Originales

Can rehabilitation through virtual reality improve the quality of the health care communication?

¿La realidad virtual en rehabilitación puede mejorar la calidad de la comunicación en los servicios sanitarios?

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Fecha de recepción: 23/01/2015 – Fecha de aceptación: 30/01/2015

Abstract

Introduction: Exercises on prescription given by physiotherapist are sometimes complex to explain & difficult to remember by the patient. Implementation of virtual reality could maybe improve such communication. **Objective**: demonstrate the effectiveness of using a VR-based protocol, with a "teaching by example" approach **Methods**: Total of 6 participants were exposed to two different exercise set: 1- with a 3D agent; 2- with a video of a real person. Each test person was: 1- video recorded to keep track on his/her experience using both programs; 2- tested with Modified PSSUQ & Words questionnaires after each performance; 3- video recorded in an interview with open questions to clarify the participants' personal experiences. **Results**: Three of the participants would prefer to use the video: Three preferred the 3D virtual reality application and all participants felt both approach were easy to use & follow. However, from the video recorded observations some participants did not perform the exercises as well as they thought themselves; **Conclusions**: No difference was found in how well the participants performed with the two approaches or how they perceived the movements of the video instructor compared to the 3D virtual trainer. Improvement of the 3D set up, could potentially show further differences between the two approaches in future studies.

Keywords: Virtual rehabilitation, virtual reality, Communications, physiotherapy, exercise on prescription.

Resumen

Introducción: Los ejercicios prescritos por el fisioterapeuta son a veces difícil de explicar y difícil de recordar por parte del paciente. La aplicación de la realidad virtual (VR) quizás pudiera mejorar dicha comunicación. **Objetivo**: demostrar la eficacia de la utilización de un protocolo basado en VR , utilizando "enseñanza con ejemplos" **Métodos** : un total de 6 participantes fueron expuestos a dos programas de ejercicios diferentes: 1 - con un agente de 3D ; 2 - con un video de una persona . Cada participante fue: 1– grabado/a en video para realizar un seguimiento de su experiencia utilizando ambos programas; 2– testeado/a con los questionarios modificados de PSSUQ y Words después de cada actuación; 3- grabado/a en video en una entrevista con preguntas abiertas para esclarecer las experiencias vividas. **Resultados**: Tres de los participantes prefirieron el programa de ejercicios en video, el resto el de realidad virtual, todos los participantes pensaron que los dos programs de ejercicios eran fácil de usar y seguir. Sin embargo, las observaciones registradas en vídeo muestran que algunos de los participantes, a pesar de que creieron realizar correctamente los ejercicios, no los hicieron como se esperaba; **Conclusion**: No se encontró diferencia entro los dos enfoques en lo que atiene la perfección del movimiento o cómo los participantes percibíeron los movimientos del instructor. El mejoramiento del programa 3D de ejercicos, podrían mostrar mayores diferencias entre los dos enfoques en estudios futuros.

Palabras clave: Rehabilitación virtual, realidad virtual, comunicación, fisioterapia, prescripción de ejercicios

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Introduction

The results from a deep interview with an experienced physiotherapist show that physiotherapists working in clinics typically consult between 10 & 15 patients every day. Each consultation typically takes between 20 to 30 minutes. During the first consultation with a new patient, diagnose is made. Based on this diagnose, several physical exercises are chosen to be executed at home by the patient between the weekly consultations.

The therapist usually advices his patient verbally with a home based exercise set & sometimes gives him printed instructions consisting of both pictures & a written description. The patients are supposed to follow these instructions to perform the exercises at home & usually have checkups once or twice weekly.

The checkups are used to monitor the patient's physical status & get other kind of physical therapy treatment, for instance, exercises that need to be performed at the clinic (for example because they need specialized equipment).

At the end of each consultation an exercise plan is created or updated with new exercises, which the patient should execute at home. The exercises are sometimes complex to explain by the physiotherapists & difficult to remember by the patient. Therefore there is a great chance that the exercises are either not being done or done the wrong way when the patients get home. Today some programs exist which can generate cartoons of exercises on printed paper. But they are often difficult to understand since they are just stick men with some arrows explaining the exercise. & chances are that the papers are lost or the exercises are done wrongly by the patients at home.

These solutions have certain disadvantages, i.e., the patients need time to remember the starting position of the exercises, the rhythm, intensity, charge, number of repetitions & most importantly, they do not get any feedback when performing their training sets, sometimes having the final consequent to be reviewed & updated.

It is important to remark the fact that patients are in a critical moment of their life, where certain disabilities & handicaps become negative factors towards optimal understanding of the exercise advice. These different challenges are extended in Fig. . & encourages the development of more pedagogical & easy detailed solutions that could improve the communication between health care suppliers & their patients.

