Promoting physical activity for Arthritis patients through a Gamified Environment

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Abstract

Aerobic exercise and physical activity have been shown to have positive effects on physical and mental health. For Rheumatoid arthritis patients who deal with painful joints, the case is even more important as they need to do a specified amount of activity to maintain a healthy lifestyle. Studies have shown that physical exercise or movement of the affected joint can noticeably improve long-term pain relief. However, little is known about the effects of a game involving physical activity on people with Rheumatoid Arthritis (RA). In this study, we aim to investigate the experience of RA patients from playing *TreasureHunt*, a Virtual reality Game with aerobic exercise.

Introduction

Rheumatoid Arthritis (RA) is a type of arthritis that causes swelling and pain in and around the joints through inflammation. With the pain and discomfort caused by this disease, people who have RA face difficulties with mobility and functional independence, which can severely affect the quality of life and ability to maintain physical activity (Haroon et al. 2007; Malm et al. 2017).

As arthritis causes a negative effect on physical health, to successfully manage arthritis disease, patients are recommended to maintain a physically active lifestyle. This recommendation is supported by several research studies that suggest that various forms of exercise and an appropriate amount of physical activity are safe and beneficial for people with RA (Chodzko-Zajko et al. 2009; van den Ende et al. 2000; Malm et al. 2017).

Virtual Reality (VR) is an emerging technology that has been shown to promote physical activity, especially for chronic pain (CP) patients who need rehabilitation for their pain management. Studies show that VR approach decreases CP patients' pain levels significantly higher than traditional management approaches (Gromala et al. 2015; Gromala et al. 2016).

While there have been numerous studies articulating the effects of exercise on the physical health of RA patients (Hernández-Hernández and Díaz-González 2017; Metsios and Kitas 2018; Verhoeven et al. 2016), there is a gap in the literature demonstrating the effects of physical activity in a VR game on people with RA. In this study, we will be investigating the effects of a game involving exercises and see if the game can promote physical activity. We are also interested in understanding RA patients' experience and feedback on the game, especially about the difficulty of game interactions.

Here, we designed and developed a game named *TreasureHunt*, to promote RA patients' physical activity. The current body of literature shows that physical activity and aerobic exercises have helped with RA patients. Additionally, seniors, specifically those with chronic pain, have shown interest in using games and virtual environments since it helps them with reducing their pain. Therefore, we expect that RA patients will be interested in playing *TreasureHunt* as well.

If this method shows promise, it can be used as a tool for motivating seniors with RA to be more physically active since it involves several body part movements. Further, we can get insights on how well people can tolerate the VR environment, their experience playing the game, and whether or not they are able to complete the exercises. Therefore, there will be contributions to research as well as benefits to patients.

Motivation

Motivation plays a key role in an active lifestyle. However, after a long day, people are usually not motivated enough to be physically active. For arthritis patients, the case is even harder because being physically active can be really painful for them. Therefore, even though RA patients are recommended to maintain a physically active lifestyle in order to manage their disease, they are not motivated enough to do so. Figure 1 explains the reasoning behind this concept clearly.

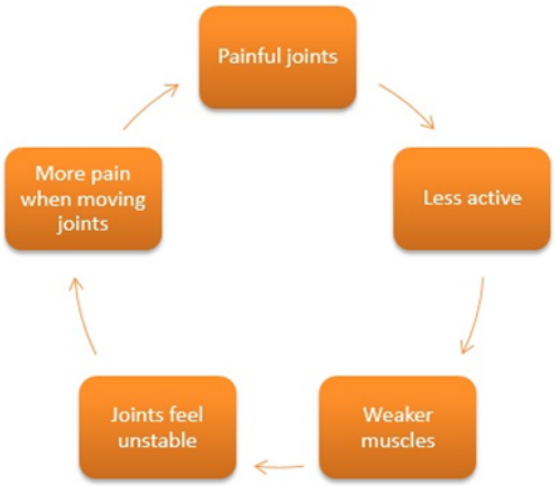

Figure 1: Lack of motivation for doing exercise

Therefore, In order to end this cycle, we are trying to find an approach to motivate RA patients to be more physically active.

