

Increasing *Super Pop VRTM* Users' Intrinsic Motivation by Improving the Game's Aesthetics

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Abstract. During physical therapy intervention protocols, it's important to consider the individual's intrinsic motivation to perform in-home recommended exercises. Physical therapy exercises can become tedious thus limiting the individual's progress. Not only have researchers developed serious gaming systems to increase user motivation, but they have also worked on the design aesthetics since results have shown positive effects on the users' performance for attractive models. As such, we improved the aesthetics of a previously developed serious game called *Super Pop VRTM*. Namely, we improved the game graphics, added new game features, and allowed for more game options to provide users the opportunity to tailor their own experience. The conducted user studies show that participants rank the version of the game with the improved aesthetics higher in terms of the amount of interest/enjoyment it generates, thus allowing for an increase in intrinsic motivation when interacting with the system.

Keywords: Technological rehabilitation · *Super Pop VRTM* · Physical therapy · Game aesthetics · Serious games

1 Introduction

In general, individuals with a motor skill disorder are required to engage in some form of physical therapy. Some common disorders include, but are not limited to: cerebral palsy, Parkinson's disease, and motor impairment due to stroke. Although the benefits of physical therapy are well-documented, many individuals fail to perform the recommended in-home exercises. For example, M. Shaughnessy et al. [1] reported that only 31 % of the 312 stroke survivors that participated in the study exercised four times weekly. They concluded that maintaining an exercise program has the potential to improve physical function in the target population. As such, clinicians use gaming platforms for serious games as part of intervention protocols to increase the individual's self-efficacy and intrinsic motivation to perform the recommended in-home exercises. In general, serious games are defined as “(digital) games used for purposes other than

mere entertainment" [2]. More specifically, serious games for rehabilitation can affect the physiological and psychological outcomes for individuals in different scenarios. In this paper, we focus primarily on virtual reality (VR) rehabilitation games in physical therapy interventions. We have previously developed a VR game called *Super Pop VRTM* [3,4]. It combines interactive game play for evoking user movement with an objective and quantifiable kinematic algorithm to analyze the user's upper-body movements in real-time. During game play, users are asked to move their arms to 'pop' virtual bubbles that appear on screen while a three-dimensional (3D) depth camera maps the user's movements into the virtual environment.

Previous studies have shown that physical appearance in the design aesthetics has a positive effect on the users' performance for attractive models [5]. We adhere to these results and focused this work on improving the game's aesthetics such that it increases the user's intrinsic motivation to interact with the *Super Pop VRTM* game thus allowing for improvements in physical function. In addition to improving the game's appearance, we also modified the game's structure such that users have the option of selecting different combinations of game settings/features to allow for a more interactive experience.

In this paper, we present a set of new features that increases the users' intrinsic motivation to comply with their intervention protocols. Section 2 presents a short literary review on previously developed virtual reality gaming systems with a similar purpose. Section 3 discusses in detail the procedure taken to implement said features. Section 4 presents the results obtained in testing sessions with human participants. Finally, we analyze the results in Sect. 5, and make our concluding remarks in Sect. 6.

2 Background

Previous studies have identified the benefits of using virtual reality (VR) systems in the rehabilitation setting. The study conducted by Viau et al. [6] showed that both healthy individuals and those with motor deficits used similar movement strategies when performing different tasks in the virtual and reality environments. They concluded that the training of arm movements in virtual environments may be a valid approach to the rehabilitation of individuals with motor skills deficiencies. Holden et al. [7] conducted a study with two stroke patients who interacted with the telerehabilitation system they developed. They concluded that both individuals demonstrated an improvement on kinematic measures of upper-extremity trajectories performed in the real world, indicating that the training in the virtual environment was transferred to real-world performance.

Based on the positive results obtained from studies conducted on VR systems in the physical therapy setting, various serious games have been developed to aid physiotherapists and increase the efficacy of the intervention protocols. Ma et al. [8] developed a VR game that adapts to the user's needs in order to maintain the rehabilitation tasks at an appropriate level of challenge and thus maintaining the

user’s motivation to continue performing the recommended tasks. Moreover, an effective rehabilitation protocol must be early, intensive, and repetitive, which can lead to problems with patient motivation and engagement. In the spirit of developing more effective systems for stroke rehabilitation in terms of good user engagement, Burke et al. [9] identified different game design principles for stroke rehabilitation and developed several games that employ these principles. Finally, Reid [10] conducted a study using the Mandala Gesture Xtreme technology, which uses a video camera that maps the users movements to the presented virtual environment. Comments from the three children with cerebral palsy that participated in the study showed a high degree of motivation and interest, thus suggesting the viability of a VR play-based intervention as part of the children’s intervention protocols.

