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Learning promotion of physiotherapy in neurological diseases: Design and application of a virtual reality-based game

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Abstract:

INTRODUCTION: The virtual reality-based (VR) game can be considered as a new approach to education and to enhance the skills of health-care students.

AIMS: The purposes of this research were to design a VR game and to apply it to teach physiotherapy in neurological diseases.

METHODOLOGY: In this study, at first, a VR game was designed for upper limb rehabilitation in brain-injured patients based on the literature and the opinions of physiotherapy experts and game designers. Then, the designed game was used for teaching physiotherapy in neurological diseases. Thereafter, the opinions of 31 undergraduate students about the teaching session were evaluated by two anonymous questionnaires. Data analysis was performed using descriptive statistics through SPSS (version 19).

RESULTS: The VR game developed under expert supervision. The evaluation showed that the median score for students' perception of learning was 3.11. The median scores of questions related to the "facilitating level of virtual reality" and "student satisfaction" were 8.66 and 9, respectively. The analysis of students' responses to open-ended questions highlighted the therapeutic aspect of the game compared to its educational aspect.

CONCLUSIONS: Application of VR games in education can enhance the students' perception of learning. Furthermore, it can provide a better understanding of physiotherapy in patients with neurological diseases as well as the satisfaction of students. However, the survey indicated that the good results of this teaching method are due to the use of VR for guiding the patient's movements.

Keywords:

Education, neurological rehabilitation, physical therapy, teaching, video games, virtual reality

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Introduction

The focus of health education is on empowering students to develop the skills required to become competent professionals.[1] Educators face several challenges in health care. In other words, the transfer of information using common educational methods (lectures) in the learning process is often tedious and reduces concentration in learning.[2] The lack of participation and motivation of students in the learning process is one of the major concerns of education across the world.[3] These issues highlight the importance of utilizing innovative educational tools. One of the tools which could increase motivation and promote learning by creating a dynamic, entertaining, and exciting environment is virtual reality (VR) games.[1,4]

These games are known as serious games that are a powerful device for strengthening the skills of health-care graduates.[5] According

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to Stokes, the aim of producing serious games is not only entertainment but also intend to educate and alter behavior.[6]

Unlike traditional learning environments in which the teacher controlled the learning (teacher-centered), the serious game has a learner-centered approach in which the learner controls the learning process interactively.[7] Such cooperation allows the learner to learn through active and critical learning. These types of learning improve knowledge and skills and change the performance and attitude of students. Serious games improve the interaction between students and promote team working. Applying educational games create an opportunity for students to test their problem-solving and decision-making skills in an active learning environment. These games could simulate problems in the real environment, which can enhance the performance of health-care professionals. The use of games in training has high flexibility and low cost and facilitates a high level of interaction.[8-11]

Some studies showed that serious games could improve the student's skill. The users of these games get better results in the learning process than those who have used other traditional methods. Furthermore, they increase the skill of health-care providers and interest in the users toward learning.[12-16] According to a review study by Scepanovic *et al*., the use of the game in the learning process increases motivation, classroom attendance, participation in discussions, and compilation of more homework.[17] Many of these games are applied for the training of midwifery,[18] psychiatry,[19] immunology,[20] pharmacology,[21] nursing,[14,22] medicine,[23,24] and physiotherapy.[25,26]

Currently, new technologies are applied in many areas such as prediction,[27-31] diagnosis,[32] treatment,[33-35] or patient education[36,37] in the field of health sciences. Technological innovations such as VR simulation can play an important role in the educational programs and are recognized as useful tools in education.[4] Physiotherapy students usually should be faced with real patients through their practice after completing specialized courses.

Regarding technology-based methods, a systematic review showed the effectiveness of the computer-based learning (CBL) methods in physiotherapy education as compared to the traditional learning method.[38] Using the VR-based game during training can also be effective in treating patients in addition to facilitating learning for learners. Active learning allows the repetition of exercises in a fun environment, which will ultimately improve the quality of health care delivered to patients. So far, no study has been conducted on the use of VR-based games for teaching therapeutic exercises to physiotherapy students; the purposes of this study were (1) to design a VR-based game and (2) to use it in the teaching of undergraduate physiotherapy students.

