Collaborative 360° Virtual Reality training of medical students in clinical examinations

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Abstract

Simulation-based training in computer-generated environments has always played an important role in clinical medical education. Recently, there has been a growing interest in using 360° videos of real-life situations for training in health professions. Several studies report positive results from using 360° Virtual Reality for individuals, however, there are no studies on collaborative 360° Virtual Reality training. In this paper, we study how 360° Virtual Reality can support collaborative training in clinical medical education. 14 medical students from a 5th -semester medical bachelor's program participated. In three groups, the students watched and annotated a 360° video of an authentic learning situation inside a collaborative immersive virtual reality space. The video shows a problem-based supervised examination of the knee collateral ligaments and the cruciate ligaments performed by students. Afterwards, the students should perform the test in a physical examination. The performance of the students has afterwards been evaluated by a professor with expertise in knee examinations. The results show that 12 out of 14 students gets a score of 2 on one or more test and thereby reaches the required learning objective. One student receives a score of 1 and one student does not perform any of the tests. The students use the tools provided by the software and different communicative strategies when working collaboratively in 360° Virtual Reality, which enables them to perform the tests in the physical examination. These results indicate that our pedagogical design in collaborative immersive 360° Virtual Reality can become a relevant addition to face-to-face clinical medical training.

Introduction

Computer simulation-based training has always played an important role in clinical medical education (Alhalabi, 2016; Imai et al., 2022; Kolla et al., 2020; Matzke et al., 2017; Moro et al., 2017; Stepan et al., 2017; Taubert et al., 2019; Zackoff et al., 2021; Zhao et al., 2020) as students can practice skills in a risk-safe environment and without harming human subjects. In light of the Covid-19 pandemic, medical educational programs experienced difficulties in supporting and giving access to the “immersive nature of medical education” (Gaur et al., 2020, p. 1995). Currently, simulation-based training is mainly taking place in computer-generated environments, and they do not convey the situated and immersive nature of medical education in all its multimodal details (Rachul & Varpio, 2020). Recently there has been a growing interest in using 360° videos of real-life scenarios for learning activities (Pirker & Dengel, 2021; Snelson & Hsu, 2020). With 360° video teachers and students in health profession education are no longer confined to viewing a video on a flat screen, instead, the 360° videos can be projected in a Head-Mounted Display (HMD) (Pirker & Dengel, 2021). The use of 360° videos also enables new opportunities for working with authentic learning situations, which according to Arents (2021) prepares the students to deal with new real-life situations and gives access to the practice they are going to be part of at a later point. Rachul et al. (2020) also suggested that health professions education should focus on all the different modes of interaction, as new technologies shape the context of medical work. Another positive outcome of using 360° Virtual Reality is a higher degree of involvement from the students while watching the video (Arents et al., 2021). Several studies report positive results from using 360° Virtual Reality for
individuals, however, there are no studies on collaborative 360° Virtual Reality. The study presented in this paper is advancing the knowledge about how 360° Virtual Reality can support training in a collaborative and Problem Based Learning (PBL) environment in clinical medical education. Basically, we are developing case-PBL (Stentoft, 2019) in a new medium allowing more sophisticated interaction with authentic cases. We report on a pilot study in which we investigate the possibilities of using a collaborative 360° Virtual Reality space for training clinical medical examinations. We are interested in understanding if it is possible to transfer knowledge from working collaboratively in immersive 360° Virtual Reality to a physical setting. Our results indicate that collaborative 360° Virtual Reality has great possibilities for supporting medical students' knowledge and skills retention. There are of course limits of this pilot study, but we use this case study (Flyvbjerg, 2006) to point to future direction of collaborative 360VR in clinical medical education.

Methods

Study design

To study how immersive 360° Virtual Reality can be used as a collaborative tool for training medical students in clinical examinations, we designed a problem based learning case (Stentoft, 2019) in which medical students had to collaborate in groups in a collaborative immersive learning space. In this setting groups of students interacted in/with a 360° video of an authentic learning situation in 360° Virtual Reality. The students were able to use different tools provided by the software to work collaboratively with/in the 360° video. Afterwards, they performed a similar examination as the one performed in the 360° video in dyads or triads. This allowed us to study how effective the training was for the student's knowledge and skills retention. A visualization of the design of the problem-based learning session can be seen in Fig. 1.

The basis for the training activity in collaborative 360° Virtual Reality is a 17-minute-long non-scripted 360° video showing a professor and two students (see Fig. 2) in a room at a hospital. The 17 minutes is part of a longer session of 100 minutes, but we decided to limit the collaborative Virtual Reality training session to a shorter and more focused part of the long session. Compared to traditional case-PBL this session is more open ended and the students have to negotiate how to work together in the virtual space, and they are given the primary responsibility for defining their learning strategies and goals.