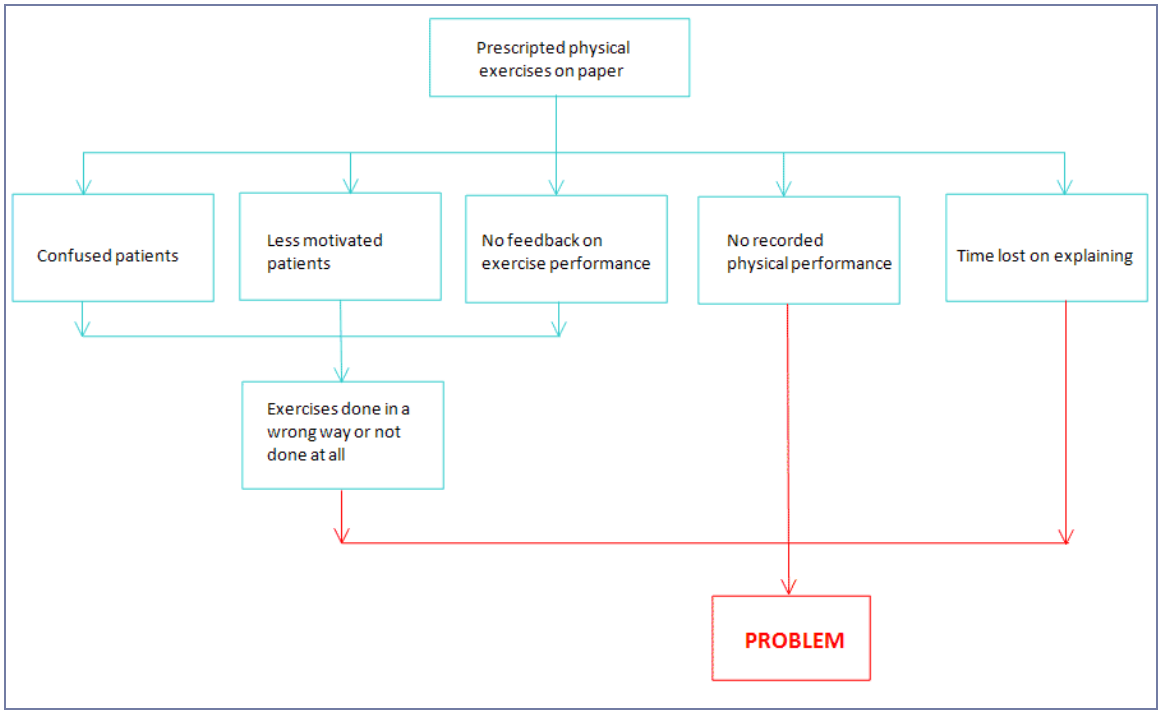

Fig. 1- the different characteristics of the main problem

Specialists have created certain solutions in rehabilitation which are trying to solve these disadvantages (“Exorlive,” n.d.)(“Physiotools,” n.d.)(“Caddi,” n.d.), but they have maybe ignored the full potential of assisted training by not using the latest state-of-the-art technologies, such as Virtual Reality (VR) to improve the communication & understanding of body movements & sensor technology to track & record patient performance remotely with the goal firstly to give real time feedback on exercise performance & secondly after-session feedback, to evaluate the progression of the treatment.

However, there is still a need for alternative solutions that help the patient with understanding exactly how the physical exercise program should be performed in practice & giving enough inspiration & motivation to perform therapeutic exercises. Due to the lack of such a solution, the rehabilitation process becomes incomplete, slow & expensive for the society & for the patient himself.

One of the hypothetical solutions is tele-rehabilitation defined as the delivery of rehabilitation services over telecommunication networks & the internet (“Tele-rehabilitation,” n.d.). It has showed to be useful in a number of different scenarios, e.g. when treating patients living in remote areas. Impairments acquired by individuals residing in remote areas can lead to permanent disabilities due to lack of appropriate rehabilitation (Burdea, Popescu, Hentz, &

Colbert, 2000). Tele-rehabilitation can provide a tool for communication between the patient & the therapist, which could empower the therapist to create smart rehab programs assuring the right communication & guidance in any moment of the exercise performance & from a distance.

Russell, TG (Russell, 2007) in his review “Physical rehabilitation using telemedicine” defines three different technologies used for tele-rehabilitation: (1) image-based tele-rehabilitation; (2) sensor-based tele-rehabilitation; & (3) virtual environments & VR tele-rehabilitation. He explains that there have been few attempts to integrate information obtained from sensor- based technologies with telecommunication technologies for the remote measurement & rehabilitation of patients. He encourages researchers to integrate them into a conventional tele-rehabilitation system as a research field not yet fully exploited. In the field of VR Russell points that computational power increases & the cost of technology decreases allow home-based VR systems for the remote rehabilitation of patients to be feasible. This shows an attractive concept that warrants further research. The author also remarks that much of the tele-rehabilitation research has been technology focused, & has consisted of single case or small sample research designs.

Sveistrup et al. have compared a conventional exercise program to VR-delivered rehabilitation in two trials for balance retraining in subjects with post-traumatic stress injury & frozen shoulder, respectively. In both trials they used the IREX™ system by GestureTek (“Gesturetek,” n.d.), which is a commercially available VR rehabilitation system. In each trial, the participants were divided into two groups, one of which used the conventional rehabilitation method (physiotherapy, NSAIDS, corticosteroid injections, surgery & manipulations (Sveistrup et al., 2003). The other group used the IREX™ system. They all received three sessions of exercise per week over a 6-week period. The outcome measures included pain, range of motion & strengths & were measured prior to starting the rehabilitation period, immediately after finishing the rehabilitation & eventually 3 months after finishing the rehabilitation program. Preliminary results showed that all 14 participants showed improvement (4 of which belonged to a control group), & that the Virtual Reality exercise group showed slightly better results compared to the conventional exercise group as mentioned in **¡Error! No se encuentra el origen de la referencia.**. The study created a basis for further testing but the conclusion to the preliminary results was that VR can be used as a supplement or alternative to conventional therapy. Moreover, the technology allows for the therapist to record targeted responses, permitting assessment of functional performance.

Having this in mind, it is anticipated that over the next ten years VR systems & their development will have a big role in the improvement of the rehabilitation methods & tools. However there are still many challenges that exist in VR, such as cost, equipment issues, patient safety & clinical acceptance.

There is a limited amount of research conducted in the field of comparing conventional rehabilitation methods to VR-delivered rehabilitation. Thus, through assessing these two approaches it would be possible to find out the advantages & disadvantages of both methods & figure out where they can be implemented & for whom.

Material & Method

The intention is to demonstrate the effectiveness of using a VR-based protocol, with a "teaching by example" approach, which means seeing & mimicking the movements of a virtual therapist. Additionally, it is important to investigate how the participants perceive the movements' level of authenticity of the virtual therapist in comparison to the movements of the real therapist. If the use of virtual therapist shows to be as effective in the precision of movements as the real therapists, this could lead to the ability to provide effective exercise sessions for patients performing at home, especially those living in distant locations & by that reducing healthcare cost. Another aspect to investigate is whether the option of real-time 3D exploration can add value to the specific virtual physical rehabilitation application, or will prove to be distracting or just an extra feature.

The zero hypothesis is as follows:
"The traditional & the VR approach are equally useful to communicate exercise on prescription (pedagogical, efficient, motivating, stimulating)."

The goal of the method is to collect qualitative data of the participants' perceived satisfaction & desirability (based on their motivation, time expend, concentration, stress & comprehension).
The aim of this project was to conduct a qualitative research method where a small group of participants was exposed to two different exercise set: 1- with a 3D agent (Cerdan, J, Ravn, P, Andonovsca, 2008a); 2- with a video of a real person (Cerdan, J, Ravn, P, Andonovsca, 2008b), both showing the exercises the test users have to observe & mimic. Each test person was video recorded to keep track on his/her experience using both programs & tested with two questionnaires Modified 1- PSSUQ & 2-Words after each performance. The test ended with a video recorded interview with open questions to clarify the participants' personal experiences comparing both approaches & the filling of The data collected from the questionnaires was compared between both approaches, with the video recorded performance.