Related Work

In this section, we position our research with respect to previous work in games and virtual environments designed for seniors. We will also take a closer look at the effects of physical activity for RA patients and technologies that have been created to promote it for them.

Games and Virtual Environments for older adults

In two studies (Gromala et al. 2015; Gromala et al. 2016), different virtual environments (VE) were designed for pain management and rehabilitation exercise purposes. In both studies, the VE approach showed a significantly higher level of impact at patients' pain levels compared to both of the traditional management approach and game approach.

In Another study by (Muñoz et al. 2018), Older adults had to interact with a VE named *Exerpong*, in which they had to hit a ball using a virtual paddle (Figure 2). Researchers designed the VE in a way that senior adults can fulfill their recommended levels of exertion and compared this method with the conventional exercise training. It was demonstrated that using the exergame within the virtual environments led to an increase in the time spent in the recommended levels of exertion compared with conventional training by 40%.

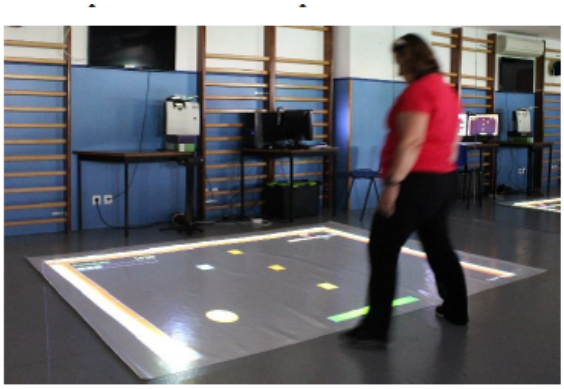

Figure 2: One of the participants interacting with the Exerpong (Muñoz et al. 2018)

Game mechanics also play a prominent role in generating motivation for seniors interacting with a VE. For example, *Wii Sports* become so popular with older adults because of its ease of use. Retirement community members in England are using *Wii Sports* for different purposes such as having fun, keeping physically fit and engaging socially with their friends (Ijsselsteijn et al. 2007).

Physical Activity for RA patients

Many studies have shown the positive effects of performing exercises for RA patients. In one study, (Brismée et al. 2007) demonstrated that a tai-chi program (Figure 3) consisting of six weeks of group exercise provides knee pain reduction and physical function improvement in elderly with knee arthritis.

In another study, results indicate that not only physical activity is safe for RA patients, but also benefits from regularly performing the exercises leads to improvement in quality of life (QOL), functionality, pain, and number of swollen joints (Hernández-Hernández and Díaz-González 2017).

With the advent of new technologies, Numerous persuasive systems have been developed in order to

Figure 3: An example of people doing tai-chi training

promote exercise over the past two decades. Different methods for encouraging physical activities are incorporated into the design of the persuasive systems. In this regard, a broad spectrum of different technologies such as web applications, mobile applications and games have been developed with the aim of promoting physical activity, specifically for RA patients whom this issue is of the utmost importance (Gupta et al. 2017; Tong et al. 2015; Thomsen et al. 2019; Mollard and Michaud 2018).

Furthermore, digital games now afford new ways of interacting that are both more natural in terms of affordances and engaging the whole body (Ijsselsteijn et al. 2007). In such a context, digital games can be regarded as persuasive technologies that provide an additional incentive to engage in healthy behavior. For instance, different interaction styles can be employed for engaging the user in an exercise.

Although these systems are useful for their intended purposes, to the best of our knowledge, there is no game with the purpose of engaging the whole body for RA patients to promote their motivation for physical activity. We argue that implementing such a game will bring benefits to patients as well as making contributions to research.

System description

TreasureHunt is a game for promoting physical activity for RA patients. Equipment that will be used in this study is the game *TreasureHunt*, which includes the exercises, and a single desktop with windows 10 installed on it. The completed version of *TreasureHunt*, which is going to be implemented in the future, will use HTC VIVE VR Head-Mounted display (HMD), a stereoscopic VR headset that has two handheld controllers, to track the user's position in space, including their arm and hand gestures. However, Due to the limitations of time, we only focused on the 2D version of the game so far.

