Narrative-based Gamification for Physical Therapy

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October 2022

Abstract

With the ageing population and the longer life expectancy, more people will seek physical therapy to prevent and recover from physical decline and injuries. Although traditional therapy programs have proven their effectiveness, they can be painful and unappealing for some patients, as they have to perform repetitive and monotonous exercises. We developed a user-friendly and engaging system, *ARCADE-N*, to support upper-limb rehabilitation by leveraging gamification elements such as feedback mechanisms and a narrative that is progressively unlocked throughout the sessions. The system was deployed and tested in a rehabilitating clinic for three weeks. The results showed that *ARCADE-N* motivated and engaged patients, mainly due to the narrative. Our results also revealed that the gamified feedback elements, such as the voice assistant and the dummy, were relevant to give patients awareness about their body movements which is essential to the rehabilitation process.

Keywords: Gamification , Physiotherapy , Rehabilitation , Narrative

1. Introduction

The overall ageing of the population and longer life expectancy will drive more people to seek medical care to improve age-related musculoskeletal decline, and injury [20]. Nowadays, advances in healthcare make it possible to prevent and treat such injuries [3]. However, survivors of such disorders often lose their motor mobility and become unable to carry out daily activities, losing their autonomy and quality of life [3].

Physiotherapy is one measure in modern healthcare used to improve and restore physical function after injury or surgery [3]. However, the traditional physical rehabilitation process can be slow, making progress sometimes invisible to patients and professionals [3]. For patients, this can affect their motivation and raise doubts about the benefits of physiotherapy [3]. For clinical professionals, it leads to inaccurate assessments of physical abilities and longer rehabilitation processes.

Ways to improve rehabilitation processes, namely through technology (new gadgets, software, and apps), have been explored. As varied as they come, these technologies can make therapy treatment more effective with advantages such as increasing patient motivation, increasing the intensity of the exercises, and an increase of the recovery speed [18]. Mainly, technologies focusing on rehabilitating the upper limbs can restore the autonomy needed to carry out everyday tasks like eating and dressing [1].

1.1. Objectives and Proposal

This project aims to increase patient engagement in their rehabilitation program by applying gamification and integrating a narrative in an upper-limb rehabilitation application. First, we applied the knowledge found in the related work to develop a functional high-fidelity prototype. We improved it through multiple iterations using the physiotherapists' input and testing its usability via Usability Tests. Then, we took our prototype and deployed it in a clinic for three weeks, where we evaluated it with the help of actual patients with upper-limb injuries. Lastly, we did a thematic analysis of the results to build our conclusions.

1.2. Contributions

The main contributions of this work are: (1) Development of a gamified Kinect-based rehabilitation system capable of supporting upper-limb therapy sessions; (2) Conducted a study with patients and professional physiotherapists that included a qualitative thematic analysis of their opinions about the implementation of our system in their therapies; (3) Results from a study on the use of narrative-based approaches in engaging patients in their physiotherapy sessions.

2. Gamification Frameworks in Healthcare

Gamification is defined by the application of game mechanics to non-game contexts to engage audiences and inject some fun into dull activities in addition to producing motivational and cognitive benefits [19]. Gamification takes video game mechanics such as leaderboards, points systems, badges and up-levelling in order to tap the natural human drive for competition and achievement. These game-like elements motivate its users to participate actively, increasing engagement. While many fields such as Business, Marketing and e-Learning have taken advantage of the potential of gamification, the digital healthcare domain has also started to exploit this emerging trend [19]. Literature [19, 12, 7, 14] proves that such motivation and enjoyment can be highly beneficial in a rehabilitation context, where tasks are often mundane and repetitive by nature. Therefore, solutions that use game elements and user-centred design have been arising to target and improve therapeutic processes.

Some frameworks explain how gamification should be applied to a solution in healthcare. One of the goals that gamification aims to achieve is to drive the behaviour of users. However, influencing behaviour in healthcare is not an easy task [8]. To influence a user's behaviour, one must understand how behaviour occurs and the factors that contribute to it.

2.1. The Fogg Behaviour Model

B.J. Fogg [6] proposed a model that explains how behaviour occurs. The Fogg Behaviour Model (FBM) asserts that for a person to perform a target behaviour, they must (1) be sufficiently **motivated**, (2) have the **ability** to perform the behaviour, and (3) be **triggered** to perform the behaviour. These three factors must occur simultaneously, or the behaviour will not happen. If a design team or a physiotherapist notices that users are not performing the desired behaviour, they can use FBM to determine what is missing. It also works on prevention: if a patient is performing unwanted behaviour, one can focus on one of the three factors (reducing motivation, taking away the ability, or removing triggers).