Based on the benefits identified by previous studies, we improved the aesthetics of the *Super Pop VRTM* game such that it provides an environment that encourages the users to perform the recommended exercises thus improving the effectiveness of their intervention protocols.

3 Methodology

3.1 Game Updates

As described in [3,4], the goal of the *Super Pop VRTM* game is to ‘pop’ as many bubbles as possible in the allotted amount of time. The original version of the game employs colored circles as bubbles and provides no costumes or options for the users to choose from (Fig. 1). Among other modifications, we improved upon the gaming graphics by interchanging the colored circles for images that better resemble an actual bubble and introduced different ‘hats’ that follow the user’s heads such that they (especially children) can enjoy seeing themselves ‘wearing’ various costumes throughout their interactions with the game (Fig. 2).

The costumes overlay and re-size according to the location of the patient and the distance between the patient and the camera. We implemented a linear model with a calibrated distance to size in order to adjust the width and height of the costume that is overlaid. Due to the fact that different costumes are worn with different style, relative position of the costume changes according to its type. For example a medieval knight helmet is positioned 15 pixels above the center of the player’s head, while a wizard hat is positioned 45 pixels above the center point of the player’s head. Chroma key compositing (green screen) is implemented to enable patients to customize the environment they want to play in. Having customizable gaming graphics motivates the patients and increases the gaming engagement.

The new game settings has been made much easier and safer to use for both patients and therapists. It contains the regular graphics settings and the advanced settings. The graphics settings allow patients to select their own costumes, game play music, and VR display brightness. The advanced setting window is password protected and is meant to be used by therapists only. This password protection layer ensures that patients can modify the game to make

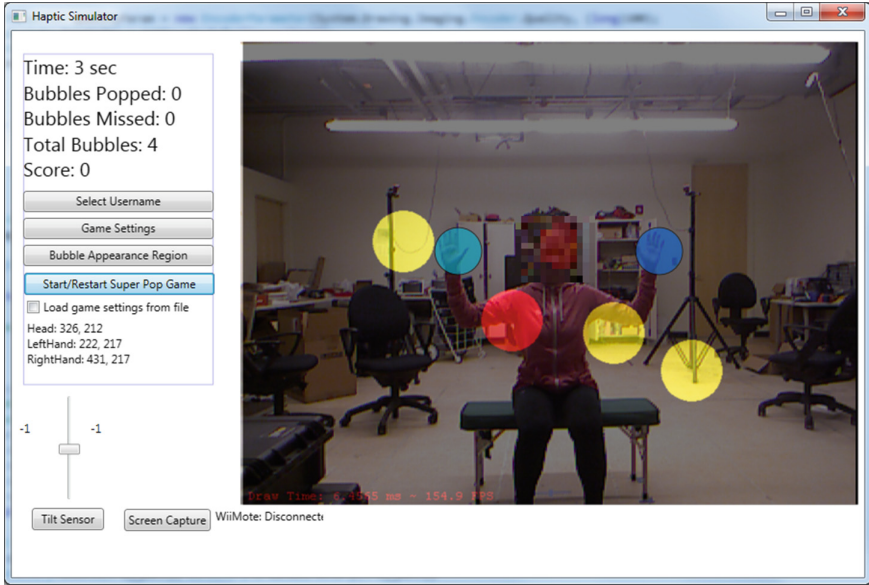


Fig. 1. Main interface of the *Super Pop VRTM* game's original version showing colored circles as representation of the virtual bubbles (Color figure online)

