert, O. P., Potvin, S., Lipp, O., Dellazizzo, L., Laurelli, M., Breton, R., Lalonde, P., Phraxayavong, K., O'Connor, K., Pelletier, J.-F., Boukhalfi, T., Renaud, P., & Dumais, A. (2018). Virtual Reality Therapy for Refractory Auditory Verbal Hallucinations in Schizophrenia: A Pilot Clinical Trial. *Schizophrenia Research*, *197*, 176–181. doi: 10.1016/j.schres.2018.02.031

Dubois, L.-É., Le Masson, P., Cohendet, P., & Simon, L. (2016). Le co-design: Au service des communautés créatives. *Gestion*, *41*(2), 70. doi: 10.3917/riges.412.0070

Dyekjær, C. D., & Dreyer, P. (2019). The Family House—A Safe Haven: A Qualitative Study of Families' Experiences Staying in a Hospital Family House During Their Children's Hospitalisation. *Journal of Clinical Nursing*, *28*(11–12), 2276–2284. doi: 10.1111/jocn.14827

Facchini, M., & Ruini, C. (2021). The Role of Music Therapy in the Treatment of Children with Cancer: A Systematic Review of Literature. *Complementary Therapies in Clinical Practice*, *42*, 101289. doi: 10.1016/j.ctcp.2020.101289

Ferguson, C., Davidson, P. M., Scott, P. J., Jackson, D., & Hickman, L. D. (2015). Augmented Reality, Virtual Reality and Gaming: An Integral Part of Nursing. *Contemporary Nurse*, *51*(1), 1–4. doi: 10.1080/10376178.2015.1130360

Fijačko, N., Gosak, L., Cilar, L., Novšak, A., Creber, R., Skok, P., & Štiglic. (2020). The Effects of Gamification and Oral Self-Care on Oral Hygiene in Children: Systematic Search in App Stores and Evaluation of Apps. *JMIR mHealth and uHealth*, *8*, 19. doi: 10.2196/16365

Findeli, A., & Coste, A. (2007). De la recherche—Création à la recherche—Projet: Un cadre théorique et méthodologique pour la recherche architecturale. *Lieux Communs - Les Cahiers Du LAUA*, *10*, 139–161.

Fortier, M. A., Chung, W. W., Martinez, A., Gago-Masague, S., & Sender, L. (2016). Pain Buddy: A Novel Use of M-Health in the Management of Children's Cancer Pain. *Computers in Biology and Medicine*, *76*, 202–214. doi: 10.1016/j.compbiomed.2016.07.012

Fullerton, T. (2014). *Game Design Workshop: A Playcentric Approach to Creating Innovative Games*. CRC press.

Geslin, E., Jégou, L., & Beaudoin, D. (2016). How Color Properties Can Be Used to Elicit Emotions in Video Games. *International Journal of Computer Games Technology*, *2016*, 1–9. doi: 10.1155/2016/5182768

Gosselin, P., & Le Coguiec, É. (2006). *La recherche-création—Pour une compréhension de la recherche en pratique artistique* (PUQ).

Guynes, S., & Hassler-Forest, D. (Eds.). (2017). *Star Wars and the History of Transmedia Storytelling*. Amsterdam University Press. doi: 10.5117/9789462986213

Haruna, H., Hu, X., Chu, S., Mellecker, R., Gabriel, G., & Ndekao, P. (2018). Improving Sexual Health Education Programs for Adolescent Students through Game-Based Learning and Gamification. *International Journal of Environmental Research and Public Health*, *15*(9), 2027. doi: 10.3390/ijerph15092027

Hemenover, S. H., & Bowman, N. D. (2018). Video games, emotion, and emotion regulation: Expanding the scope. *Annals of the International Communication Association*, *42*(2), 125–143. doi: 10.1080/23808985.2018.1442239

Hodent, C. (2017). *The gamer's brain: How neuroscience and UX can impact video game design.* (CRC Press).