2.2. Wheel of Sukr

In 2015, Marshedi et al. [15] proposed a conceptual framework named The Wheel Of Sukr to assist in the self-management of diabetes for young adults in Saudi Arabia (see Fig. 1). The goal is to influence users to better self-manage their condition and motivate them towards healthy behaviours that are hard to start or maintain through gamification. The authors state that rewarding patients for taking their medication is much more effective than punishing them for not taking it regularly. However, some systems that rely solely on rewards like points and badges are not successful in the long term. To gain full advantage of specific gamification techniques, they need to be tailored to a specific environment [15]. The Wheel of Sukr provides the guidelines to design for diabetic users. However, we believe it is adaptable to the rehabilitation environment.

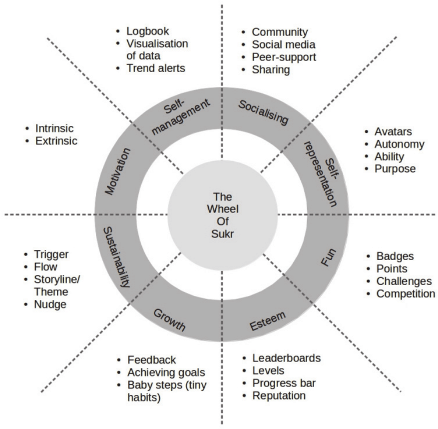

Figure 1: The Wheel of Sukr - a framework that uses gamification to design solutions in healthcare. Image taken from [15].

2.3. Game design principles for rehabilitation

In 2009, Burke et al. [4] identified three aspects that are important for optimising engagement for gamified applications for physical rehabilitation:

Meaningful play - A well-designed game should provide clear, consistent and meaningful feedback (visual, auditory or haptic) in response to the player's actions. Meaningful play is necessary for users to know their goals, what actions they need to achieve them, and if they are achieving them.

Challenge - Games for rehabilitation should be designed to dynamically adapt the difficulty or level of *challenge* depending on the player's performance.

Handling of Failure - Since some patients have poor motor control and a possible unfamiliarity with playing video games, the probability of them experiencing *failure* is high. It is less likely that players will feel discouraged when failure is positively handled by encouraging and rewarding them.

3. Related Work

In this chapter, we describe studies that use gamification techniques in the context of rehabilitation and then detail the studies that developed a solution specifically for upper limb recovery.

3.1. Gamification in Physical Rehabilitation

Natural Interaction is a Human-Computer Interaction technique that allows the user and the machine to communicate using actions commonly practised by human beings, such as facial expression, gestures, and voice [22]. Therefore, Natural Interaction presents itself as a promising approach in rehabilitation, as it allows the user to interact with an application using the actual therapy exercises. Motionsensor-based devices such as *Kinect* support Natural Interaction and can assist physical therapy.

Madeira et al. [13] sought to understand the opinion of Portuguese physiotherapists regarding the use of Gamification and Kinect in rehabilitation. The results revealed that both patients and physiotherapists are receptive to this type of application and that it is a novelty, as a rehabilitation aid, to the Portuguese community.

McClincy et al. [16] conducted a user-centred design process with a total of 10 athletes aged 10-18 years with a history of *Anterior cruciate ligament* (knee joint) reconstruction. The design process included a workshop where the participants ranked cards representing the components of the Wheel of Sukr in order of interest. The results showed that the participants would feel more motivated to complete their prescribed home exercises if they had their therapist monitoring their progress. Therefore, having a device that tracks and registers patients' progress when doing exercises was highly beneficial. Additionally, a good approach would incorporate performance thresholds or milestones to understand better how their recovery progressed.

Murnane et al. [17] evidenced a problem with the use of quantitative data representations (e.g., charts, graphs, and statistical reports) in most health tools. They suggest that such feedback can fail to motivate behaviour and fuel negative mindsets about exercise, as these data representations can be hard to interpret and overwhelming to users. To address this problem, the authors developed a smartphone application called *WhoIsZuki* that visualises physical activities and goals as components of a **multi-chapter quest**, where the main character's progress is tied to the user's. To ensure the narrative was understandable and appealing, the engagement of 7 participants was measured based on five dimensions from the Narrative Engagement Scale [5]: empathy, cognitive perspective taking, narrative involvement, ease of cognitive access, and narrative realism. The results led the authors to conclude that multi-chapter narratives can boost physical activity levels and engagement with both the system and its story.