Methodology

This study was a type of applied research that was carried out in two stages. In the first stage, a VR-based game was designed to rehabilitate the upper limb (UL) of neurological patients. In the second stage, the developed game was used to teach a topic of the physiotherapy in neurological disease course by a physiotherapy professor. In the following, the detailed explanation of both stages is explained.

Stage one: Designing of a virtual reality-based game

Determining the game content

First, the literature review on related studies on UL rehabilitation of neurological patients was done. Hence, some of the therapeutic exercises were selected as the game content based on Brunnstrom method. Then, a checklist about these contents was sent to nine physiotherapists to assess the clinical aspect of the exercises. Some of the experts "criticized" the specialty of the exercises. Hence, the exercises were re-evaluated based on motor recovery stages in adult hemiplegic patients and some experts' suggestions. As a result, the training content of the virtual game was designed.[39] The physiotherapists comments about these exercises were re-examined once more.

Determining the essential features of the virtual reality-based game

At this stage, another questionnaire containing the necessary features needed for a VR-based game was designed and sent to nine physiotherapists and 11 computer game designers.

Development and designing the game

The results of movement analysis determined that the essential exercises are related to rehabilitation which had been calculated using the content validity ratio (CVR). The CVR was used to assess the validity of the questions of Stage two. According to this index, the least value of the acceptable CVR for nine-person samples should be 78%. Furthermore, the least value of the acceptable CVR for a twenty-person sample should be 42% for the content analysis of the games.[40]

The analysis showed that some movements had acceptable validity including:

- Touching the chin, mouth, ear, and opposite shoulder
- Lifting up the affected hand from the front to the horizontal level

- Raising the shoulder from the front or sides more than 90°
- Extending hands forward to get objects by both hands
- Holding a ball or box with two hands and lifting it up and taking it down and also pushing and pulling it away and close to the body.

In addition, the analysis results showed that using avatars and the inclusion of picking objects and scores were necessary to make the game more fun. Alarming and scoring systems were found to be a necessity to create feedback in the game. The existence of speed level, timing, and obstacles were also identified as necessities to create a challenge throughout the game. Consequently, the game was designed and developed.

Software and hardware

The Unity environment (version 3.5) was applied to develop a VR-based game. Unity also has the ability to support Kinect[41] and it uses C-sharp language to write codes in monolingual compiler environment. The Kinect sensor (Xbox 360) was also used to track movements. The sensor had an RGB camera, a deep sensor, and a multilayer microphone which could track the body's three-dimensional movements and detect faces and sounds. These properties allowed Kinect to define and recognize the user's body movements. Furthermore, Kinect's most important feature was that it did not need any wearable device.[42,43] In this study, the Lenovo laptop (G50 model, Windows 7, 4GB RAM) was employed [Figure 1].

Stage two: Using the game for teaching

Teaching

The designed VR-based game was used by a physiotherapy professor to teach a topic of "Physiotherapy in Neurological Diseases" course. Sampling was done by convenience method. Thirty-one third-year undergraduate students were recruited for this study.

Figure 1: Hardware used in the game design

First, a brief description of VR and its applications was given. Then, the common exercises for physiotherapy of neurological patients in the form of five games (spacecraft, falling snow, butterfly, tubes, and sorting of home) were taught to students. During the training, the professor answered the students' questions. Later, two anonymous questionnaires were given to each student to express his/her opinion about the teaching session. The pictures of education through VR-based game are shown in Figure 2.

Description of the system

The system comprised five games. Each game could generate movements in the patient's UL and also was able to adapt to the patient's side.

Butterfly game

In this game, the Kinect tracked the user; the system displayed a butterfly superimposed over the user's body. The user's task was removing butterflies with hand movement. The students experienced a combination of movements including touching the affected shoulder, as well as elbow movements. The students perceived that this game could be useful in patients with limitations in proximal joints of the UL.

Spacecraft

Through this bonus game, the student navigated the spacecraft through obstacles. By lifting a hand, the user prevented the spacecraft from hitting to meteors. As part of this game, students observed a combination of shoulder movements with elbow extension.