Evaluation was done using methods that evaluated perceived satisfaction & "desirability", The goal was to modify some of the questions in such questionnaire & customize it to the projects goals with some open questions about the participants' experience comparing both approaches. The evaluation methods used where the modified PSSUQ (Figure 2), Words (Figure 3) & some open questions regarding their experience using the two different exercise sets.

The Post-Study System Usability Questionnaire (PSSUQ)

The PSSUQ ("Quantifying the User Experience > 8 Standardized Usability Questionnaires > Description of the PSSUQ - Pg. 192e," n.d.) is a 19-item instrument designed for the purpose of assessing users' perceived satisfaction with their computer systems. It has its origin in an internal IBM project called SUMS (System Usability MetricS), headed by Suzanne Henry in the late 1980s. The mission of SUMS was to document & validate procedures for measuring system usability, including performance, usability problems, & user satisfaction (Lewis, 1993).

The items are 7-point graphic scales, anchored at the end points with the terms "Strongly agree" for 1, "Strongly disagree" for 7, & a "Not applicable" (N/A) point outside the scale. The selected items are characterized for their comprehensive content regarding hypothesized constituents of usability. For example, the items assess such system characteristics as ease of use, ease of learning, simplicity, effectiveness, information, & the user interface.

In this study the PSSUQ is modified to be adapted to this project. The adapted questionnaire is shown in figure 2. It is decided that questions 4, 9 & 15 were not relevant for this approach because the 2 different prototypes of an exercise set used in this study has a fixed time exposure; It is not offered any motion feedback & question 15 could be related in question 16; & questions 16 & 17 were just relevant for the 3D exercise set approach because of the use of the mouse to interact with the real time exploration of the agent.

The first item illustrates the item format. The remaining items show only the item text to conserve space. Each item also has an area for comments (not shown).

1. Overall, I am satisfied with how easy it is to use this exercise set approach

STRONGLY AGREE	1	2	3	4	5	6	7	N/A	STRONGLY DISAGREE

2. It was simple to use this exercise set approach.
3. I could effectively complete the tasks using this exercise set approach. (adapted)
4 (Not relevant) I was able to complete the tasks & scenarios quickly using this system.
5. I was able to efficiently complete the tasks using this exercise set approach. (adapted)
6. I felt comfortable using this exercise set approach.
7. It was easy to learn to use this exercise set approach.
8. I believe I would be more motivated to perform a home base exercise set using this exercise set approach.
9. (Not relevant) The system gave error messages that clearly told me how to fix problems.
10. Whenever I made a mistake using this exercise set approach, I could recover easily & quickly.
11. The information (such as on-screen messages & other documentation) provided with this

exercise set approach was clear.
12. It was easy to find the information I needed.
13. The information provided for the exercise set approach was easy to understand.
14. The information was effective in helping me complete the tasks.
15. (Not relevant) The organization of information on the system screens was clear.
Note: The "interface" includes those items that you use to interact with
the system. For example, some components of the interface are the keyboard,
the mouse, the microphone, & the screens (including their use of
graphics & language).
16. (Relevant for the 3D approach) The interface (use of the mouse & the interaction with the viewer of the 3D character) of this exercise set approach was pleasant.
17. (Relevant for the 3D approach) I liked using the interface of this exercise set.
18. This exercise set approach has all the functions & capabilities I expect it to have.
19. Overall, I am satisfied with this exercise set approach.

Figure 2 - Shows the Administration & Scoring of the adapted PSSUQ in this project.

Words (based on Microsoft's Product Reaction Cards)

The 118 product reaction cards, is a collection of words cards used to collect feedback on "desirability". The main advantage is that this technique does not rely on a questionnaire or rating scales & users do not have to generate words themselves. Participants are asked to pick the words that best describe the product or how using the product made them feel. The total set of words has a 60% positive & 40% negative/neutral balance (Benedek, Miner, Corporation, & Way, 2002).

The final result of using this tool can help us to describe the participants' perceived differences when being exposed to the two exercise sets of this project & maybe result in feedback advice on design changes for future exercise set approaches.

The set of words from this tool has been shortened from 118 to 60 unities relevant to this project where 80 % are positive and 20% are negative or neutral as in the original.

Set of complemented questions for a final interview

It was decided to use certain questions to complement the data & elaborate a full picture of the participants' experience using the different approaches. Here it is used two different methods; open & closed questions. The closed questions are the same for both approaches & the open are focused on the different exercise sets. The questions can be seen in Figure 4-7.

	Annoying		Controllable		Efficient		Flexible		Intuitive		Responsive
	Appealing		Convenient		Effortless		Frustrating		Inviting		Satisfying
	Attractive		Creative		Empowering		Fun		Meaningful		Stressful
	Boring		Customizable		Energetic		Hard to Use		Motivating		Time-consuming
	Clear		Cutting edge		Engaging		Helpful		Optimistic		Time-Saving
	Comfortable		Desirable		Entertaining		High quality		Poor quality		Too Technical
	Complex		Difficult		Enthusiastic		Impersonal		Powerful		Unattractive
	Comprehensive		Distracting		Exceptional		Ineffective		Predictable		Understandable
	Confusing		Easy to use		Exciting		Innovative		Professional		Useful
	Consistent		Effective		Fast		Inspiring		Relevant		Valuable

Figure 1 - shows the Administration & Scoring of the adapted “Microsoft’s Product Reaction Cards” to this project.

Did you complete the task? (Cross one of the answers)

□Yes □No □I don´t know

How well do you think you were able to complete the exercise set? (Cross the level that fits your answers)

TOO BAD	1	2	3	4	5	6	7	N/A	VERY WELL

How difficult or simple was it to follow the instructions?

TOO DIFFICULT	1	2	3	4	5	6	7	N/A	VERY EASY

Do you think you were able to follow the rhythm?

□Yes □No □I don´t know

To which degree did you feel comfortable using the video?

UNCONFORTABLE	1	2	3	4	5	6	7	N/A	VERY CONFORTABLE

How would you describe the difficulty level of the exercises?

TOO DIFFICULT	1	2	3	4	5	6	7	N/A	VERY EASY

Did you ever get lost or behind in the exercise set?

□Yes □No □I don´t know

If yes, how difficult or easy was it to get back on track?

TOO DIFFICULT	1	2	3	4	5	6	7	N/A	VERY EASY

How easy or difficult was it for you to see what the instructor was doing?