3.2. Interactive Upper Limb Rehabilitation

In the previous section, we saw that gamification could be supported by techniques like Natural Interaction, User-centered design and Narratives. This section explored which and how gamification elements are used in serious games and gamified solutions that address Upper Limb Rehabilitation.

Whittinghill [23] created a Kinect-based serious game that gamifies upper arm physical therapy by placing the player in the role of a bird navigating a nature-themed obstacle course. The player controls Burnie by flapping their arms and performing one of four poses that correspond directly to physical exercises defined by the medical professionals. The essence of Burnie's gamification is the motivation to collect prizes, which give points, and avoid hazards, which subtract points if the user hits them. The results indicate that transforming the exercise movements into the character controller increases the connection and engagement of the user with the game.

Ferreira et al. developed a smartphone application containing three games that use stroke rehabilitation exercises [10]. These games were designed to promote and evaluate different movements of the upper limbs, and their difficulty level is adaptable to each patient's impairment level. Before each game, a calibration phase evaluates the user's range of movement (in degrees), ensuring the games are always adapted to the patient's recovery stage.

In a study [1] carried out by Aranha et al., a Kinect-based serious game called MoVEROffice was developed to induce paraplegic patients to perform tasks inside a Virtual Reality (VR) scenario using Natural Interaction. The results showed that all users have a learning curve to manipulate the objects, but it can easily be overcome after a few sessions, proving that the difficulty relating to using Natural Interaction devices tends to be conquered after some uses.

4. Designing a Narrative for Rehabilitation

Narratives are known to be immersive and mentally engaging. A rich body of literature suggests that such immersion is persuasive because beliefs, emotions, and intentions can change to reflect those presented in the story [11]. In the context of health care, some narrative technologies have been used in the form of mobile applications. In particular, personalized narratives that positively frame exercise in terms of enticing and playful challenges presented through aesthetically pleasing interfaces may promote a more crave-worthy mindset and, in turn, more physical activity [17]. However, such interventions have not fully explored the use of narrative to instantiate effective and engaging storytelling techniques to motivate activity [2]. For all the reasons above, we decided to integrate a narrative into our system due to its potential to engage people to persist motivated in activities.

4.1. Interviews on patient Narrative Experiences

We conducted semi-interviews with 9 regular patients from *Clínica Dentária Egas Moniz* to gather insights and inspiration to create a suitable story that appeals to as many patients as possible. We started by briefing the project participants and then the semi-structured interviews, using a TV to illustrate the questions and recording the audio using a smartphone. The questions aimed to gather information about their favourite scenarios for the story (i.e. farm, sea, western), types of plots (i.e. family story, hero adventure) and genres (i.e. adventure, drama, mystery). Then, we transcribed and coded the audio to get the results.

4.1.1 Results

We can infer that most patients would enjoy watching an adventure story featuring family members and with the classic style of old movies. Similar to documentaries and old stories, a good narrative should also contain teachings and morals. Regarding the scenery, we believe that a story featuring the ocean would be more suitable for these patients, as they live in *Caparica* and visit the beach regularly, which makes patients naturally associate this scenario with their "home".

4.2. The Narrative and Illustrations

After receiving feedback from the interviews, we hired a writer with experience writing fictional stories and an illustrator to bring our story to life by illustrating the images the patients would see during the sessions. The final result was a five-chapter story named "An unexpected treasure", and each chapter is composed of 4 or 5 illustrations (a total of 23 illustrations). The visual language of the story is a mix of "Asterix & Obelix" and "Tintin" - two comics whose style we believe to be suitable to our story. As a final detail, we decided that every chapter would have a Portuguese proverb associated with it, as proverbs have the potential to "bring out" their childhood times. A summary is presented next.

Chapter 1: The apple does not fall far from the tree - introduces the main character, Pedro, whose objective is to fulfil the old dream of his grandfather: to find the hidden treasure on an unknown island in Chile.

Chapter 2: Every jack to his trade - Pedro arrives on the island, and shortly afterwards, he comes across a tribe of indigenous people who, at first glance, seem threatening. Without realizing it, Pedro is caught, getting himself into a sticky situation.

Chapter 3: Don't judge a book by its cover - Pedro is taken to dance with the indigenous people around the fire pit. At the end of the ritual, the chief gives offerings to demonstrate his friendship and respect for Pedro. Finally, Pedro says goodbye to his friends and heads to the island's south coast, where he will find the long-awaited treasure.

Chapter 4: Long time no see - After hours of walking through the forest, Pedro finds a strangely familiar hat. Following his sixth sense, he starts digging and, to his surprise, finds small bags full of diamonds. Finally! Pedro had fulfilled his grandfather's dream! Then, a nearby presence shows up, revealing to be his grandfather.

