Caring is Sharing – Exploiting the Value in Data for Health and Innovation
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Feasibility of a Virtual Reality App to Promote Pulmonary Rehabilitation

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Abstract. One of the major barriers to joining pulmonary rehabilitation (PR) programs is a lack of awareness about its benefits, combined with overall skepticism about regular exercise among COPD patients. Empowering COPD patients with foundational knowledge about PR may potentially facilitate their decision to join a PR program. A virtual reality (VR) app may serve as an engaging and interactive means to deliver PR education; however, the feasibility of this approach in COPD patients is unknown. The goal of this project was to assess the feasibility of VR-based PR education in COPD patients. Using mixed methods design, the feasibility of the VR app was assessed by evaluating its usability, patient acceptance, and its impact on patient knowledge about PR. The results of the usability assessment showed high user acceptance of the VR system and the ability to successfully operate the VR appliances. The use of the VR education app resulted in a statistically significant increase in patient understanding of the main concepts of pulmonary rehabilitation. Further development and evaluation of VR-based systems for patient engagement and empowerment are warranted.

Keywords. Virtual reality, patient empowerment, pulmonary rehabilitation

1. Introduction

Pulmonary rehabilitation (PR) has been shown to significantly improve the quality of life and clinical outcomes in patients with Chronic Obstructive Pulmonary Disease (COPD) [1]. One of the major barriers to joining PR programs is a lack of awareness about its benefits, combined with overall skepticism about regular exercise among COPD patients [2]. Empowering COPD patients with foundational knowledge about PR may potentially facilitate their decision to join a PR program [3]. A recent scoping review concluded that virtual reality (VR) could potentially be instrumental in supporting health education and called for more studies in this field [4]. A VR app may serve as an engaging and interactive means to deliver PR education. However, the feasibility of this approach in COPD patients, who usually are represented by older adults, is unknown. The goal of this project was to assess the feasibility of VR-based PR education in COPD patients.

2. Methods

2.1. System Design

The Virtual Reality app to empower and engage COPD patients in pulmonary rehabilitation (PR) was designed for Oculus Quest 2 system using the Unity

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Development Platform in our lab. The educational framework was driven by the concepts of adult learning theories previously shown effective for interactive patient education [5]. The system comprised a headset and 2 controllers (Figure 1). To simplify its use, the device was preset to access the PR education app once the headset was mounted. To further simplify the system interface, it was controlled by a single button represented by the trigger of the right or left controller (Figure 2). The educational content was organized into 5 modules: Introduction; Rehabilitation overview; Exercise overview; Rehabilitation benefits; Telerehabilitation overview. Each module starts with a short 2-3-minute instructional video, followed by 4 multiple-choice questions. The user was required to reply to all multiple-choice questions correctly to continue to the next module. If the subject selects a wrong answer, there is an option to go back and select another answer until the questions are answered correctly (Figure 3).

Figure 1. VR Headset.

Figure 2. VR app control.

Figure 3. PR app.

2.2. Study Design

The feasibility of the VR app was assessed by evaluating its usability, patient acceptance, and its impact on patient knowledge about PR. The system testing was carried out in a convenience sample of nine COPD patients. Each participant was instructed to complete a package of pre-test surveys that included socio-demographics, BRIEF Health Literacy Screening Tool [6], and Pre-PR Education Questionnaire [7]. As a next step, the use of the headset and the controllers was explained by a team member. The subject then completed a PR education using the VR app, followed by completing 3 post-task surveys. The post-task surveys contained both quantitative and qualitative data. Post-task questionnaire focused on the completion of 3 main tasks: 1. Start the VR app; 2. Complete the education module; and 3. Answer multiple-choice questions. Next, participants completed a Post-PR Education Questionnaire, an Attitudinal Survey [8], a Heuristic evaluation form [9], and a System Usability Scale (SUS) [10]. A semi-structured qualitative interview was completed at the end of each study visit.

All tasks reflected in the post-task surveys were completed without assistance, however, users could request help anytime. Any requests for assistance were noted. Post-task surveys asked participants to rank each task on a scale of 1 (very difficult) to 5 (very easy), 1 (very unsatisfied) to 5 (very satisfied), 1 (too much time) to 5 (very little time), and 1 (strongly disagree) to 5 (strongly agree). Survey questions for Task 1 included: 1) How difficult or easy was it to start the VR app? 2) How difficult or easy was it to point to the app and start it? 3) How satisfied are you with using this system to complete this task? 4) How would you rate the amount of time it took to complete this task? 5) Is the system visually appealing? 6) Is the system easy to navigate? Survey questions for Task 2 included: 1) How difficult or easy was it to review the content and finish the sections?

2) How difficult or easy was it to advance from one screen to another? 3) How satisfied are you with using this system to complete this task? 4) How would you rate the amount of time it took to complete this task? 5) Is the system visually appealing? 6) Is the system easy to navigate? Lastly, survey questions for Task 3 included: 1) How satisfied are you with using this system to complete this task? 2) How would you rate the amount of time it took to complete this task? 3) Is the system visually appealing? 4) Is the system easy to navigate? These questions were followed by two open-ended questions asking the participant to describe any problems and give additional feedback. The study was approved by the IRB at the Icahn School of Medicine at Mount Sinai.