TOO DIFFICULT	1	2	3	4	5	6	7	N/A	VERY EASY

How clear do you think the movements were to you?

UNCLEAR	1	2	3	4	5	6	7	N/A	VERY CLEAR

Fig. 2 - Closed questions

How was your overall experience of the video?

What did you like &/or dislike about the video?

How do you think we could improve this system?

Fig. 3 - Open questions for the video

What did you think about the virtual trainer?

What did you think about using the mouse?

How did the use of the mouse influence your performance?

How was your overall experience of the application?

What did you like &/or dislike about the system?

How do you think we could improve this system?

Fig 4 - Open questions for the real-time 3D

How realistic or believable did you find the movements of the 3D character/virtual trainer to be?
Which one of the two systems did you prefer?
Why?

Fig. 5 - Open questions for both approaches

How the test was performed

During the test, video record & notes regarding the performance of the participants using both exercise sets were taken & then an interview with open questions regarding their experience was also recorded. To finish the participant was encourage filling on modified PSSUQ & Word for each exercise set.

Protocol of the test & participants

The tests were conducted throughout a whole day. Each test had duration of approximately one hour. Six participants took part in the testing; three men & three women aged between 25 & 38 years. One of the participants had an injury (lumbar discus prolepsis) from seven years ago. A few of the participants had experience with physical exercise sets, primarily for fitness purpose.

The tests took place in a large lecture room. The visual content of both the exercise video & the 3D application was played back from a laptop & presented on a large screen via a projector. The sound was played back on regular but powerful external stereo computer loudspeakers. First the participant filled out a questionnaire with demographic questions. Next, the participant was exposed to one of the exercise approaches & had to perform the exercises.

After this, the participant had to fill out two questionnaires about this approach. When this was done the same procedure was done for the other approach. Before the participants were exposed to the 3D approach they were encouraged to try out a test application in which they could practice the use of the mouse for viewpoint manipulation. The test ended with a personal interview which was recorded on video. In order to prevent biased answers the three first participants (Group A) got presented the exercise video first, followed by the 3D application. The last three participants (Group B) were tested with the opposite order of process.

The resume, the methodology consisted of multiple choice questionnaires combined with personal interviews & video recorded observations of the participants' performance. Each participant was introduced according to: (1) demographic description, (2) the participant's own evaluation of his/her performance of the video exercise set & the 3D application relatively, with a comparison with author own observations of the performances, (3) excerpts from the personal interviews.

The Modified PSSUQ (Figure 2) & The Modified Microsoft's Product Reaction Cards (Figure 3) were used to search for possible directions or tendencies in the two groups. The open questions

in the interview & the filmed performance of the exercise sets were used to get a better understanding on the participant's personal experience when exposed to the two exercise sets.

The study follows the general research ethics rules as expressed in the Helsinki Declaration II ("WMA Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects," 2013)

Results

Participant 1:

The first participant was a 38-year-old woman with a bachelor degree & a high level in English, who had experience in the use of exercise sets for rehabilitation purpose & did not suffer from a physical injury.

Video approach: According to the extra multiple choice questionnaire, participant number 1 felt that she completed the task & that she was able to complete the whole exercise set. She thought it was easy to follow the instructions, which were clear to her, but not the rhythm. She felt comfortable using the approach. When she got behind in the exercise set, she felt that it was very easy to get back into the rhythm. All of this corresponds very well to the observations the author did during the testing phase, where the user had a generally good performance but performed some of the exercises too slowly.

3D application: According to the extra multiple choice questionnaire, she thought she completed the task very well. It was easy for her to follow the instructions but not the rhythm of the music. She felt very comfortable using the 3D approach, & the exercises were very easy to her. When she got behind on the exercises it was very easy for her to get back on track. It was very easy for her to see what the virtual trainer (VT) was doing & his movements were quite clear to her. From authors observations it is observed, that participant number 1 did some of the exercises incorrectly. She did not use the mouse at all, even when she seemed confused about an exercise.

Excerpts from the interview: "I liked it (the video) because it was very clear with the instructor. I think there was something about the music; it was quite hard sometimes to see if you had to follow the instructor or listen to the music. To me it would be more motivating with some different exercises, but that's just me. If you're at home it doesn't have to be so complicated it has to be very simple, so I think it's quite good. The music (in the 3D application) was not very motivating. The music didn't stop together with the exercise. There was something about the way he (the virtual trainer) moved his head, I didn't figure that out. With the head rolls actually the lady said what you had to do, & he (the VT) was standing in front of me & doing it to the opposite side. Then I could have turned him around. Maybe I could have used the mouse a bit

more, but I didn't want him flying around in the sky, so I thought I better not touch him now. If I had been more familiar with the mouse, cos he was very alive, it was like driving a new car… Maybe you could have picked another person (*about the character*). With different exercises I would like to use it (the 3D application) (…) maybe yoga. I don't think it's very motivating with this machine guy standing there. *About improvement of the 3D approach*: A different character & music. Maybe some more variation in his body or expression or something (…) something in the background, just something, because it was too monotone. I would prefer the first one (the video), it was more alive. I did not think the movements of the VT were natural. I would like some more facial expressions."

Participant 2:

The second participant was a 28-year-old male, with a master degree & a good level in English. He had experience in the use of exercise sets for fitness purpose & did not suffer from a physical injury.

Video approach: According to the extra multiple choice questionnaire, participant number 2 felt that he completed the task at a medium level. He found it easy to follow the instructions but it was difficult for him to follow the rhythm of the music. He felt comfortable using the video. He got behind on some of the exercises, but it was easy for him to get back on track. He found it to be easy to see what the instructor was doing & the movements were clear to him. From authors observations it is showed, that it was difficult for him to follow the rhythm of the music. He also did not perform some of the exercises correctly, as he himself also acknowledged in the questionnaire.

3D application: According to the extra multiple choice questionnaire, participant number 2 felt that he completed the task very well, & it was very easy for him to follow the instructions & the rhythm of the music. The exercises were very easy to him, however he did get lost during the exercise. It was very easy for him to get back into the rhythm. It was also very easy for him to see what the VT was doing, & the movements were very clear. o that he used the mouse to manipulate the view quite a lot. He performed the exercises better than with the video & also followed the rhythm better.