Chapter 5: You get what you give - Pedro follows his grandfather to his "house" - a village in the middle of the forest. The grandfather had founded a community that lived in harmony with the island and with the other tribe. His grandfather gives him a choice between staying on the island, away from consumerist vices or leaving with the diamonds and being rich. Upon reflection, Pedro chooses to return the diamonds to the island and stay.

Figure 2: Chapter 5, Image 5: "*Because wealth is everything that cannot be bought*, Pedro understood this there, on an unnamed island more than 10 thousand kilometres from home. Far from everything he thought he needed, he found the true treasure that every man seeks. Freedom, peace, love... Life. And he had never felt so rich."

5. ARCADE-N

5.1. Base prototype

ARCADE is a Kinect-based application developed by Duarte et al. [9] that supports physiotherapists and patients in upper-limbs physical rehabilitation. Duarte's research studied the physiotherapists' adoption process of markerless motion capture systems (technologies such as Kinect), using *ARCADE* during the evaluations. They concluded that the system was valuable to professionals, but it lacked in motivating patients to use it.

Our project, *ARCADE-N*[1], focused on the patients and their preferences, as we aimed to develop a more personalized and fun experience for them. The main goals of our project were to implement gamification and a narrative to motivate patients to enjoy our system, and to explore if it is a viable tool in assisting physiotherapists in creating engaging sessions.

5.2. Architecture

Similarly to the architecture of the base prototype, the movement data is captured by the Kinect and

[1] N stands for narrative

processed by the application developed in Unity3D, a computer runs the application, and a touch-screen TV serves as the interface to receive commands (see Fig. 3).

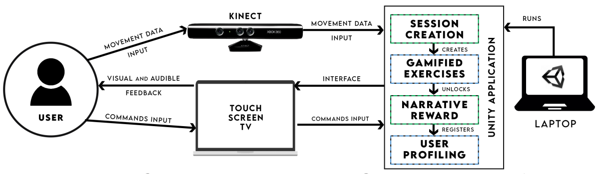

Figure 3: *ARCADE-N architecture*. Our contribution focused on the Unity application: in blue are the modules extended from existing features, and in green are the modules created from scratch.

5.3. ***ARCADE-N*: The Final version**

In this subsection, we describe the main features of the final version of *ARCADE-N*.

5.3.1 Creating the Session

To create the session, the physiotherapists can choose to Add, Delete or Edit **Sequences** of exercises (see Fig. 4). Essentially, creating a session is equal to creating a list of Sequences, in which every Sequence is a given Exercise repeated S x R times, with a given Arm (S is the number of Series, and R the number of Repetitions).

Figure 4: Session Creation screen: Multiple Sequences.

5.3.2 Exercise-Types

After creating the session, the application jumps to the "Exercise" screen, where the patient will perform the planned exercises. There are three different *exercise types*:

- **Vertical Raise.** The patient raises and lowers the arm forward in a line.
- **Horizontal Sweep.** The patient elevates the arm forward to shoulder level and then moves the arm sideways in a line.
- **Grid.** The patient uses their arm to go through multiple points on the screen, following one of four patterns (see Fig. 5).

Figure 5: Exercise screen: Grid exercise.

On the **left side**, we can see the progress of the current Sequence. On the **right side**, we can see the Pause, Voice assistant and Sound Buttons (that mute the voice assistant and the background music, respectively), and a panel containing information about the following Sequence with the button to jump to that Sequence. On the **top side**, we can see a progress bar that fills up whenever the patient performs a correct repetition. Each checkpoint on the bar corresponds to an illustration of the narrative. Finally, in the **middle of the screen**, we have the *exercise space* and the dummy that represents and mimics our patient in real-time. The dummy works as an "avatar" controlled by the patient, and is essential to completing the exercises. It expresses self-representation and helps to use a correct body posture.

Figure 6: Setup of the Vertical exercise: adjusting the green box.

5.3.3 Calibrating the exercises

For the vertical and horizontal exercises, the physiotherapy should adjust the position, height and width of the **green box** to match the desired range of movement (see Fig.6). The purpose of the green box is to work as a container for the patient's movements and prevent any compensatory movements that would further increase their injury. This setup allows the adjustment of the exercise difficulty for patients with different arm amplitudes and injury degrees. For the grid exercise, this step only requires the physiotherapist to choose between four different patterns.

5.3.4 Gamified Exercises

During the exercises, we implemented several gamification elements.