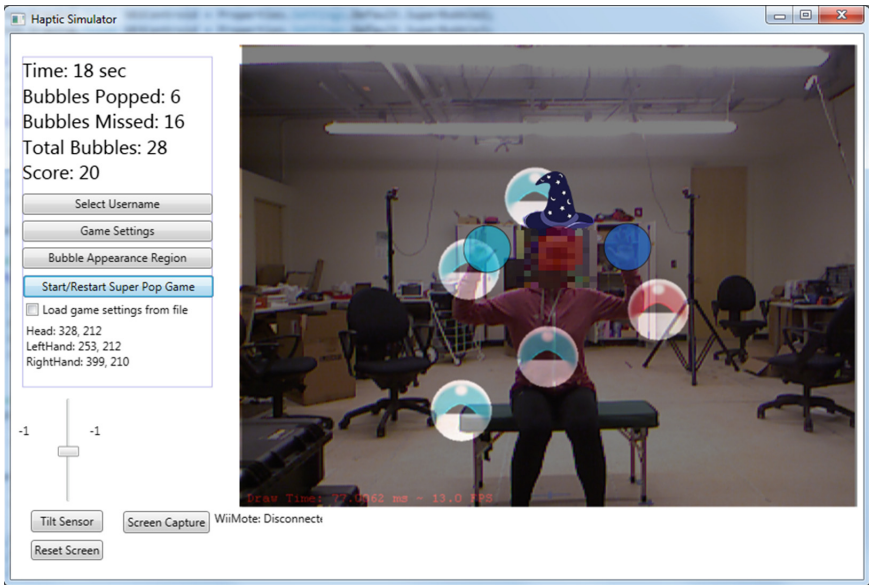


Fig. 2. Main interface of the *Super Pop VRTM* game's updated version showing bubble images as representation of the virtual bubbles and the 'Wizard Hat' as an example of the available 'helmet' options (Color figure online)

the game more enjoyable without changing the backend analysis methods. Therapists are enabled to define game mode, difficulty, game duration, number of levels, game speed, good and bad bubble ratio, bubble size, bubble scores, etc. The game is highly customizable so that therapists can design completely different games for every single patient according to his/her up-body movement ability.

3.2 Assessment Methodology

We used the Intrinsic Motivation Inventory (IMI) to compare the participants' responses after interacting with the original and updated versions of the *Super Pop VRTM* game. The IMI is a device intended to assess participants' subjective experience related to a target activity in laboratory experiments [11]. The instrument measures the participants' self-reported motivation by assessing several subscales. In this study, we focused on assessing the participants' interest/enjoyment, perceived competence, effort/importance, pressure/tension, and value/usefulness to measure their self-reported intrinsic motivation, thus yielding five subscale scores. The interest/enjoyment scale is considered the self-report measure of intrinsic motivation, thus we focus the better part of the analysis on this subscale. The perceived competence and pressure/tension sub-scales are theorized to be a positive and negative predictors of self-report of intrinsic motivation respectively. Effort is considered to be an additional relevant variable to some motivation questions, and the value/usefulness sub-scale is used to determine how individuals become self-regulating with respect to activities that they experience as useful or valuable for themselves. Strong support for the validity of the IMI was found in [12]. Thus, various studies have used the IMI as a measure of self-report of intrinsic motivation [13–15].

4 Experimental Results

4.1 Experimental Setup

Fourteen able-bodied adults were recruited to interact with the *Super Pop VRTM* system. Nine females and five males ranging in age between 18 and 31 years played both the original and updated versions of the game. None of the participants had any previous interactions with any version of the system to eliminate the bias that their relative experience might provide. For each version, participants were asked to choose the most appropriate responses to a subset of selected statements randomly ordered from the 7-point Likert scale that is the Intrinsic Motivation Inventory (IMI). We compared the participants' responses organized by the selected five subscales to determine which version of the game promotes more interest and motivation.

Participants played two games for each version such that they could have enough experience to get familiarized with the system. When interacting with the original version of the game (Fig. 1), the virtual bubbles were represented

as colored circles, no 'hats' were provided, the bubble popping sound was constant for the two games, and no game options were provided to the user. When interacting with the updated version of the game (Fig. 2), the virtual bubbles were represented with colored images that better resemble bubbles, four 'hat' options and four bubble popping sounds were provided for the users to choose from before each game, and users were allowed to select the size and appearance speed of the bubbles to better tailor their own experience. The order of the game versions they interacted with was randomized to reduce the bias of the participants' responses.