Excerpts from the interview: "It (the video) was complex. I didn't feel like it was attractive. I was thinking of something else while I was doing [the exercises]. It had a very good combination of the music & the movements. I disliked that the duration is uncontrollable; it was too lengthy for me. It was quite hard work for me. There could be a pause in between the movements. I was not expecting it (the 3D application) like that. The 3D motions were very good. It is very important for the users to feel familiar with the avatar, & I think it was very interesting; it was very familiar to me. The colors were very balanced. Instead of a mouse if you had something

portable which you can have in your hand or you can place or attach to your suit like that (…) so you don't have to break the sequence of the exercise. I thought the mouse was a big obstacle. If you make a control system, like, if I want to replay it, if I feel like I missed something I should have a chance to see it again. You have to describe the levels; like basic level, medium level & professional level. The background should look relevant to the customer. You should have some textual interface as well. You could have some real time feedback & then you just have to compare the two motions [that of the VT & that of the user]. I think I would prefer the second one (3D system) (…) it's very user friendly."

Participant 3:

The third participant was a 28-year-old female, with a master degree & a high level in English. She had no experience in the use of exercise sets & did not suffer from a physical injury.

Video approach: According to the extra multiple choice questionnaire, participant number 3 felt that she completed the task at a medium level. It was neither easy nor difficult for her to follow the instructions but she found it easy to follow the rhythm. She felt very comfortable using the video & thought the exercises were very easy. When she got behind on the exercises she found it rather easy to get back into the rhythm. The movements were very clear to her. This corresponds very well with the observations the authors did during the test. Participant number 3 performed very well, was able to follow the rhythm & seemed to enjoy the exercise.

3D application: According to the extra multiple choice questionnaire, participant number 3 felt that she completed the task but not as well as with the video approach. It was quite easy for her to follow the instructions & the rhythm of the music. She felt very comfortable using the 3D application & that it was very easy. She got lost sometimes but was able to get back on track. She felt it was very easy to see what the instructor was doing & the movements were very clear. From the observations during the test the author could see, that she followed the rhythm perfectly & performed the exercises correctly. She did not use the mouse much.

Excerpts from the interview: "I think it (the video) was fun, it was fast-paced & I could follow most of the time. It's more immersive to me when I'm doing it (the exercise) with a real person compared to a 3D character. I think he (the VT) was not immersive at all. The character was not immersive, the settings were not immersive. After every animation it was just… like he freezes. I think it was fun [using the mouse] even though I didn't use it much apart from the beginning. First you give me a really fast-paced exercise which was energetic & then I come into this [???] after that, so I really got bored, at some point I was just like, I wanted it to end! I think the music was really good. I think the voice-over was quite good. Change the environment, change the character, make it fit, because I feel like as I'm exercising I feel like there's this character that's imitating me instead of someone who is showing me what to do. I think that has a lot to do with

the character you have chosen. I think that's the difference with the video that you made cos once I see that figure I'm like ok it's time to exercise. He's wearing sports clothes, the whole… I think most of them (movements of the 3D character) were quite natural. The fact that, like I said, he freezes, it reminds me that ok this is a 3D character, & it kills the immersion for me."

Participant 4:

The fourth participant was a 25-year-old male, with a master degree & a high level in English. He had experience in the use of exercise sets for fitness purpose & did not suffer from a physical injury.

Video approach: According to the extra multiple choice questionnaire, participant number 4 felt that he completed the task very well. It was easy for him to follow the instructions & he was also able to follow the rhythm of the music. He felt very comfortable using the video & he thought that the exercises were very easy. He did not feel that he got behind in the exercise set. It was easy for him to see what the instructor was doing & the movements were relatively clear. Form authors observations it is showed that he did not follow the rhythm. He also performed some of the exercises too slowly or incorrectly.

3D application: According to the extra multiple choice questionnaire, participant number 4 felt that he completed the task quite well. He felt that it was too easy to follow the instructions & that he was able to follow the rhythm. He felt quite comfortable using the 3D application & the exercises were relatively easy. He did not feel that he got behind on the exercises, it was very easy to see what the VT was doing & the movements were very clear to him. From the video observations it was possible to observe that participant number 4 did not follow the rhythm of the music nor the virtual trainer. He performed some of the exercises incorrectly & did not appear very motivated or entertained. He did not use the mouse.

Excerpts from the interview: "It (the video) was good. It's kind of like you have your own personal trainer. You can do it alone at home; you don't have to go to the gym. If there is someone in front of you doing the exercises then it's more inspiring than if you are alone. [There should be] easier steps in the start, like initial level, advanced level & medium level (…) so it would be easier for everyone to do that. It (the 3D character) was innovative, because usually you don't see a 3D character; usually you have videos of aerobics & all that. It (the 3D system) was slower; it was more informed. It was really a good idea (to be able to use the mouse to manipulate the view), because you can actually change the point of view according to your comfort, it was really nice. The animation could be improved. It could be made more attractive. I would prefer to use the 3D system, because it's simpler, easier, more innovative, more attractive & something new. The movements of the 3D character were all very realistic. It would be a good idea if it was possible to change the speed, change the character…"

Participant 5:

The fifth participant was a 28-year-old female, with a bachelor degree & a good level in English. She had experience in the use of exercise sets for fitness purpose & did not suffer from a physical injury.

Video approach: According to the extra multiple choice questionnaire, participant number 5 felt that she completed the task very well. It was very easy for her to follow the instructions & the rhythm of the music. She felt very comfortable using the video & the exercises were very easy for her to perform. She did get lost sometimes but was able to easily get back into the rhythm. It was relatively easy for her to see what the instructor was doing, & the movements were very clear to her. From the authors observations from the recorded videos, it is showed that participant number 5 followed the rhythm very well, did the exercises correctly & seemed to enjoy performing the exercise.

3D application: According to the extra multiple choice questionnaire, participant number 5 felt that she completed the task very well. She found it very easy to follow the instructions & she was also able to follow the rhythm. She felt very comfortable using the 3D application & the exercise set was at a very easy level to her. She did get lost or behind sometimes but it was very easy for her to get back on track. It was very easy for her to see what the virtual trainer was doing & she found the movements to be very clear. From the authors observations from the recorded videos, it is showed that she followed the rhythm very well. She used the mouse a few times & performed most of the exercises correctly. She started performing some of the exercises during the voice-over explanation but before the virtual trainer started.