Voice Assistant. The voice assistant is a feature that speaks personalized voice lines during the exercises. There is a 50% chance that the voice assistant generates one of these lines whenever the patient completes or fails an exercise repetition. The auditory feedback differs depending on patients' correct or incorrect movements. Some examples of audio feedback for correct movements were: *"Keep going! You can do it!"*, *"Good job! You're almost there!"*; whereas for incorrect movements were: *"Oops, you got off track"*, *"Oh-oh, the movement did not follow the line"* (see Fig. 7).

Figure 7: Voice assistant - After patient leaves the green box (incomplete repetition): "You are a little off track."

Colors, sounds and music. There are multiple visual and sound cues that provide feedback on the exercise. When the patient makes a mistake and leaves the green box, it turns red and makes a "warning sound". When the user touches a ball, it shakes and makes a "beep" sound. A cheerful animation is played if a checkpoint on the bar is reached. We play upbeat background music to create a sporty and vibrant atmosphere.

Figure 8: Story screen: playing the unlocked narrative illustrations.

Progress bar and Unlocking the Narrative. As our main gamification element, the narrative is unlocked and seen during the session. The progress bar fills with every successful movement. When the patient performs a given number of exercises, they reach checkpoints on the bar and are rewarded with a piece of the narrative: in form of illustrations. Then, whenever there is a rest, the illustrations and respective captions are shown in a different screen, the *Story screen* (see Fig.8). To increase the immersion, we have a narrator, played by the same voice used in the voice assistant, that reads the captions aloud.

Performance score and medal. After finishing the planned exercises, the application recaps the whole unlocked chapter and then shows the *Session Results screen* (see Fig.9). There, the patients can see their end of session results: the duration of the session, the performance score (calculated by $\frac{Correct Repetitions}{Total Repetitions}$) and a medal according to their score (0-49% bronze, 50-79% silver, 80-100% gold).

Figure 9: Session Results screen: Shows the Performance score and medal.

5.3.5 Ending the session

The application then returns to the *Main Menu* and saves the session's results. These metrics can be consulted in the *Results Menu*. For each session, the following data is saved: type of exercises, number of correct and incorrect repetitions (named *out-of-paths*), performance, and total duration.

5.4. Design Process

This section describes the design process behind developing the application. The design process includes Usability Tests of a low-fidelity prototype and a Focus Group with the physiotherapists.

5.4.1 Usability Tests

We made a low-fidelity paper prototype using A4 sheets representing our screens. To evaluate the prototype, we asked 4 participants (Computer Science Master students) to complete four tasks. These tasks were the same actions of the physiotherapists creating the session for their patients. The "Wizard-of-Oz" and "Think-Aloud" methods were used. We recorded the audio and took notes during the tests. Afterwards, we transcribed and analysed them to reach the main conclusions.

Results. The low-fidelity prototype was particularly useful for exploring designs for the "Session Creation" and" Exercise" screens. We also gathered helpful feedback regarding the User Interface, such as showing and hiding information that potentially overwhelms the patients in the Exercise screen. However, we found that we still needed some input from the physiotherapists to implement the narrative and the exercise flow. Namely, questions related to the narrative were "Should the patient always get rewarded?" and "Should the story only be displayed at the end of the session?". Questions related to the exercise flow were "Should the patient take a rest after N repetitions or after T seconds?", "Is it ok to create the session on the go, or do you prefer to plan it beforehand?".

5.4.2 Focus Group with Physiotherapists

After the Usability Tests, we developed most of our application and then had one meeting with 3 physiotherapists at the clinic to ask for their feedback on the current version at the time and to clarify some critical questions mentioned in the last subsection. We recorded the audio and later transcribed and analysed it to form our conclusions.

Results. The main findings helped us make design decisions. We learned the importance of adjusting the difficulty during the exercises so we implemented the possibility of calibrating the green box at any time by pressing the "PAUSE" button. Instead of using forms of punishment, such as taking away the narrative reward, the physiotherapists suggested to give medals based on their performance score. The narrative should always be displayed piece-by-piece as they complete exercises, disregarding their performance.

6. User Study

The User Study aimed to test our prototype with real patients with upper limb injuries and their therapists. The results of this study gave us the data required to answer the following research questions:

1. What is the potential of this gamified application in improving the patient experience during their upper-limbs rehabilitation process?
2. What are the barriers and facilitators of this application?
3. Does *ARCADE-N* help physiotherapists in their daily activities?

6.1. Participants

The evaluation was carried out with eight patients (P1 to P8) and the help of 3 physiotherapists (F1, F2 and F3) from the rehabilitation clinic "Clínca Dentária Egas Moniz". The eight patients had two to three sessions weekly in the clinic due to their upper-limbs injuries. Five were women, and three were men. During the evaluations, the physiotherapists were responsible for creating the sessions.