Hoffman, H. G., Boe, D. A., Rombokas, E., Khadra, C., LeMay, S., Meyer, W. J., Patterson, S., Ballesteros, A., & Pitt, S. W. (2020). Virtual Reality Hand Therapy: A New Tool for Nonopioid Analgesia for Acute Procedural Pain, Hand Rehabilitation, and VR Embodiment Therapy for Phantom Limb Pain. *Journal of Hand Therapy*, *33*(2), 254–262. doi: 10.1016/j.jht.2020.04.001

Hudson, S., Matson-Barkat, S., Pallamin, N., & Jegou, G. (2019). With or Without you? Interaction and Immersion in a Virtual Reality Experience. *Elsevier*, 37, 459-468. doi: 10.1016/j.jbusres.2018.10.062

Hunter, J. F., Acevedo, A. M., Gago-Masague, S., Kain, A., Yun, C., Torno, L., Jenkins, B. N., & Fortier, M. A. (2020). A Pilot Study of the Preliminary Efficacy of Pain Buddy: A Novel Intervention for the Management of Children's Cancer-Related Pain. *Pediatric Blood & Cancer*, *67*(10). doi: 10.1002/pbc.28278

International Association for the Study of Pain. (2020). *IASP Announces Revised Definition of Pain—International Association for the Study of Pain (IASP)*. https://www.iasp-pain.org/publications/iasp-news/iasp-announces-revised-definition-of-pain/

Isbister, K. (2016). *How Games Moves Us* (MIT Press).

Jenkins, H. (2010). Transmedia Storytelling and Entertainment: An annotated syllabus. *Continuum*, *24*(6), 943–958. doi: 10.1080/10304312.2010.510599

Jenkins, H. (2017). Adaptation, Extension, Transmedia. *Literature/Film Quarterly*, *45*(2).

Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., & Walton, A. (2008). Measuring and Defining the Experience of Immersion in Games. *International Journal of Human-Computer Studies*, *66*(9), 641–661. doi: 10.1016/j.ijhcs.2008.04.004

Johnson, D., Deterding, S., Kuhn, K.-A., Staneva, A., Stoyanov, S., & Hides, L. (2016). Gamification for Health and Wellbeing: A Systematic Review of the Literature. *Internet Interventions*, *6*, 89–106. doi: 10.1016/j.invent.2016.10.002

Khadra, C., Ballard, A., Paquin, D., Cotes-Turpin, C., Hoffman, H. G., Perreault, I., Fortin, J.-S., Bouchard, S., Théroux, J., & Le May, S. (2020). Effects of a Projector-Based Hybrid Virtual Reality on Pain in Young Children With Burn Injuries During Hydrotherapy Sessions: A Within-Subject Randomized Crossover Trial. *Burns*, *46*(7), 1571–1584. doi: 10.1016/j.burns.2020.04.006

Kyrlitsias, C., & Michael-Grigoriou, D. (2022). Social interaction with agents and avatars in immersive virtual environments: A survey. Frontiers in Virtual Reality, 2, 786665. doi: 10.3389/frvir.2021.786665

Laforest, M., Bouchard, S., Bossé, J., & Mesly, O. (2016). Effectiveness of In Virtuo Exposure and Response Prevention Treatment Using Cognitive–Behavioral Therapy for Obsessive–Compulsive Disorder: A Study Based on a Single-Case Study Protocol. *Frontiers in Psychiatry*, *7*. doi: 10.3389/fpsyt.2016.00099

Lazor, T., De Souza, C., Urquhart, R., Serhal, E., & Gagliardi, A. R. (2021). Few Guidelines Offer Recommendations on How to Assess and Manage Anxiety and Distress in Children With Cancer: A Content Analysis. *Supportive Care in Cancer*, *29*(5), 2279–2288. doi: 10.1007/s00520-020-05845-8

Le May, S., Hupin, M., Khadra, C., Ballard, A., Paquin, D., Beaudin, M., Bouchard, S., Cotes-Turpin, C., Noel, M., Guingo, E., Hoffman, H. G., Déry, J., Hung, N., & Perreault, I. (2021). Decreasing Pain and Fear in Medical Procedures with a Pediatric Population (DREAM): A Pilot Randomized Within-Subject Trial. *Pain Management Nursing*, S1524904220302046. doi: 10.1016/j.pmn.2020.10.002