Excerpts from the interview: “I thought it (the video) was fun, but I couldn’t use it for fitness. I wasn’t sure how it was made, if it was something you did yourselves or if you found it in YouTube. I liked the notice about the fact that I had to use a chair in the next exercise. It would be cool with a video like this as a pop-up with exercises on the computer in my office. I think the VT was totally fabulous. I could feel related to him, but it would be nice if he smiled back at me. It was easy to use the mouse; the reaction to the mouse movements was fine. I didn’t use the mouse very much, but it’s a good possibility to have – to see if the character is ergonomically correct. I think it (the 3D system) was really really good. It was fun. I preferred to use the 3D because it was just more fun. The naturalness of the movements was somewhere in between robotic & human. The hands & fingers were static; there could have been some more movement.”

Participant 6:

The sixth participant was a 36-year-old female, with a bachelor degree & a good level in English. She had experience in the use of exercise sets for rehabilitation purpose & suffered from a physical injury (lumbar discus prolepsis in 2000).

Video approach: According to the extra multiple choice questionnaire, participant number 6 felt that she completed the task very well. It was neither difficult nor easy for her to follow the instructions & she felt that she followed the rhythm. She felt comfortable using the video but thought that the exercises were a little too difficult. She got behind in the exercise set but it was very easy for her to get back on track. It was very easy for her to see what the instructor was doing & the movements were very clear to her. Form authors observations it is showed that she followed the exercises & the rhythm of the music very well. She thought some of the exercises were too fast.

3D application: According to the extra multiple choice questionnaire, participant number 6 felt that she completed the task very well. She found it relatively easy to follow the instructions & she felt that she was able to follow the rhythm of the music. She felt neither comfortable nor uncomfortable using the 3D application. She thought that the exercises were too difficult & she got lost during the exercise set, but it was very easy for her to get back on track. It was very easy for her to see what the virtual trainer was doing & the movements were very clear. From the video observations it is possible to observe that participant number 6 did the exercises correctly, but did not follow all of them mostly because of a neck injury a few years back. She was very interested in exploring the application & used the mouse a lot.

Excerpts from the interview: “I think it’s nice to look at a real person. One is not alone standing there doing the exercise. I thought some of the exercises are a bit difficult. The speed was too fast I think. You need some instruction to prevent injuries. It could have been nice to hear a voice saying “*try not to do this & this*”. I don’t know if it could be possible to have different kinds of music, so one can choose, if there are different numbers for the exercises, then one can choose, is it rock, is it dance, whatever. It (the 3D application) was fun but it doesn’t really motivate me with cartoons. Maybe people who like to play [computer] games, they would be motivated by this, but I don’t do that. It felt a bit odd standing up there doing the exercise, & then I had to bend over to use the mouse. That didn’t feel nice. It would have been nice to have it in the hand, standing up. It was fun to try. & it’s fun to play a little also, to be able to move the man & see it in 3D. It was like a game, a little. Some of the exercises didn’t feel so good. I wouldn’t make exercises with the neck like that. The neck is just so sensitive. There would be need of more specific instructions during the neck exercises: “*Try to do this, prevent doing that…*”. I think it (the music) was a bit boring. It was the same number & the speed was too

slow. The environment around the character was fine. I preferred the video, because I felt less alone. I thought the movements (of the 3D character) were quite good. I think it's a very good idea but I don't think it can stand instead of the physical therapist because he needs to give specific instructions to prevent injuries."

It seems that all six participants thought that both the video approach & the 3D application were easy to use. There are varying opinions on which system is preferred; two participants from Group A preferred the video approach & two of the participants from group B the 3D application. It is interesting to note, that all participants thought that they completed the task rather well, as the video observations show, that several of them did not perform the exercises correctly and/or did not follow the rhythm of the music or the instructor & virtual trainer.

Comparison between the two test groups

The results of the multiple choice questionnaires where used to observe which questions were answered equally for all participants in each group. This was done in order to figure out whether or not the order of the presentation of the two approaches had an effect on the test results.

Group A about the video:

When answering the modified PSSUQ the three participants strongly agreed that they felt comfortable using the video, it was easy to learn to use the exercise set approach, & that whenever they made a mistake using this exercise set approach, they could get back into it easily & quickly.

When answering the modified "Microsoft's Product Reaction Cards", all of them thought that the video approach was *easy to use*, *understandable* & *valuable*.

From the extra questions: all participants got lost or behind in the exercise set at some point but they still felt they completed the task.

Group B about the video:

When answering the modified PSSUQ the three participants strongly agreed that: overall they were satisfied with how easy it was to use the exercise set approach. They were able to efficiently complete the tasks using the exercise set approach, they felt comfortable using it & it was easy to learn to use it. Whenever they made a mistake using this exercise set approach, they could get back into it easily & quickly. It was easy for all of them to find the information they needed & the information provided for the exercise set approach was easy to understand.

When answering the modified “Microsoft’s Product Reaction Cards”, all of them thought that the video approach was *easy to use*, *fun*, *helpful* & *motivating*.

From the extra questions: all participants felt that they completed the task.

Group A about the 3D application:

When answering the modified PSSUQ the three participants strongly agreed that: overall they were satisfied with how easy it was to use the exercise set approach, it was simple to use it & they could effectively complete the tasks using this exercise set approach. Whenever they made a mistake using the 3D application they could recover easily & quickly.

When answering the modified “Microsoft’s Product Reaction Cards they did not choose the same words.

From the extra questions: all participants got lost or behind in the exercise set but anyway they felt they completed the task.

Group B about the 3D application:

When answering the modified PSSUQ the three participants strongly agreed that: overall they were satisfied with how easy it was to use this exercise set approach, it was simple to use it & whenever they made a mistake using the 3D application they could recover easily & quickly. It was easy for them to find the information they needed & they liked using the interface. Overall, they were satisfied with this exercise set approach.

When answering the modified “Microsoft’s Product Reaction Cards”, all of them thought that the 3D application was *easy to use*.

From the extra questions: the participants all felt they completed the task.

Discussion

Test results are discussed according to, 1- which approach the participants preferred to use; 2- how difficult or easy it was for the participant to use 3D application: 3- whether they felt like they were able to complete the task; 4-thoughts on the possibility of manipulating the view; 5- opinions on the virtual trainer; 6- possibility to choose between different levels; 7- realism or believability of the animation of the virtual trainer; 8- thoughts on the audio/music; 9- the

participants' perception of the movements of the video instructor & the virtual trainer; 10-a comparison of the replies from *Group A* & *Group B*. The theme of each paragraph will be marked in bold in the text.