6.2. Methodology

The experiment was conducted over three weeks, during the morning time, inside an isolated room at the clinic. We conducted an exploratory study in which each patient used *ARCADE-N* for four sessions. The experiment was comprised of the following stages: 1) Briefing, 2) Procedure, 3) Patient Post-Interview, and 4) Physiotherapists Post-Interview.

6.2.1 Briefing

In their first session, before the experiment began, all participants were given consent forms. These forms outlined the purpose and goals of the study and the information regarding the privacy and safety of their personal data. Participants were also informed that the audio and video from the sessions was being recorded for posterior transcription and analysis.

6.2.2 Procedure

We started every session by greeting the participant and setting up the system. We taught the physiotherapists how to use the system on their first use. To prepare for the experience, we would: (1) connect the Kinect to the PC and PC to the TV via HDMI; (2) run *ARCADE-N*; (3) login using the patient account; (4) turn on the phone camera and audio recorder; (5) the physiotherapist creates the session by adding the desired exercises; (6) start the exercises and adjust the green box.

During the exercises, the patients were placed in front of the TV. We were seated behind or on the side, taking notes. Both the patient and the therapists were encouraged to make comments.

After the proposed exercises were completed, the patients would see a recap of the narrative chapter, performance and medal, and greet us before leaving the room. Then, we would log out and wait for the next participant. On average, every session lasted 10 to 15 minutes, depending on the specific planning done by the professionals.

6.2.3 Physiotherapists Post-Interview

At the end of four sessions, each patient will have unlocked the five chapters of our story and will be prepared to answer a semi-structured interview, which is composed by two different sets of questions: *the narrative-engagement questions* and *experience using ARCADE-N*.

6.2.4 Physiotherapists Post-Interview

At the end of the study, we interviewed the three physiotherapists that used *ARCADE-N*. The questions aimed to clarify the potential of our system in the context of their daily routines and the application's positive and negative aspects (barriers and facilitators). The interview was audio-recorded for further analysis.

7. Results

In this section, we present a thematic analysis of the sessions and post-interviews collected during the user study at the clinic.

7.1. Thematic Analysis

First, we transcribed the audio/video recordings from each session and read them several times to have a broad understanding of the results, as a whole. Then, we did the same for the patient and physiotherapists interviews. On the second stage, we use the thematic analysis technique [21]. Through an inductive and deductive approach, we identified and labeled **92 codes** relevant on the transcripts. We then organized the codes into four themes: 1) Exercises: Potentialities and Patient's Adaptation; 2) Voice assistant: a motivational feature; 3) Narrative: a rewarding element; 4) Adoption of the system by the physiotherapists.

7.2. Theme 1 - Exercises: Potentialities and Patient's Adaptation

This theme focuses on how the patients perceived the *ARCADE-N* exercises and their potentialities.

We observed that all three exercises had a period of familiarization, especially the horizontal/vertical ones, of 20 to 30 repetitions. Most patients started slowly, but as the various sessions progressed, they desired to achieve better performances and acted as if the exercises were a challenge, which indicates an increase in their motivation. One example of this was P6, who, in his 3rd session, was already practising the exercises with a minimal margin of error, despite having felt shoulder pain and made compensatory movements in the first two sessions.

All participants recognized the dummy in the screen as a representation of their body and its benefits: *"It was good to keep your back straight"* (P3). The dummy, rigged based on the input data from Kinect, revealed a second advantage besides the visual feedback, as it disappears from the screen whenever the Kinect detects two or more people. Due to this programming bug, we learnt that our program is not prepared to work when the device captures more than one person, which limits the physiotherapists to providing verbal input to the patients.

We noticed that incomplete exercise repetitions (when patients fail to stay inside the green box) do not count as a repetition, and the counter did not advanced, making it difficult to proceed to further exercises. In the vertical/horizontal exercises, an exercise repetition is programmed as follows: start in target A, reach target B, and then make the way back to target A. If the patient leaves the path during this time, they have to restart from point A. It was annoying to go back to the starting target after failing mid-repetition, resulting in patients doing, for example, 15 movements to complete a series of only five repetitions (this problem occurred frequently to P2, P4, and P7).

7.3. Theme 2 - Voice assistant: a motivational feature

This theme focuses on the patients' perception of the voice assistant feature and how it affected their experience using *ARCADE-N*.