Snowflake

The student was standing in front of the motion detector sensor and extending his hands to catch the snowflakes. This game focus was on speed and the user's UL. Through the game, the students experienced shoulder abduction/adduction and elbow flexion/extension. They found out that this game could be beneficial to increase the coordination of both ULs.

Tubes

The student had to move a green object through three

Figure 2: The pictures of training with virtual reality-based game

pipes to reach the end of the pipe. After that, the pipes disappeared. Students in the game experienced a combination of elbow flexion/extension movements, forearm supination, and shoulder horizontal abduction/adduction.

Hometidy

Through this game, the students played in a virtual room. During the game, general functionalities assigned to the player, including turning on the fan, selecting and moving chairs, closing drawers, placing food and dishes on the table, and making coffee. The last stage included making the bed and moving pillows. Therefore, the students experienced gross movements of UL which is necessary for doing activities of daily living.

Questionnaire design for evaluating teaching session

We developed separate questionnaires for the assessment of student's perception of learning and the facilitating level of the game in education. The first questionnaire was designed based on the Dundee Ready Educational Environment Measure (DREEM) questionnaire which is one of the best tools developed for the quantitative assessment of the educational environment.[44] This questionnaire comprised ten items which covered the student's perception of the learning. Items were scored using a five-point Likert scale, ranging from 0 (lowest value) to 4 (highest value). The validity and reliability of this tool have been confirmed.[45,46]

The second questionnaire had three main parts. The first part of the questionnaire consisted of three questions about the facilitating ability of VR. The second part comprised five questions about student satisfaction. A ten-point Likert scale was used to indicate the degree of agreements ranging from 1 (low agreement) to 10 (high agreement).

The fifth question of the second part was reversed, and the score of 10 was equal to the score of 1 in other questions. The third part contained two open-ended questions. Therefore, the students could express their opinions about "using the game in the teaching of physiotherapy in neurological patients" and "using the game to treat neurological patients."

The second questionnaire items were adapted from two studies on VR-based education.[47,48] The results of questionnaires were analyzed using SPSS software (Version 19, Armonk, NY IBM Corp, New York, USA).

Ethical approval

Ethical approval for this study was obtained from the Ethical Committee of our university.

Results

In this study, 31 undergraduate physiotherapy students from our faculty, who were studying in the academic year 2017–2018, were reviewed by convenience sampling method, of them 10 (32%) were male and 21 (67.7%) were female.

Students' perceptions of learning

The descriptive statistics associated with the student DREEM score are represented in Table 1. The mean (standard deviation) of the total scores of the first nine questions related to the students' perception of learning was 2.95 (0.70) with a median score of 3.11. Question 10 was reversed and its mean (standard deviation) and median scores were 2.2 (0.71) and 2, respectively.

Facilitating level of the game in education and students satisfaction

Three questions were given to the students to evaluate the facilitating level of the game in education [questions 1–3 in Table 2]. The mean (standard deviation) and median of the three questions in this section were 8.04 (2.18) and 8.66, respectively.

The student's satisfaction in using the game in education was assessed by five questions [questions 4–8 in Table 2] in the second part of the questionnaire. The mean (standard deviation) and median of the first four questions in this section were 8.27 (2.07) and 9, respectively. Question 5 in the second part of the questionnaire was reversed. Thus, the mean (standard deviation) and median of the 10 were 1.79 and 1, respectively.

The third part of the questionnaire contained two open-ended questions. All students answered these two questions in the second questionnaire. The students' responses and the analysis of some of them are shown (each sentence reflects a student's response) in Table 3.

Discussion

The purpose of this study was to design a VR-based game and apply it in the education of undergraduate physiotherapy students. After designing the game, the content was verified and validated. Then, the educational game used to teach the topic of principles of physiotherapy in neurological patients and the students' perceptions of learning, the facilitating level of the game, and student satisfaction were evaluated. The results of the study showed that game-based learning enhances students' understanding of learning. According to the results of the second questionnaire, the game had a great role in facilitating learning and student satisfaction. Survey on closed questions showed that using VR games can help students perception of learning and also increase understanding the main concepts of physiotherapy in neurological patients and student satisfaction.