The test results showed that three of the participants would **prefer to use the video**: *"I would prefer the first one [the video], it was more alive. I did not think the movements of the virtual trainer were natural."* Three preferred the 3D virtual reality application: *"I would prefer to use the 3D system, because it's simpler, easier, more innovative, more attractive & something new."* The participants all felt that they were able to follow the exercises in both approaches & that it was easy to use them both. However, from the video recorded observations it is showed that several of participants did not perform the exercises as well as they thought themselves according to the questionnaires with regards to following the rhythm of the music & performing the exercises correctly. This tells us that there is a need for a system that could give real time feedback on the performance informing the user when he do the right movement or not. The implementation of motion capture systems would be useful here to evaluate the user's performance. With this feature the user's rehabilitation could be improved & made more efficient, & potential injuries avoided.

Five of the participants thought that the 3D application was easy to use. This could be related to the fact that those participants have been, more or less in touch with computers & other technical devices (they have a high academic level). Therefore the use of the mouse to explore the 3D character's movements has not been so difficult for them, & the easy task of mimicking movements could also lead to the participants' opinion. It could also be interesting to get feedback from people with other backgrounds or ages to observe if such 3D application could also be easy to use for them or not.

All the participants felt that they **completed the task** both in the video & in the 3D application. The fact that both exercise sets had a specific duration & that the participants were there from the start to the end of the exercises could induce the participants to think they completed the task, even if they did not follow the rhythm or perform the total number of repetitions. This statement could improve a motivation factor for both approaches, where the user feels that something has been done.

All of the participants liked the **possibility to manipulate the view of the virtual trainer**: *"I think it was fun [using the mouse]"* & *"It was really a good idea [to be able to use the mouse to manipulate the view], because you can actually change the point of view according to your comfort, it was really nice."* However there were limits to their excitement as a few of them thought it was unnatural having to move over to the computer & bend down to manipulate the mouse & others thought it was difficult to control. As one participant said: *"It felt a bit odd standing up there doing the exercise, & then I had to bend over to use the mouse. That didn't*

feel nice. It would have been nice to have it in the hand, standing up." Another participant agreed: *"Instead of a mouse if you had something portable which you can have in your hand or you can place or attach to your suit like that (…) so you don't have to break the sequence of the exercise. I thought the mouse was a big obstacle."* People who are not used to e.g. playing computer games or navigating around in 3D environments may feel insecure in how to use the mouse: *"Maybe I could have used the mouse a bit more, but I didn't want him (the virtual trainer) flying around in the sky, so I thought I better not touch him now*." So all in all there seems to be a positive response to the feature of being able to manipulate the view of the virtual trainer itself. However there could be made some improvements in the implementation of this feature. A few of the participants suggested a portable device which the user can have in his hand or attach to his clothes, so it is no longer necessary to move over to the computer when there is a need to change the viewpoint.

In regards to the person who did not feel familiar enough with the use of the mouse there are not so many other solutions than letting the users explore the use of the mouse, or in the future the Wii remote, to get to know it better. It is important to develop a remote control as the Wii remote as intuitive as possible to make everyone no matter their level of experience feel comfortable using it, but if the target population has difficulties to use the mouse or the Wii remote, then it could be possible to implement other technologies such as augmented reality, where the user with a semi-transparent HMD could be exploring the virtual physiotherapist standing in the middle of his own living room.

The **opinions of the virtual trainer** from the 3D application were much divided. Three participants liked it: *"It (the 3D character) was innovative, because usually you don't see a 3D character; usually you have videos of aerobics & all that"*, or as another participant put it: *"It is very important for the users to feel familiar with the avatar, & I think it was very interesting; it was very familiar to me"*. Three participants disliked it: *"It (the 3D application) was fun but it doesn't really motivate me with cartoons. Maybe people who like to play [computer] games, they would be motivated by this, but I don't do that".* It is important to note, that the 3D character used in this study was not the first choice but was chosen because of problems with the initial character choice. Since the physical appearance & aesthetics were not the main focus of this project, & due to the fact that the character can easily be replaced later on. In this project the creation of a new 3D character was down prioritize & the focus was based on the prototype functionality. Of course this choice of priorities had an effect on the test results. On the positive side, the study collected a large amount of constructive feedback & thereby a clear idea of what users of this system would prefer with regards to the appearance of the virtual trainer. First of all, according to test participants' opinions the virtual trainer should be an adult instead of a child, which was an expected reaction. Furthermore, one participant expressed a wish to see a character wearing sports clothes, so it would be similar to the trainer of the video, because sports clothes signals what is going to take place: *"I feel like there's this character that's*

imitating me instead of someone who is showing me what to do. I think that has a lot to do with the character you have chosen. I think that's the difference with the video that you made because once I see that figure I'm like; ok it's time to exercise. He's wearing sports clothes, the whole…" Another participant suggested the possibility to choose between different characters, so the user can pick a character that appeals them best. The users of an application like this will be a very mixed population, & the prototype should reflect that.

This brings us on to another feature which a couple of participants felt was missing, i.e. the possibility to choose between different **levels**. Some participants found some of the exercises to be quite difficult to perform, some found the speed to be too fast, while others thought it was all very simple: *"[There should be] easier steps in the start, like initial level, advanced level & medium level (…) so it would be easier for everyone to do that".* With the possibility to choose for example between three different levels (beginner, intermediate, experienced), more users could feel satisfied with the 3D application. Multiaerobics is although thought to create personalized exercise sets focused on the users' exercise needs, which the physiotherapist collects from a database of specialized body movements. Two general exercise sets were created in this study to be tested for almost anybody, it could be the factor of getting so varied opinions on type & speed of the exercises depending on the participants' physical condition or past injuries.

To go back to the 3D character for awhile, specifically the **animation** got a few comments. As is the case with a number of other issues in the study tests, the participants were rather divided on this issue, although the majority was positive: *"The 3D motions were very good".* Another participant said: *"The movements of the 3D character were all very realistic".* One participant was indecisive: *"The naturalness of the movements was somewhere in between robotic & human. The hands & fingers were static; there could have been some more movement."* This participant also wanted the character to have some more facial expressions. Two participants were quite unimpressed when it came to the animation of the virtual trainer: *"After every animation it was just… like he freezes (…) it reminds me that ok this is a 3D character, & it kills the immersion for me."* There is in fact animation between the exercises, but this feedback tells us that the standing still animation could be more alive, & facial expressions might help too. One participant also noticed that a few of the exercise loops were "jittering", i.e. the beginning & the end of some loops were not perfectly synchronized causing the animation to "jump". This of course also adds to the impression that the movements of the 3D character were not natural. The solution to this problem is simple; it is important to be more careful & detail oriented when creating exercise loops derived from a motion capture data. So to sum up the feedback given in relation to the animation of the virtual trainer, there needs to be a more expressive animation in between the exercise loops, possibly mixed with facial expressions, & then the editing of the motion capture data into exercise loops needs to be conducted with more precision. This would

give us a much better result with regards to creating a believable, realistic & natural virtual trainer.