4.2 Qualitative Results

We compiled the answers of all participants and organized the scores by the selected five IMI subscales. Figure 3 shows the comparison of average IMI scores ± 1 std between the original and updated versions of the game for each subscale. Looking at the interest/enjoyment subscale, the average score for the original version of the game was 5.7 ± 0.52 while the average score for the updated version was 5.8 ± 0.51 . Similarly, looking at the value/usefulness subscale, the score for the original game was 5.5 ± 0.29 while the score for the updated version was 5.6 ± 0.42 .

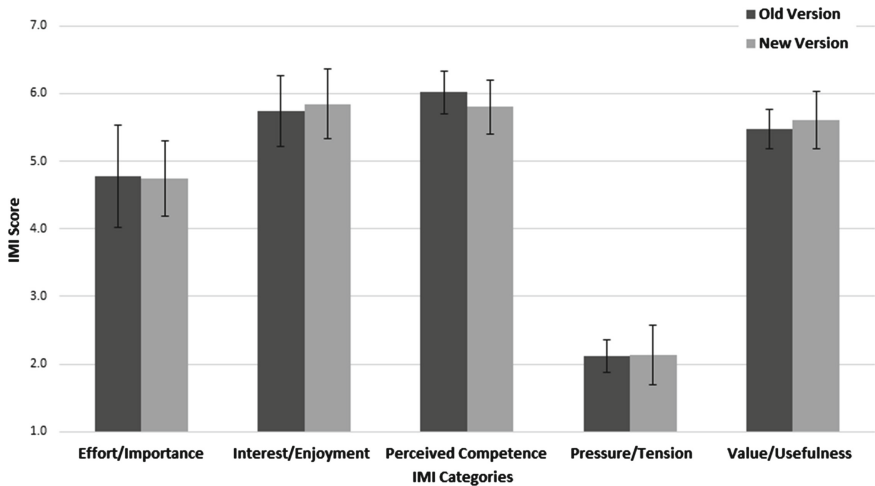


Fig. 3. Comparison of the average IMI scores from all participants between the original and updated versions of the game organized by the selected subscales

We also wanted to investigate if there were any trends related to the order in which the participants interacted with the *Super Pop VRTM* game. Figures 4 and 5 show the average IMI scores ± 1 std for both versions of the game for the participants that interacted with the original version first and for the participants that interacted with the updated version first respectively.

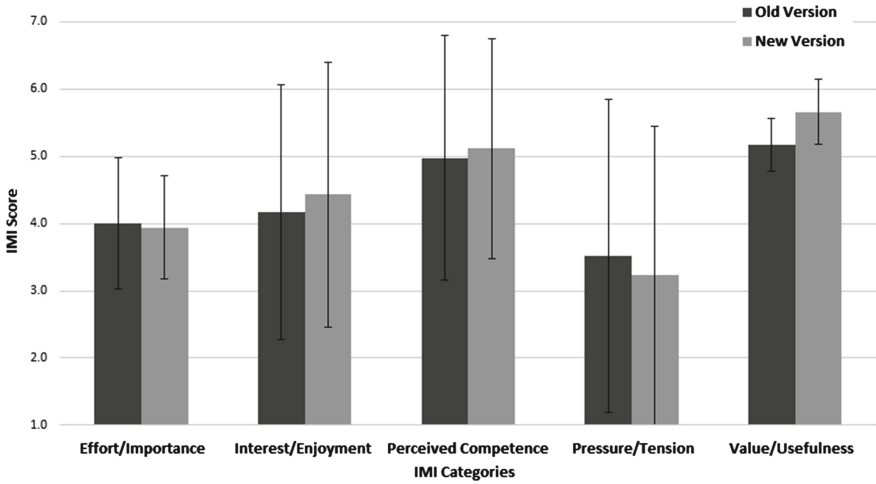


Fig. 4. Comparison of the average IMI scores between the original and updated versions of the game from the participants that played the original version first