Le May, S., Tsimicalis, A., Noel, M., Rainville, P., Khadra, C., Ballard, A., Guingo, E., Cotes-Turpin, C., Addab, S., Chougui, K., Francoeur, M., Hung, N., Bernstein, M., Bouchard, S., Parent, S., & Debeurme, M. H. (2020). Immersive Virtual Reality vs. Non-Immersive Distraction for Pain Management of Children During Bone Pins and Sutures Removal: A Randomized Clinical Trial Protocol. *Journal of Advanced Nursing*, *n/a*(n/a). doi: 10.1111/jan.14607

Léchot Hirt, L. (2015). Recherche-création en design à plein régime: Un constat, un manifeste, un programme. *Sciences du Design*, *n° 1*(1), 37. doi: 10.3917/sdd.001.0037

Lopes-Junior, L. C., Silveira, D. S. C., Olson, K., Bomfim, E. O., Veronez, L. C., Santos, J. C., Alonso, J. B., Nascimento, L. C., Pereira-da-Silva, G., & Lima, R. A. G. (2020). Clown Intervention on Psychological Stress and Fatigue in Pediatric Patients With Cancer Undergoing Chemotherapy. *Cancer Nursing*, *43*(3), 290–299. doi: 10.1097/NCC.0000000000000690

Magnenat, S., Gross, M., Sumner, R. W., Ngo, D. T., Zund, F., Ryffel, M., Noris, G., Rothlin, G., Marra, A., Nitti, M., & Fua, P. (2015). Live Texturing of Augmented Reality Characters from Colored Drawings. *IEEE Transactions on Visualization and Computer Graphics*, *21*(11), 1201–1210. doi:10.1109/TVCG.2015.2459871

Marsh, L. E., Kanngiesser, P., & Hood, B. (2018). When and How Does Labour Lead to Love? The Ontogeny and Mechanisms of the IKEA Effect. *Cognition*, *170*, 245–253. doi: 10.1016/j.cognition.2017.10.012

Mascarenhas, D. R. D., & Smith, N. C. (2011). Developing the performance brain. In *Performance Psychology* (pp. 245–267). Elsevier. doi: 10.1016/B978-0-443-06734-1.00017-1

McCloud, S. (1992). *Understanding Comics: The Invisible Art*. Kitchen Sink Press.

McMurtry, C. M., Noel, M., Chambers, C. T., & McGrath, P. J. (2011). Children's Fear During Procedural Pain: Preliminary Investigation of the Children's Fear Scale. *Health Psychology*, *30*(6), 780–788. doi: 10.1037/a0024817

Merhi, O., Faugloire, E., Flanagan, M., & Stoffregen, T. A. (2007). Motion Sickness, Console Video Games, and Head-Mounted Displays. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *49*(5), 920–934. doi: 10.1518/001872007X230262

Miller, W. F. (1954). A Physiologic Evaluation of the Effects of Diaphragmatic Breathing Training in Patients With Chronic Pulmonary Emphysema. *The American Journal of Medicine*, *17*(4), 471–477. doi: 10.1016/0002-9343(54)90122-9

Mori, M., MacDorman, K., & Kageki, N. (2012). The Uncanny Valley [From the Field]. *IEEE Robotics & Automation Magazine*, *19*(2), 98–100. doi: 10.1109/MRA.2012.2192811

Murray, J. (1997). *Hamlet on the Holodeck: The Future of Narrative in Cyberspace*. MIT Press.

Mütterlein, J. (2018). The Three Pillars of Virtual Reality? Investigating the Roles of Immersion, Presence, and Interactivity. *Proceedings of the 51st Hawaii International Conference on System Sciences*, 9.