The training video features novice students performing an examination of the knee collateral ligaments and the cruciate ligaments for the first time. The students in the training video have no experience in performing this type of examination. Therefore, they are also identifying and solving a problem together that they have no professional experience with. In the video one student is examining the other student's knee. Because of their lack of experience with this type of examination, we witness some failures and uncertainties about how to perform the examination. In the training video, the professor instructs and guides the students through questioning their examination, e.g., how they twist and bend the knee to perform certain tests. We consider this training video as authentic as the students and professor are
mutually creating a situated learning space and did situation was not planned or scripted in any way. The idea of using authentic material (non-scripted) is different compared to very structured and autorotative material, which is normally the case in clinical education.

To support collaborative learning in 360° Virtual Reality among the students we used the software prototype CAVA360VR, which is developed by the unknown group at Aalborg University (Davidsen & McIlvenny, 2022; McIlvenny, 2021). This software enables the students to play and annotate a 360° video while being situated in different physical locations. Currently, the prototype supports up to 20 users in the virtual environment at the same time. When immersed in the virtual space the students are represented by avatars. The avatar consists of a floating head and hands and on top of each avatar head, the name of the student/user is visible (see Fig. 2). The students can use a laser pointer to visualize what they are oriented toward and referring to and they can also use the laser pointer as a drawing tool if they need to illustrate something in the video. The software also enables the students to stop and pause the video (McIlvenny, 2021).

**Setting and research participants**

In late November and early December 2021, we conducted our pilot study which consisted of three experiments in which a total of 14 students (2 male, 12 female) from the 5th -semester medical bachelor program at Aalborg University participated.

In the first experiment, three students participated using an unscripted version of the training session in 360° Virtual Reality. The students had not received any teaching or been shown how to perform clinical examinations before the experiment, nor had they had any substantial experience with 360° Virtual Reality. In the second experiment, six students participated also using an unscripted version of the training setup. This group of students all had participated in the clinical examination course which is part of the curriculum of the 5th -semester medical bachelor's program. The teaching consisted of the students watching a professor perform the different clinical tests. None of the students had tried to perform the tests themselves. In the third experiment five students participated and this time they used a scripted version of the training setup, which meant one of the students had a number of questions appearing as they played through the video. This enabled us to understand how a collaborative 360° Virtual Reality space can be designed by trying out different setups. Like group two, this group had also received prior teaching in clinical examinations and had not themselves tried to perform the tests.

All of the students were before the training placed in different physical rooms and given an HMD and a short presentation of the different buttons on the controllers, so they had a basic understanding of the hardware and software (see Fig. 2).

There was no time limit for the training because we were interested in exploring how much time the students used on preparing for the examination. The time spent by the three groups inside the collaborative 360° Virtual Reality space seeing and interacting with the 17-minute clip is as follows: group one used 40 min 17 sec., group two 36 min 28 sec., and group three 49 min 36 sec.
After the training ended, the students were allocated to an examination room, where they performed the physical examination of the knee collateral ligaments and cruciate ligaments (see Results).

**Data collection**

As 360° Virtual Reality is a new context for clinical medical education, we decided to collect multimodal data (Rachul & Varpio, 2020). All of the actions and interactions of the students both inside 360° Virtual Reality and outside in the physical were recorded using video cameras and screen capture tools. The reason to collect dual data was to see if the students’ performed gestures or body movement in the physical space which were not mediated into the virtual space.

To record the actions of the students during the physical examination, we used one camcorder placed at the foot end of the bed, two 360° cameras placed at each end of the bed, and a GoPro mounted on the ceiling. We used several cameras to make sure we had the best possible overview of how the students performed the clinical tests (see Fig. 3).

To record the audio, two students had a microphone placed on their shirt, and a 360° spatial recorder was placed next to the bed.

**Data analysis**

In this paper, we are focus on how the students accomplish the different clinical tests to see if the student’s performance lives up to the learning objectives required by the University. The tests we are focusing on are tests of the medial and lateral collateral ligament on a stretched knee and tests of the anterior cruciate ligament on a 90-degree bend knee. We do not expect the students to know how to perform a test of the posterior cruciate ligament because it is not mentioned in the training video. The students’ performances have been assessed by a clinical professor with expertise in knee examination and a graduation system has been developed for this purpose (see Table 1). In our analysis of the data, we also focus on the software tools and communicative strategies used by the students in order to plan how they will solve the problem of performing the physical examination (see Table 2).

**Ethical approval**

All the data collected in this project follows the rules and GDPR regulations provided by Aalborg University and the research has been approved by the Contract Unit at the university (2021-068-01827). Informed consent was obtained from all students who participated in the three pilot experiments. Because the data is used for educational purposes there was no need for approval from the local ethics committee of North Denmark Region.