The **audio** in both the video & the 3D prototype consisted of verbal instructions & music. In the video there was different music at different speeds for each exercise. The verbal instructions consisted of a short introduction before the exercise set began. In the 3D prototype there was only one long song for the whole exercise set. The verbal instructions consisted of an introduction in the beginning & descriptions of each exercise. The users were generally quite satisfied with the audio in the video: *"It (the video) had a very good combination of the music & the movements"* said one person, while another one told us, *"I think the music was really good. I think the voice-over was quite good."* There were however a couple of participants who did not agree. One got confused because she did not feel like the rhythm of the music & the movements of the trainer fitted together: *"I think there was something about the music; it was quite hard sometimes to see if you had to follow the instructor or listen to the music."* This could be due to the fact, that some of the exercises in the video were not performed 100% in sync with the metronome used to keep a constant speed of 60 BPM. Therefore, it was very difficult to make the music, which of course has a constant speed, fit together with the image. In a couple of the exercises the synchronization was a bit off, which is the reason for this user's confusion. Despite of this, the general opinion about the music in the exercise video was quite positive. Most participants found the music to be motivating.

The **music** in the 3D application did not please the participants in the same degree. Several of them found it to be boring & not very motivating: *"The music (in the 3D application) was not very motivating. The music didn't stop together with the exercise."* Or as another participant puts it, *"I think it (the music) was a bit boring. It was the same number & the speed was too slow."* The reason why the music was slow is that the exercises were slow, & the two had to fit together. This feedback encourages the idea of using different types of exercises at different speeds & with different background music. One participant came up with a solution which could probably make many users more pleased with the 3D application: *"I don't know if it could be possible to have different kinds of music, so one can choose, if there are different numbers for the exercises, then one can choose, is it rock, is it dance, whatever."*

With regards to the participants' **perception of the movements** of the trainer in the video & the virtual trainer, there seemed to be no difference. According to the questionnaires all of the participants found it to be *easy* to *very easy* to see what the instructor or 3D virtual trainer was doing, & the movements were clear to all of them. There seems to be no relation between the use of the mouse to manipulate the view of the virtual trainer & the participant's performance. Only one participant (Participant number 2), who used the mouse a lot, performed significantly better using the 3D system compared to the conventional exercise video. However, It is not conclude that the possibility of manipulating the view of the virtual trainer will help the user to

perform better based on just one participant's performance, since there could be other factors affecting the performance such as the speed of the exercises, which was slower in the 3D application, or the type of exercises in the 3D application, which could have been easier to that particular participant.

The observation from participant 2 suggests that the 3D application invites (motivating) him to explore the actual exercise to mimic, improving (being efficient & pedagogical) his final performance compared to the performance observed in the video approach. In the same context participant 5 admits the pedagogical potential of using real-time exploration with the mouse: *"I didn't use the mouse very much, but it's a good possibility to have – to see if the character is ergonomically correct".* In contrast to that it is shown also that one participant who was not so confident in computer 3D-exploration felt this new feature to be a barrier for getting a new pedagogical experience of the movements, as participant 1 expressed, *"Maybe I could have used the mouse a bit more, but I didn't want him flying around in the sky, so I thought I better not touch him now".* But this fear to use the mouse in this application could maybe disappear when participants are exposed more than once to the application, getting more familiar with the interface.

As there is a risk of getting biased results when exposing participants to two different approaches in the same order, the participants were divided into two groups of 3 people. The comparison to the answers from the questionnaire from the two groups showed a very positive feedback. There is however a small difference in the way they answered the questionnaires, as the participants in Group B were very positive on a few more points than Group A, which had ticked more answers in the middle of the 7-point scale & fewer in the extreme numbers (1-2 or 6-7). Group B was exposed to the 3D application first, followed by the conventional exercise video. The questionnaires were filled out after each exercise set approach, & therefore they did not have anything to compare with when filling out the questionnaire about the 3D application. The participants could possibly be more positive towards the video approach after being exposed to the 3D application because the video-presented exercise set is more fast-paced & requires the user to move larger parts of his body. So even though they already had a positive attitude towards the 3D application, the speed of the exercises & music in the video could influence them psychologically in such a way that they would have more positive feelings after the video exercise. However, because of the small amount of test participants & the relatively small difference in the replies it could all simply be a coincidence.

Conclusion

This study tries to find a way to understand the benefits & challenges of using a Virtual Reality approach compared to conventional rehabilitation therapy testing the hypothesis: *The traditional & the VR approach are equally useful (pedagogical, efficient, motivating, stimulating).*

There did not seem to be any difference in how well the participants performed with the two approaches or how they perceived the movements of the video instructor compared to the 3D virtual trainer. One half of the participants preferred to use the conventional therapy approach & the other half preferred the 3D prototype. Based on this, it is not possible to say whether the Virtual Reality approach or the conventional therapy is more useful. Therefore, the results are inconclusive but can be used as a foundation for further research on the subject where more extensive quantitative studies, focusing on specific target populations, with repetitive exposures to exercise sets, using control groups & testing a higher number of participants before & after the exposure, try to get an answer to the same or similar hypothesis.

However, with a little more work on the exercise set created in 3D, such as integrating the use of motion tracking systems to give real time feedback to the user on performance, customizing the character, enhancing its facial expressions, adding a variety of movements & rhythms & other features to the 3D application as buttons to start, pause or tools to speed or slow the rhythm of movements & music loops, the results could be different & there could possibly be a bigger difference between the two approaches.

Another feature that could be done to improve the prototype could be to change the appearance of the virtual trainer. Some of the participants did not find it motivating to watch a cartoon style boy performing the exercises. It would make more sense to the users if the virtual trainer looked more realistic, was an adult & was wearing sports clothes. Or as one of the participants mentioned, the possibility of choosing between different characters could be a good solution to the problem.

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