Nazari, B., Bakhshi, S., Kaboudi, M., Dehghan, F., Ziapour, A., & Montazeri, N. (2017). A Comparison of Quality of Life, Anxiety and Depression in Cancer and Non-cancer Children in Kermanshah, Iran. *International Journal of Pediatrics*, *Online First*. doi: 10.22038/ijp.2017.23540.1978

Nevin, C. R., Westfall, A. O., Rodriguez, J. M., Dempsey, D. M., Cherrington, A., Roy, B., Patel, M., & Willig, J. H. (2014). Gamification as a Tool for Enhancing Graduate Medical Education. *Postgraduate Medical Journal*, *90*(1070), 685–693. doi: /10.1136/postgradmedj-2013-132486

Nolin, P., Besnard, J., Allain, P., & Banville, F. (2019). Assessment and Rehabilitation Using Virtual Reality after Stroke: A Literature Review. In *Virtual Reality for Psychological and Neurocognitive Interventions* (pp. 307–326). Springer. doi: 10.1007/978-1-4939-9482-3_14

Norman, D. A. (1988). *The Psychology of Everyday Things.* Basic books.

Norman, D. A. (2013). *The Design of Everyday Things: Revised and Expanded Edition*. Basic books.

Norton, M. I., Mochon, D., & Ariely, D. (2012). The IKEA effect: When labor leads to love. *Journal of Consumer Psychology*, *22*(3), 453–460. doi: 10.1016/j.jcps.2011.08.002

Osmanlliu, E., Trottier, E. D., Bailey, B., Lagacé, M., Certain, M., Khadra, C., Sanchez, M., Thériault, C., Paquin, D., Côtes-Turpin, C., & Le May, S. (2021). Distraction in the Emergency department using Virtual reality for INtravenous procedures in Children to Improve comfort (DEVINCI): A Pilot Pragmatic Randomized Controlled Trial. *Canadian Journal of Emergency Medicine*, *23*(1), 94–102. doi: 10.1007/s43678-020-00006-6

Paquin, L.-C., & Noury, C. (2018). Définir la recherche-création ou en cartographier les pratiques ? *ACFAS Magazine*, 12.

Patyal, N. (2022). *Ikea Effect: Creating Customer Value Through Customer Engagement* [PhD Thesis].

Roohi, S., & Forouzandeh, A. (2019). Regarding color psychology principles in adventure games to enhance the sense of immersion. *Entertainment Computing*, *30*, 100298. doi: 10.1016/j.entcom.2019.100298

Ryan, R. M., & Deci, E. L. (2020). Intrinsic and Extrinsic Motivation from a Self-Determination Theory Perspective: Definitions, Theory, Practices, and Future Directions. *Contemporary Educational Psychology*, *61*, 101860. doi: 10.1016/j.cedpsych.2020.101860

Rogers, K., Aufheimer, M., Weber, M., & Nacke, L. E. (2018). Towards the Visual Design of Non-Player Characters for Narrative Roles. Graphics Interface Conference.

Schiller, M. (2018). Transmedia Storytelling: New Practices and Audiences. In *Stories* (Ian Christie and Annie van den Oever, pp. 97–108). Amsterdam University Press. http://www.jstor.com/stable/j.ctv5rf6vf.10

Selye, H. (1956). Stress and psychiatry. *American Journal of Psychiatry*, *113*(5), 423–427.

Spielberger, C. D. (1972). Current Trends in Theory and Research on Anxiety. In *Anxiety* (pp. 3–19). Elsevier. doi: 10.1016/B978-0-12-657401-2.50008-3

Srimookda, N., Saensom, D., Mitsungnern, T., Kotruchin, P., & Ruaisungnoen, W. (2021). The Effects of Breathing Training on Dyspnea and Anxiety Among Patients With Acute Heart Failure at Emergency Department. *International Emergency Nursing*, *56*, 101008. doi: 10.1016/j.ienj.2021.101008

Stévance, S. (2012). À la recherche de la recherche-création: La création d'une interdiscipline universitaire. *Intersections: Canadian Journal of Music*, *33*(1), 3. doi: 10.7202/1025552ar

Suncksen, M., Bendig, H., Teistler, M., Wagner, M., Bott, O. J., & Dresing, K. (2018). Gamification and Virtual Reality for Teaching Mobile X-Ray Imaging. *2018 IEEE 6th International Conference on Serious Games and Applications for Health (SeGAH)*, 1–7. doi: 10.1109/SeGAH.2018.8401364