**Results**

*Results from the physical examination*
The results from table 1 are showing that in the test of the medial collateral ligament 6 students get a score of 2, 4 students get a score of 1 and 4 students did not perform the test (-). In the test of the lateral collateral ligament 6 students get a score of 2, 4 students get a score of 1, and 4 students did not perform the test (-). In the test of the anterior cruciate ligament 9 students get a score of 2, 1 student get a score of 1, and 4 students did not perform the test (-). No students performed the test incorrectly. Thereby 12 out of 14 students reach the required learning objectives in one or more tests.

The students also used a different amount of time on the examination, shortest time spent 3 min. 42 sec. and the longest time spent 16 min. 21 sec.

Results from the training in collaborative 360° Virtual Reality

In table 2 the results from the training in the collaborative immersive space is presented. The results show that the students actively use different tools in the software and communicative strategies to construct a shared understanding of the information presented to them in the 360° training video. These tools and strategies enable them to solve the problem of performing the physical examination after the collaborative activity in Virtual Reality.

From the results, we see that group three doesn’t end the session with a preparing and planning phase instead they extend their learning session to the physical examination. This illustrates that the students have different communicative strategies and understandings of how to solve the problem of performing the physical examination.

Discussion

In this pilot study, we have studied the ability to transfer knowledge and skills from a virtual collaborative space to a physical examination. To do this, we recruited students from the 5th-semesters medical bachelor’s education program. This group of students matched the inclusion criteria, students with no experience in clinical practice and with a basic knowledge of anatomy (Astorp et al., 2020). The design of the Problem Based Learning case allows the students to learn clinical skills which normally are taught through physical training in clinical examination. The results show that the students can perform the three tests even though they have never done it before and only have seen it been done by an instructor and even the students who never received any prior teaching can reach the objective learning requirements. Despite that some of the students do not perform one or more of the tests, they still participate in the examination by guiding and helping the other student(s), this is for example the case with student B in group one. This correlates with the other results that the students by watching an authentic learning situation and working together with others can train skills and competencies related to communication, collaboration, and problem-solving in order to construct a shared understanding of the information presented to them. By using and incorporating the software tools in their learning strategies, the students use the collaborative immersive learning spaces to analyze the material in a collaborative way. The ability of being social becomes a strength because the training video is not giving the student’s
full access to see the different tests, e.g., sometimes the students cannot see what is going on because of the camera angle or because it is hard to hear what the students in the video are saying. By working collaboratively, they can integrate each other’s knowledge and experiences to fill in the gaps of the material and construct a better understanding of the physical examination. During the training in the collaborative virtual space and afterwards in the physical examination the students use their prior knowledge about e.g., anatomy to help and guide each other. This is a positive outcome of the session showing that the students can use their knowledge in an active way in a collaborative virtual space.

These results make us confident that our training design with the use of collaborative immersive 360° Virtual Reality have the possibility to become a relevant substitute for or addition to face-to-face teaching and training of medical students in clinical training. Collaborative 360° Virtual Reality offers the students a more sophisticated and advanced learning space, where they can immersive themselves inside of the video material together with their fellow students. In our follow interviews with the students many of the expressed an interest in having a library of 360° Virtual Reality cases. This would allow them to return to the different cases and practice their skills and competences with fellow students.

As noted in the introduction the dominant type of simulation-based training used in medical education is the use of computer-generated 3D simulations (Bailenson, 2018; Radianti et al., 2020). This type of simulation can be used for training, where students can practice new skills in a simulated environment, which enables corrections, repetition and non-dangerous failure and offers access to interaction with expensive or far-away environments (Jensen & Konradsen, 2018). Despite all of the positive outcomes this technology have contributed with to the field of medical education, there is still a need for platforms supporting collaborative learning, while still providing the immersive nature of medicine (Gaur et al., 2020). With our training design and the authentic problem-based learning case, we suggest a new digital format, enabling medical students to work collaboratively while being situated in different locations at home or in the hospital. It would even be possible to work together with students from other countries using the software. The research is still in an early stage, but we see a potential and an opportunity to fill a gap in the training of medical students when face-to-face training is not an option. As mentioned by the students there are still possibilities to improve the usability of the software and also the placement of the cameras. The results have given us an understanding of the strength and weaknesses of collaborative 360° Virtual Reality and we are now ready to produce new training material based on the knowledge from the three experiments. It is our plan to test the training setup at a larger scale, which will provide us with more data and help us develop the design even more. Further, we want to develop the user interface to test if that will make a difference for the students.

References


**Table 1 And 2**

Table 1 and 2 is available in Supplementary Files section.

**Figures**
Figure 1

A visualization of the problem based learning session.

Figure 2

(A) Picture from the 360° training video. (B) The technical setup outside of the CAVA360VR space. (C) The technical setup inside the CAVA360VR space.
Figure 3

An overview of the different camera angles used to capture the physical examination.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1and2.docx