Table 1: The mean score of the domains: "Students perceptions of learning" of Dundee Ready Educational Environment Measure questionnaire

n	Item	Mean (SD)	Median
1	I'm encouraged to attend the class	3.2 (0.92)	3
2	Teaching is often encouraging	3.1 (1.02)	3
3	Education is student-centered	2.8 (0.88)	3
4	Education is being desirably done to develop my abilities	3 (0.87)	3
5	Education is focused and targeted	3.2 (0.88)	3
6	Education helps my self-esteem	2.8 (0.92)	3
7	The training time has been considered to be beneficial	3 (0.96)	3
8	Education focuses on real learning	2.9 (0.97)	3
9	Teaching encourages me to be an active learner	3 (0.87)	3
10	Education is very teacher-centered	2.2 (0.71)	2

SD=Standard deviation

Table 2: Questions related to the facilitating level of virtual reality and student's satisfaction

n	Topics	Question	Mean (SD)	Median
1	Virtual reality facilitation items	Does this game improve the understanding of the theory of physiotherapy principles in neurological patients (exercise therapy topic)?	8 (2.39)	9
2		Is this activity useful for learning?	8.5 (2.11)	9
3		Has the level of your knowledge been increased?	7.6 (2.6)	8
4	Student's satisfaction items	Did this game expand the content of the therapeutic exercises of neurological patients?	8.1 (2.54)	9
5		I expect virtual reality to help me more than I've ever done	8.7 (2.32)	10
6		Has this activity met your expectations?	7.9 (2.11)	8
7		Is the length of the session suitable for the learning objectives?	8.2 (2.19)	10
8		Is the use of this tool a waste of time?	1.8 (2.19)	1

SD=Standard deviation

According to various studies, the benefits of using games in education are included that they encourage gamers, motivate students, and enhance their participation in learning.[10,49-52]

Due to educational game effectiveness, various games have been used for training in various health-care settings.[1] However, information on the use of VR-based games in the education of physiotherapy students in Iran was not found. In this regard, Veneri conducted a systematic review to examine the effectiveness of computer-based education in physiotherapy. The results showed that although physiotherapists believe that using computer-based training is very useful, this method cannot be widely used because of the high cost.[53] But now, thanks to the advance in technology, utilizing educational games becomes easier. Extensive research currently is being done on the computer-based education in physiotherapy and occupational therapy.[54,55] Nowadays, the application of computer-based games is considered in the teaching of medical students and other medical disciplines.[56]

These results are consistent with the findings of our study. The research showed that practical games give the necessary training and create an entertaining environment for users. This kind of training can be very useful for health-care professionals as it improves learning outcomes and provides a learner-based approach.[5] Kron *et al*. conducted a study for examining the attitude of medical students about the use of video games for education. They concluded that about 98% of them were interested in using video games for education, and 96% of them felt that using this method promotes education.[57] Likewise, the authors note that practical games have a positive impact on students' fear, knowledge, mistake, and attitude.[58] Furthermore, using this method in learning reduces the training time, could increase the cognitive skills of learners, and decreases fatigue during the learning process. Furthermore, the use of this method is convenient, accessible, and economically feasible. These findings are consistent with the results of other studies that confirmed the use of practical educational games to increase the level of participation in the classroom, improves the learning, and increases the students' skills and satisfaction.[10,49-51] These results are consistent with the findings of our study. The research showed that practical games give the necessary training and create an entertaining environment for users. This kind of training can be very useful for health-care professionals as it improves learning outcomes and provides a learner-based approach.[5] Kron *et al*. conducted a study for examining the attitude of medical students about the use of video games for education. They concluded that about 98% of them were interested in using video games for