This feature had predominantly positive reviews. Some of the first impressions were that two patients (P3, P8) reacted to the voice by replying to it as if it was a real person: P3 replied back to "Good morning!" and P8 thanked after hearing the line "Keep going, you can do it!". As participants completed repetitions, the voice would congratulate them and probably make them feel good: *"This is fun, to hear the voice praise and encourage me. I love it! I think it is cute and a spectacular idea. We are old, we need cheer!"* (P7), *"It gives us encouragement when we complete the exercise and strength to try to do better"* (P6).

However, we observed that the voice assistant could be frustrating to listen in certain situations. First, when a patient is fast at completing exercises, the voice assistant generate lots of expressions in a short period of time, as they are programmed to randomly play with a 50% probability after every exercise repetition. Secondly, the voices could cause more impact if they were adjusted to the right moments, as F1 explains: *"Listening to a "Sensational!" on the second repetition is weird. It could be better calibrated"*.

7.4. Theme 3 - Narrative: a rewarding element

This theme explores how the narrative impacted patients' experience in terms of it being a rewarding and motivating element.

All but one participant paid attention to the story and wanted to know the ending. In the first chapter, our participants felt emotions like excitement and nostalgia. In the second chapter, when Pedro got caught by the indigenous tribe, two patients said they worried for him. In the fourth chapter, Pedro finds the treasure and his grandpa, which triggered the patients' curiosity to guess the possible solutions to the mystery. Two patients suggested the theory that Pedro imagined the treasure and his grandfather. The last chapter's plot effectively engaged the patients in the story because all eight participants expressed their opinion regarding Pedro's choice (to stay on the island vs take the diamonds).

The effect of the narrative was not limited to the sessions. For instance, P2 would think about the story on her way home, and P6 would talk about the story with other people before the sessions. Patients found the proverbs a fun touch, and in particular, three of them were mentioned several times during the study: "Every jack to his trade", "Appearances can be deceiving" and "Long time no see".

Lastly, some participants made noteworthy observations. P5 and P6 claimed that the story was a great "accessory" to the exercises. P8 thought the illustration style and the story format would be attractive to her seven-year-old granddaughter. P1, P3, P6 and F1 suggested integrating the story into the exercises, for example, making gestures such as ironing clothes or rowing to match the storyline.

7.5. Theme 4 - Adoption of the system by the physiotherapists

The last theme focuses on what the physiotherapists think of the system as a tool capable of creating motivating and fun sessions for their patients. Additionally, we explored its pros and cons in the working practice of physiotherapists.

All therapists could see the benefits and potentialities of *ARCADE-N* as it complements and improves the rehabilitation of their patients by transforming the regular dull exercises into a motivating experience. F2 told us that when P6 did a set of exercises moments before using *ARCADE-N*, he showed signs of pain. Then, he used the system to do the same set of exercises and did it without complaining: *"He was doing the same exercise [in the gym] feeling pain and here [using ARCADE] he was so excited that he did not complain!"* (F2).

We discussed the possibility of leaving the patients using the system alone. F1 said that the system had to be assembled in the gym, the common room where the other patients are. There, the therapists could manage their patients closely. F3 added that the system could be used at home with the proper follow-up.

F3 found it useful to adjust the margin of error (green box) and compare the performance scores throughout the sessions. F1 said that the most valuable aspect of the system is the vast number of options and parameters that they can use for different users. F3 added that it would be interesting to have exercises explicitly targeted to the inferior members. F1 suggested to add the option of adding more repetitions/exercises during the session.

8. Discussion

The first and main research question (RQ1) we posed was: "What is the potential of this gamified application in improving the patient experience during their upper-limbs rehabilitation process?". When we analyse the effects of the **gamification**, in themes 1 to 3, it becomes clear that they had a relevant role in providing positive experiences.

First, we observed a growing self-improvement and self-challenging feeling that led the patients to achieve better results in each session. During the interviews, they confirmed that looking at their performance scores **(gamification element: "pointification")** at the end of a session was motivating, but not the medals. Using pointification is not always a good practice in rehabilitation environments. Still, in this case, using the performance score functioned as a motivational factor because they did not get frustrated after failing a repetition (unless it was a Kinect problem), but instead, they concentrated more on improving their results. Secondly, as seen in theme 2, patient motivation also came from the voice-assistant **(gamification element: auditory feedback)** that praised and steered them.

The RQ2: "What are the barriers and facilitators of this application?" can be answered by analysing the application's features individually, and the voice assistant had both barriers and facilitators. In theme 2, participants claimed that the voice was kind, motivating, helpful in correcting their movements, and a facilitator in their adaptation to the exercises. The voice assistant was realistic enough that two patients replied to it as if it was a real person, which added to their positive experience. However, we found a barrier when the voice assistant became frustrating for one patient. For users that complete the exercises at a fast pace, this feature may result in a constant "avalanche of voice lines" as they are programmed to play on a 50% chance at every exercise repetition. A solution would be to have a "cooldown or timer" between two voice lines. Additionally, this feature could be improved by better adjusting the lines to the specific moments.