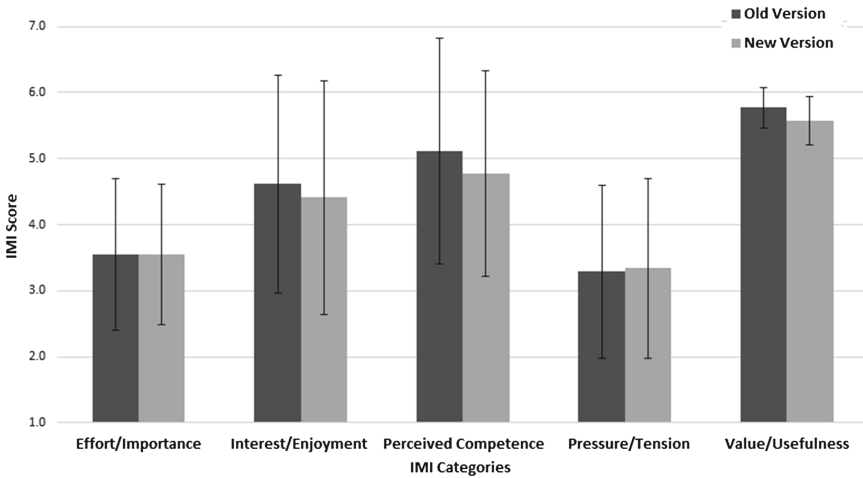


Fig. 5. Comparison of the average IMI scores between the original and updated versions of the game from the participants that played the updated version first

5 Analysis

Although not significant, the results shown in Fig. 3 suggest that participants favored the updated version of the Super Pop VR game over the original version. In terms of the interest/enjoyment IMI subscale, participants maintained their interest and better enjoyed the version of the game that provided more options and features to choose from. In terms of the value/usefulness subscale, they determined that the experience was useful and/or valuable for themselves.

Moreover, all participants gave the pressure/tension subscale a relatively low score for both versions making a positive prediction in the users' self-report of intrinsic motivation. These findings confirm our hypothesis that attractive models increase motivation and user performance thus allowing for an improvement in the efficacy of the recommended intervention protocol. It's important to keep in mind that the interest/enjoyment subscale is the one that assesses intrinsic motivation per se. As such, even though participants gave the original version a higher score in the effort/importance and perceived competence subscales, we can still conclude that updated version of the game promotes more interest than the original version. These results just mean that the participants put in more effort, and thought to be more competent when interacting with the original version of the game.

There is something to be said about the similar scores in all five subscales. Even though the results favor the updated version, it's not by much. This suggests that the original version of the *Super Pop VRTM* game is still engaging and interesting as is. Future work can include a study that further increases the game's aesthetics to determine if there is a bound on how much more interest can the developed system promote.

Figures 4 and 5 show that the order in which users interact with the game matters. The trend in both figures determines that participants favored the second system which they interacted with in terms of the interest/enjoyment and value/usefulness. From Fig. 4, the participants that played the original version first favored the updated game. From Fig. 5, the participants that played the updates version first favored the original game. This trend may have surfaced because of inexperience given that none of the participants had interacted with the *Super Pop VRTM* game before. It may be the case that participants did not fully enjoyed themselves in the first round of games because they were worrying about their initial performance. In general, the more they played the game, the more comfortable they got and the more they enjoyed it regardless of the added game features. However, it's also important to note that the standard deviation for the interest/enjoyment subscale is very high for both scenarios: ± 1.90 for the original game in the case where the original version was played first, and ± 1.78 for the updated version in the case where the updated version was played first. This suggests that the responses are not consistent. Possibly due to the fact that only half the population is considered in each group. As such, more data would help reduce the variation in responses.

6 Conclusion and Future Work

After improving the *Super Pop VRTM* game's aesthetics and updating the game structure, the overall participants' self-reported motivation was slightly higher when interacting with the updated version of the game as determined by the Intrinsic Motivation Inventory (IMI). This suggests that, because of the improved game aesthetics, users can improve their performance when interacting with the system. However, it's important to keep in mind that the study's results are

limited by targeted population. The volunteers that were recruited for this study were young adults even though the final system is targeted to children who have some form of motor skills disorder. As such, additional studies will need to be conducted in order to determine the level of self-reported motivation a child has when interacting with the *Super Pop VRTM* game. Another item to keep in mind is that there is a possibility that the game users' self-reported motivation may vary as a function of their experience with the system.

In the meantime, we can conclude that the developed system has the potential to be used in the rehabilitation setting. By maintaining the user's interest and enjoyment while reducing the pressure and tension of complying with the recommended intervention protocol, the *Super Pop VRTM* game can increase the efficacy of said protocol thus helping users make progress in their physical therapy.

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