Suso-Ribera, C., Fernández-Álvarez, J., García-Palacios, A., Hoffman, H. G., Bretón-López, J., Baños, R. M., Quero, S., & Botella, C. (2019). Virtual Reality, Augmented Reality, and *In Vivo* Exposure Therapy: A Preliminary Comparison of Treatment Efficacy in Small Animal Phobia. *Cyberpsychology, Behavior, and Social Networking*, *22*(1), 31–38. doi: 10.1089/cyber.2017.0672

T. J. (2016). *Pixar Demographics: What The Average Pixar Fan Looks Like? - Pixar Post*. Pixarpost.Com. https://pixarpost.com/2016/07/pixar-demographics.html

Tao, G., Garrett, B., Taverner, T., Cordingley, E., & Sun, C. (2021). Immersive Virtual Reality Health Games: A Narrative Review of Game Design. *Journal of NeuroEngineering and Rehabilitation*, *18*(1), 31. doi: 10.1186/s12984-020-00801-3

Tekinbas, K. S., & Zimmerman, E. (2003). *Rules of Play: Game Design Fundamentals*. MIT press.

Tola, Y. O., Chow, K. M., & Liang, W. (2021). Effects of Non-Pharmacological Interventions on Preoperative Anxiety and Postoperative Pain in Patients Undergoing Breast Cancer Surgery: A Systematic Review. *Journal of Clinical Nursing*, *30*(23–24), 3369–3384. doi: 10.1111/jocn.15827

Treviño-Guzmán, N., & Pomales-García, C. (2014). How can a serious game impact student motivation and learning?. In IIE Annual Conference. Proceedings (p. 514). Institute of Industrial and Systems Engineers (IISE).

Tutelman, P. R., Chambers, C. T., Stinson, J. N., Parker, J. A., Fernandez, C. V., Witteman, H. O., Nathan, P. C., Barwick, M., Campbell, F., Jibb, L. A., & Irwin, K. (2018). Pain in Children With Cancer: Prevalence, Characteristics, and Parent Management. *The Clinical Journal of Pain*, *34*(3), 198–206. doi: 10.1097/AJP.0000000000000531

Udara, S. W. I., & Alwis, A. K. D. (2019). Gamification for Healthcare and Well-Being. *Global Journal of Medecine Research*, *19*(4), 25–29.

Vial, S. (2015). *Le design*. Presses Universitaires de France.

Villani, D., Carissoli, C., Triberti, S., Marchetti, A., Gilli, G., & Riva, G. (2018). Videogames for emotion regulation: a systematic review. Games for health journal, 7(2), 85-99.

Wang, H., Liu, X.-L., Wang, T., Tan, J.-Y. (Benjamin), & Huang, H. (2022). Breathing Exercises for Pain Management in Cancer Survivors: A Systematic Review. *Pain Management Nursing*. doi: 10.1016/j.pmn.2022.11.003

Wilkinson, P. (2016). A Brief History of Serious Games. In R. Dörner, S. Göbel, M. Kickmeier-Rust, M. Masuch, & K. Zweig (Eds.), *Entertainment Computing and Serious Games* (Vol. 9970, pp. 17–41). Springer International Publishing. doi: 10.1007/978-3-319-46152-6_2

Williams, A. C. de C., & Craig, K. D. (2016). Updating the Definition of Pain. *Pain*, *157*(11), 2420–2423. doi: 10.1097/j.pain.0000000000000613

Xiang, H., Shen, J., Wheeler, K. K., Patterson, J., Lever, K., Armstrong, M., Shi, J., Thakkar, R. K., Groner, J. I., Noffsinger, D., Giles, S. A., & Fabia, R. B. (2021). Efficacy of Smartphone Active and Passive Virtual Reality Distraction vs Standard Care on Burn Pain Among Pediatric Patients: A Randomized Clinical Trial. *JAMA Network Open*, *4*(6), e2112082. doi: 10.1001/jamanetworkopen.2021.12082

Zhang, C. (2020). Investigation on Motion Sickness in Virtual Reality Environment from the Perspective of User Experience. *2020 IEEE 3rd International Conference on Information Systems and Computer Aided Education (ICISCAE)*, 393–396. doi: 10.1109/ICISCAE51034.2020.9236907