Table 3: Student's response to the virtual reality-based game

Questions row	1. What is your opinion about the use of this game in teaching physiotherapy principles in neurological patients?	2. What is your overall opinion about the use of this game in patient treatment?
1	It is an interesting idea, but if the range of upper limb movements is increased and the patient's walking is taken into account to some extent (referring to the therapeutic aspect of the game and its limitation in the treatment of patients)	If the problems are resolved, it will be interesting and useful (referring to the need to upgrade the game)
2	It is a new method that makes patient treatment appealing (refers to the therapeutic aspect of the game)	It is useful for orthopedic patients and those with little or no movement in their shoulder and elbow joints
3	Virtual reality could be useful for patient recovery, because of the feedback and encouragement that it provides to the patient (referring to the therapeutic aspect of the game)	It is an interesting and new idea, and by diversifying the games in the future, it can be used to treat many patients (referring to the need to upgrade the game)
4	VR encourages patients to maximize their ability (referring to the therapeutic aspect of the game)	It is beneficial as it reduces fear and errors through the provision of feedback
5	It's very good, especially in patients who are weak in spirit (refers to the therapeutic aspect of the game)	It is a good way to encourage patients to work and it also reduces the fear and increases patient's collaboration
6	The game is efficient for the large joints of the body (refers to the therapeutic aspect of the game)	The game helps to facilitate patients' movements and increases their range of movements
7	The game unconsciously increases the range of joints' movement (points to the therapeutic aspect of the game)	It would have been better if it was a bit more realistic and had a better quality (pointing to the need to upgrade the game)
8	The game can lead to mental and motor development, and it would be much more useful if it focuses on smaller movements and joints in the future (referring to the therapeutic aspect of the game)	As the score increases during the game, the patient is encouraged to make further moves
9	It's a new and great idea	It increases self-esteem and the desire for progress by providing feedback
10	These types of exercises are attractive for the patient and also apply the principles of physiotherapy (refers to both therapeutic and educational aspects of the game)	It is very good for patient training
11	It may be useful to teach several lessons with virtual reality in the future (referring to the educational aspect of the game)	This method can save the therapist and patient time
12	The interesting point is the combining of the two models of PNF in the form of a butterfly game (referring to the educational aspect of the game)	This method can save the therapist and patient time
13	This method can be very useful because physiotherapy is not always available at any time	In general, it is an attractive method for patient education. It can be very useful, especially in the field of neurological diseases, but it should be improved for other types of disorders
14	It is especially useful for people who have been neglected and also to enhance the general body sensation where a patient is undergoing a sensory loss	For a large group of patients, this variety will probably be very enjoyable. I hope it will be extended
15	It was a great start	It is a very interesting and new idea in the field of physiotherapy. It is still like a newborn baby needs to grow. The game budget should be provided, and a variety of movements to perform different exercises should be added with high accuracy
16	There is room for improvement	It will be very useful, but it needs to be culturized and to specify therapeutic goals more fully and accurately
17	It is usable and useful for the classroom	If it is economical, it would be useful

PNF=Proprioceptive neuromuscular facilitation

education, and 96% of them felt that using this method promotes education.[57] Likewise, the authors note that practical games have a positive impact on students' fear, knowledge, mistake, and attitude.[58] Furthermore, using this method in learning reduces the training time, could increase the cognitive skills of learners, and decreases fatigue during the learning process. Furthermore, the use of this method is convenient, accessible, and economically feasible.

These findings are consistent with the results of other studies that confirmed the use of practical educational games to increase the level of participation in the classroom, improves the learning, and increases the students' skills and satisfaction.[17,59,60]

Examining the open-ended questions in this research revealed interesting results. These questions were designed to show which aspects of the game were more prominent from the perspective of students. The analysis of the students' response to open-ended questions indicated the dominancy of the therapeutic aspect of the game to its educational aspect. Although the first question was merely related to the usefulness of the

games in teaching of the lesson, eight students referred exclusively to its therapeutic aspects, and only two students (15.38% of the students) clearly and precisely pointed to the role of gaming in education.

Conclusions

As a whole, it seems that the positive effects of the designed game in teaching might be due to not only the effectiveness of the CBL methods in physiotherapy education but also the fact that the application of the VR-based game as a new technology for rehabilitating the patients had been interested for the students to be more engaged and active in the classroom. Hence, using the games as a new approach to teach the principles of physiotherapy in neurological patients is recommended.

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Conflicts of interest
There are no conflicts of interest.

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