TreasureHunt is a maze-based game (Figure 4), in which RA patients are going to move inside and interact with different items, which are all going to elevate level of exertion in the players. There are also different tasks designed inside the game with the intent of moving different body parts, especially movements that involve the motion of joints.

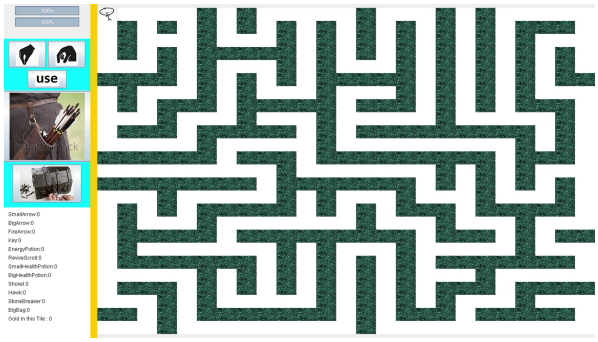

Figure 4: A snapshot of the game

When the game starts, the player has to move inside the maze in order to find the treasure. As shown in Figure 4, there is an energy bar in the top left corner of the picture (in the left panel), which is going to decrease upon the movement of player inside the game. There are also different icons seen in the left panel (pick, drop, use) that the player can employ in order to interact with different items. The player is also able to view her inventory by simply clicking on its icon.

Upon entering each tile, there are different items found that the details about each can be easily viewed from the left panel (bottom left corner). There are also tiles incorporating a specific task for elevating physical activity, which are randomly scattered throughout the maze. In one of these tasks, players need to complete a pattern by following numbers from 1 to 9 in ascending order. The players should make multiple attempts in order to complete the task and to be able to move to the next tile. Figure 5 shows the error which is given to the player upon entering the wrong order of numbers.

In the 3D version of the game, the window showing numbers is going to be projected in front of the player so that they can actually walk around and move their arms in order to push the buttons and follow the pattern.

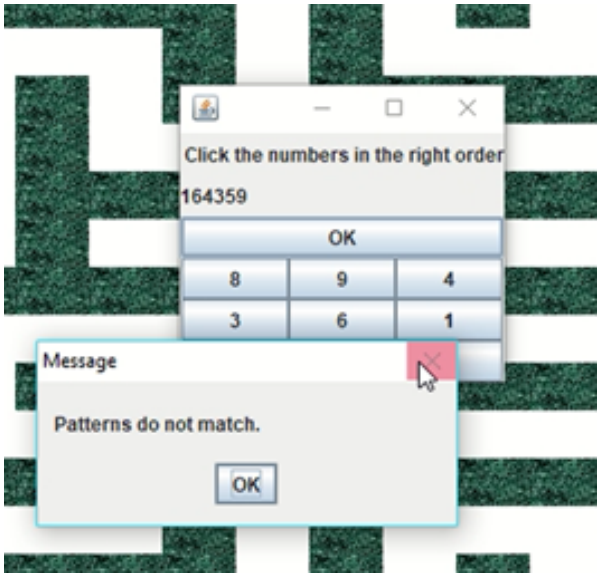

Figure 5: An error message showing to player because of not following the right order of numbers

System Implementation

Trying to implement the *TreasureHunt* in Java, we used Object-Oriented Programming Paradigm to implement our classes and the relationships between them. The main character of the game is an instance of the "Hero" class. The hero has a list of items in its inventory, which are implemented using a List of Items. Item class, which is an abstract class, is inherited by multiple classes such as BigBag, Potion, and Shovel. This is a nice and meaningful example of inheritance, which has been carefully taken into consideration. There is an abstract method named "Use" in our "Item" class, which is implemented in the successors of "Item" class. The overriding of this method and the castings which have happened in our program, state that polymorphism is also respected in our design and implementation. In Figure 6, The big picture of the classes and the relationships between them are shown.