3. Results

The study sample comprised nine COPD patients, 67% of whom were females, 22% were White, 11% were Asian, and 67% were Black, mean age of 71±7 years old ranging between 59 and 82 years old; none of the study participants used VR in the past. The mean score of the BRIEF Health Literacy Screening Tool was 16.2, indicating a marginal health literacy level that usually requires assistance and is indicative of individuals who struggle with patient education materials.

The mean post-task scores on a scale from 1 to 5 were 4.74, 4.85, and 4.89 for tasks 1 (Start VR app), 2 (Complete the education module), and 3 (Answer multiple-choice questions), respectively. The lowest score for task 1 corresponded to the study participants' feedback, some of whom exhibited difficulties in finding and starting the VR app using VR appliances. Overall, 89% were able to accomplish task 1 without any prompts, and 100% were able to complete tasks 2 and 3 independently. All subjects eventually completed all tasks.

Table 1. Heuristic assessment of the VR app

		N	Minimum	Median	Maximum	Mean
1	The system shows you what's going on and gives you feedback (visibility)	9	4	5	5	**4.89**
2	Language and words make sense (match between system and real world)	9	3	5	5	**4.78**
3	There are clearly marked 'exits', buttons to go back or move forward (control/freedom)	9	4	5	5	**4.89**
4	Words, situations, and actions mean the same thing as elsewhere (consistency)	9	3	5	5	**4.44**
5	There are very few errors, and minimal error-prone conditions (error prevention)	9	3	5	5	**4.78**
6	Instructions are obvious, no need to remember how things work (recognition, not recall)	9	3	5	5	**4.67**
7	The system works for both new and expert users (flexibility, efficiency of use)	9	4	5	5	**4.89**
8	Information is streamlined and relevant (aesthetic / minimalist design)	9	1	5	5	**4.44**
9	Error messages are clear and in plain language (recognize, recover from errors)	9	3	5	5	**4.67**
10	Help is available, searchable, and relevant (help and documentation)	9	4	5	5	**4.89**

The results of the heuristic evaluation of the user interface are presented in Table 1. The mean score was 4.7 (on a scale between 1 and 5), indicating sufficient usability of the VR app, with the consistency dimension receiving the lowest score and visibility and flexibility – the highest. The mean System Usability Score (SUS) was 95.8. With the maximum SUS score of 100, a score of 95.8 indicates a high usability assessment that is typically indicative of people who love an app or site and will recommend it to their friends. The pre-post comparison of PR knowledge demonstrated a statistically significant increase in PR knowledge after using the VR app based on the paired t-test (an increase of the mean score from 7.2 to 7.9; $p<0.04$).

Table 2. Concept map

CONTENT		INTERFACE		PROCESS	
Facilitators	**Barriers**	**Facilitators**	**Barriers**	**Facilitators**	**Barriers**
Clear	Low volume during the last video	Amazing	Additional information needed	Accessible	Lack of additional COPD information
Different		Concise	Clearer directions needed	Assists with focus	Lack of exercises
Easy to see		Convenient	Heavy headset	Beneficial	Lack of music
Enjoyable		Easy to operate	Lack knowledge about the location of the volume button	Good idea	Lack of research information
Flawless	None	Engaging	Lack of manual	Interesting	None
Interactive		Excellent	None	Short	
Relevant information		Fun		Useful	
Self-explanatory		Good experience			
Three-dimensional		Good learning tool	Tight headset	Understandable	
		Intuative			

The semi-structured qualitative interviews were analyzed using thematic analysis [11] which showed high acceptance of the VR system content, interface, and process. A number of valuable suggestions on how to improve the system were provided by the patients. Based on the qualitative analysis results, a concept map [12] was built to represent facilitators and barriers across three major themes: app content, app interface, and app process (Table 2).

4. Discussion

An interactive virtual reality app for COPD patient education and engagement in pulmonary rehabilitation was tested in a convenience sample of VR-naïve COPD patients. This is the first study testing a VR app for PR education. The patients demonstrated a high interest in using the interactive VR format for health education and personal empowerment. The results of the usability assessment based on the cognitive walkthrough and heuristic assessment of the user interface showed high user acceptance of the VR system and the ability to successfully operate the VR appliances. The use of the VR education app resulted in a statistically significant increase in patient understanding of the main concepts of pulmonary rehabilitation. Semi-structured qualitative interviews uncovered barriers and facilitators of VR use for patient engagement and empowerment. Our results concur with the previous studies that

demonstrated that avatar-based or mobile interactive platforms using concepts from adult learning theories could significantly increase disease-specific knowledge in patients with low health literacy and limited computer skills [5,13].

5. Conclusion

The interactive VR app for patient education and empowerment was well accepted by COPD patients. The use of the VR app resulted in a statistically significant increase in patient knowledge about pulmonary rehabilitation. Further development and evaluation of VR-based systems for patient engagement and empowerment are warranted.

6. Acknowledgements

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