Correlating themes 1 and 2, we conclude that the combination of voice-assistant and dummy **(gamification element: visual feedback)** proved to be a great help during the exercises. These two facilitators contributed the most to giving an enjoyable experience to the patients. However, they needed to provide more feedback to make physiotherapist supervision expendable. Only 3 out of 8 patients felt comfortable enough to use *ARCADE-N* without the supervision of a therapist, as the majority of patients think that they could aggravate their injuries during the exercises. Despite that, we observed that most patients kept exercising whenever the therapist left the room for a few moments, proving that *ARCADE-N* can provide partial autonomy to some patients.

To answer the RQ3: "Does *ARCADE-N* help physiotherapists in their daily activities?" we can start by saying that, according to the last paragraph, the system does not possess the advantage of substituting the professionals and their time in a consistent way. To better answer the question, we must analyse how physiotherapists dealt with "creating sessions", as this was the main feature used by them. We observed in theme 1 that creating exercises was easy and intuitive. However, one barrier was not being able to add more exercises after the session started, which would help to mend any human errors during the creation phase. Theme 4 suggests that physiotherapists admit a lot of benefits in using this system. From quick setups to being able to compare results from previous sessions, therapists can improve their daily practices by using *ARCADE-N*. In the same theme, we found that the large variety of options was a huge facilitator, which allowed them to personalise the exercises to different patients. The therapists recognised that *ARCADE-N* was giving motivation to their patients and possibly making them ignore their pain. All things considered, it is reasonable to assume that physiotherapists would have the usage intent to apply *ARCADE-N* in their daily practises.

Lastly, and still regarding RQ1, we constructed theme 3, which talked about the narrative, to explore how it affected the patient experience. We cannot ensure that the narrative **(gamification element: rewarding)** was responsible for motivating patients to complete the proposed exercises because we did not have a control group to compare with (using *ARCADE-N* with and without the narrative). However, considering the results and positive feedback, we can assume that it may have improved the experience of all but one patient. Patients remembered some of the proverbs that made them feel nostalgic for old happy times. They were enthusiastic about the story during and after the sessions.

In summary, patients that used *ARCADE-N* felt motivated and interested in doing more sessions with the system, manifesting that it was an enjoyable experience. Also, the physiotherapists seemed very interested in utilizing the prototype as a rehabilitation option.

9. Conclusion

The main goal of this project was to improve the rehabilitation experience of patients with upper-limb injuries by developing a narrative-based gamified application that uses Kinect motion capture technology. Although traditional therapy programs have proven their effectiveness, they can be painful and unappealing for some patients, as they have to perform repetitive and monotonous exercises [3]. To face this issue, we partnered with professional physiotherapists and engaged with patients in a user-centred design process to build a system that could be deployed in the clinic environment to support upper-limb rehabilitation.

Ultimately, we learned that *ARCADE-N* could have a positive impact as a rehabilitation tool. The system may not substitute a physiotherapist but has the advantage of supporting the patients to understand their own movements through the dummy feedback, which complements the verbal input of an external observer. The system takes the traditional simple exercises and improves them through the motivational component, which is achieved not only through the different forms of feedback but also through the narrative and score system.

We believe this research contributes to establishing narrative-based gamified applications as a potential rehabilitation technology to boost patients' motivation, optimise intervention processes and improve overall physiotherapy rehabilitation.

9.1. Limitations and Future Work

As future work, we propose fixing the main barriers found during the user study, which include: 1) adjusting the frequency and selection of the voice assistant lines; 2) modifying the program to enable two or more people to stand in front of the Kinect; 3) implementing the possibility of adding new exercises during the session run-time; 4) counting incomplete exercise repetitions.

Physiotherapists provided helpful suggestions for future development and adoption of *ARCADE-N* in physiotherapy. To make the exercises more meaningful, they suggested transforming them into daily activities and trying to match them with the story (e.g. waving goodbye to the indigenous tribe as a pattern to the grid exercise, moving diamonds from a pile to a bag as the horizontal exercise). Moreover, implementing new exercises, specifically for the inferior members (legs and knees), would provide more flexibility to the solution. They also suggested making the tests in a shared room with other patients to see if the physiotherapists can manage multiple patients simultaneously. This will allow to understand if the system is helpful in a more realistic scenario instead of doing it in a separate room.

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