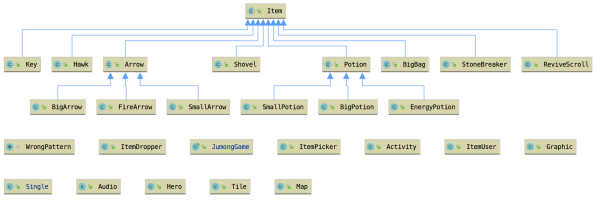

Figure 6: High level description of classes and their relationships

In Figure 7, we have brought the UML class diagram for a subset of classes to show more details.

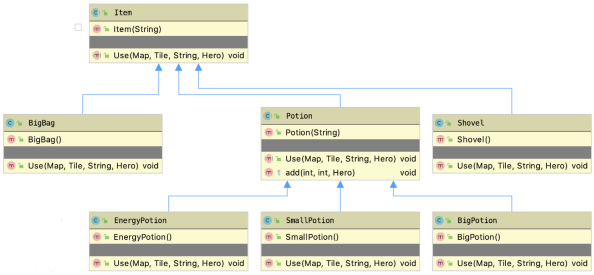

Figure 7: Low level description of a subset of classes showing details

Diving deeper into details of implementation, there are two other notable facts about the implementation, which I'd like to address here. Creating customized exceptions, throwing, and catching them is one of the upper sides of the implementation of this project. The other notable part about this project is its graphical user interface, which is implemented using Swing. During our implementation process, we carefully separated the logic of the game from its graphical user interface (GUI). This will simplify any future development and contributions to this project. Another best practice which has been used in this project is the clean separation of logic, graphics, and hierarchical structure in the GUI implementation. Separating containers, panels, and components have made the code readable and understandable.

Evaluation & Discussion

For evaluating this project, we would design a pilot user study in which we will ask RA patients to play the game. We will then employ different methods in order to evaluate our approach. At this stage, we have two goals in our research:

- **Physical activity and exertion analysis**
  We would like to study and find out if the tasks affect RA patients' physical activity and exertion. We will collect their perceived exertion with the Borg Rating of Perceived Exertion (RPE) questionnaire (Williams 2017).
- **Qualitative analysis on game experience**
  We are also interested in understanding RA patients' experience and feedback on the game and how they interact with the VE, especially about the difficulty of game interactions. We will collect qualitative data by conducting a semi-structured interview in which we are going to ask about the game aesthetics, feeling of discomfort during the game, instructions and tasks

and input simplicity.

If this method shows promise and the VR game can distract the patients from the amount of physical activity they are involved with, without them noticing that they are in an aerobic state, it can be used as a tool for motivating seniors with RA to be more physically active since it involves several body part movements. Furthermore, by asking about the game mechanics, players' experience and feedback on the game, we would get insights on how well people can tolerate the VR environment and whether or not they are able to complete the tasks. Therefore, not only we can iterate on the future versions of the game, but also there will be contributions to research in the design of game interactions for RA patients.

Despite all the benefits that this game will bring to both patients and the research community, there are limitations that should be noted. Firstly, because of the novelty of our approach, Unfortunately, there is no baseline to compare our game with. Therefore, we could only prove that patients can get into an aerobic state.
Additionally, in this study, we are focusing on positive changes in physical health that RA patients might benefit from, contrary to the fact that physical activity has numerous psychological and mental benefits as well. In the future, we will try to design tasks in which RA patients can take advantage of psychological benefits too.
Another limitation that was considered while designing the VE for the senior population was the simplicity. Aging changes not only affect how an individual uses VR controllers but also affects how they learn the conventions inside a game. The game should be simplified enough that the RA patients are comfortable interacting with and not in a way that is not interesting at all. Therefore, we designed the game and the interactions so that not only it is challenging enough for them but also not too complicated to complete. However, other populations, specifically from younger ages, might find this game too boring and easy.

Conclusion & Future Works

This game is currently in progress to make it easier for arthritis patients to be physically active by motivating them to move their body parts through exercises designed inside the game. However, Due to the limitations of the time, we could only focus on the 2D version of the game. In the future, we will implement the 3D version of the game in which the user has to move and interact with 3D objects.

Acknowledgements

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