The effect of Virtual Reality on Learning and Engagement in Anatomy Education

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Ethical approval

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Introduction

Learning the anatomy of the musculoskeletal system requires a lot of insight from students. The limitation of many learning materials is that the perception of anatomy is two-dimensional (2D), while in reality the anatomy is three-dimensional (3D) (1). The use of anatomical models is therefore an important addition to anatomy education at universities because these models are three-dimensional. Virtual reality (VR) creates the possibility of studying anatomy three-dimensionally, with an added benefit that interaction with the 3D-model is possible. This could possibly contribute to a meaningful learning strategy when used as an additional learning tool.

VR is an emerging technology in education that offers realistic and immersive 3D experiences and provides visual feedback from body movements (2). In an educational age where experience is the most common source of learning (3) and where 21st century skills are becoming essential, VR offers multiple advantages. First, VR offers the opportunity to make learning more immersive and engaging. Students are able to build their own knowledge through active learning in meaningful experiences (2). An additional advantage is the engagement that arises from the feeling of presence when someone immerses themselves in the virtual environment (1). Specifically for anatomy education, VR offers the opportunity not only to look at anatomical structures in 3D, but also to interact with the anatomical model by moving structures and thus investigating their mutual relationships (4). This is useful in an educational setting, where you want to activate and motivate students.

The learning effect of virtual reality interventions in anatomy education are diverse (5,6). In the study of Kurul et al. (5) both groups performed a pre- and post-test of anatomy tests. The results of the post-test were significantly higher than the results of the pre-test for both groups ($p < 0.001$), but the difference between the pre- and post-test was significantly higher for the VR group ($p < 0.001$). On the other hand, Stepan et al. (6) did not find differences in the pre, post and retention tests between the intervention and control groups. A recent meta-analysis reviewed 15 RCT studies and indicated that anatomical knowledge was moderately increased by the use of interactive 3D models in VR in education compared to traditional learning methods such as anatomical atlases, PowerPoints, and dissection. There was a small improvement in the test results (SMD = 0.53, $p < 0.01$) (7).

To enhance learning it is important that students are engaged, as engagement has positive correlations with achievement-related outcomes (8). Fredericks et al. (8) created a framework for school engagement, which defines engagement in three ways; behavioral, emotional and cognitive engagement. Behavioral engagement focuses on participation in academic activities (either intra- or extracurricular) and social activities. It's about behavior like effort, concentration and attention. Emotional engagement entails the reactions to teachers and students and the willingness to participate. Lastly, cognitive engagements says something about the investment of the student. When a student shows cognitive engagement, the student is thoughtful and eager to make the necessary effort to master the learning goals. Especially behavioral engagement appears to correlate with achievement.

While Stepan et al. (6) found no differences in learning effect, the VR group found the learning experience to be significantly more engaging, enjoyable and useful ($p<0.01$) and scored significantly higher in motivation ($p<0.01$) than the control group. In a more recent study a comparison was made between traditional education and education with VR and Mixed Reality. A main effect was found for engagement, where VR was evaluated higher than traditional education (4.0 vs 3.4, p=.012). This study also found that students experienced more positive emotions during education with VR than during traditional education (9).

Because of the diverse outcomes on learning effect and lacking studies on the effect of VR on engagement in the light of the framework of Fredricks et al. (10), this study will focus on both. Therefore we sought to answer two research questions: 1) What is the short term learning effect of a virtual reality intervention on

factual knowledge of anatomical structures in students of human movement sciences? And 2) What is the effect of a virtual reality intervention on the engagement of students of Human Movement Sciences?

Methods

Participants

39 participants were included in this study. Participants were recruited from the Bachelor of Human Movement Sciences of the Vrije Universiteit Amsterdam and participated in the course 'Anatomy of the Musculoskeletal System' in the third year of the Bachelor program. All participants completed the first year Functional Anatomy course to ensure approximately the same prior knowledge of the anatomy of the musculoskeletal system. Participants were excluded when diagnosed with epilepsy. No other inclusion or exclusion criteria were applicable. All participants signed an informed consent to participate voluntarily in the research at the start of the course.

Design

The research was carried out during the course 'Anatomy of the musculoskeletal system'. The course consisted of two periods. This study was a randomized control design, conducted twice (period 1 and 2). Students participated either in one period or in both periods, but focused on different regions (upper extremity, lower extremity, core). The duration of one period was six weeks, including the final exam. During the other five weeks, there were three partial exams and six in vivo workgroups. After signing informed consent, participants in period 1 were randomly divided into an experimental group and a control group. The experimental group participated in two VR sessions (linked to partial exams 2 and 3). The control group did not. In addition to the VR sessions, all participants were free to participate in the regular educational sessions of the course.

With the group of students who participated both in periods 1 and 2, a cross-over design was used. Students who were in the experimental group in period 1 were assigned to the control group in period 2, and vice versa. Students who did not participate in the study in period 1 were also allowed to participate in period 2. They were randomly assigned to the experimental or control group. The groups and assignment procedure are summarized in Table 1.

Table 1: Procedure for assigning to groups.

	Experimental		Control	
P1	Students only P1 (random) Students P1 and P2 (random)	(N=10)	Students only P1 (random) Students P1 and P2 (random)	(N=10)
P2	Students only P2 (random) Students P1 and P2 (cross-over)	(N=11)	Students only P2 (random) Students P1 and P2 (cross-over)	(N=10)

Procedure

During each period, two VR sessions were organized (four in total) for the experimental group as an addition to the regular educational activities. The first VR session took place one day before the second partial exam. The second VR session took place one day before the third partial exam. A timeline of the interventions and measurements is shown in Figure 1. The attendance of VR sessions and scores of partial exams 1, 2 and 3 were measurements during the course. After the students completed the course, they had to complete the online questionnaire. The course was repeated with another group of students, following the same structure.

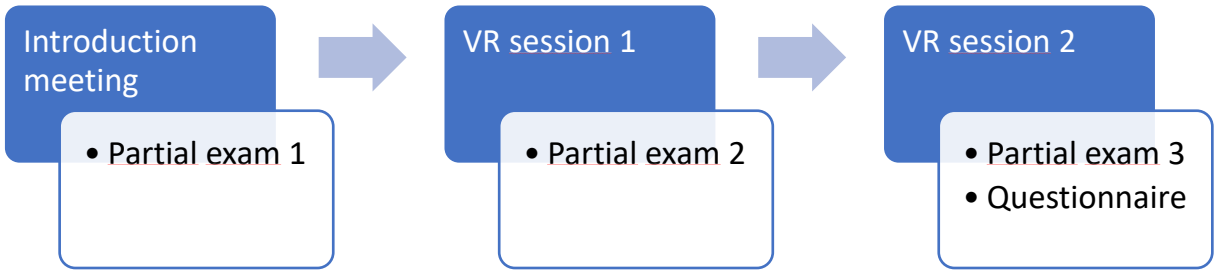

Figure 1: Interventions and timeline measurements.

VR sessions

Every VR session started with a general introduction to the VR headset and the session program. This included the instruction on how to navigate in VR and in 3D Organon and the safety instructions. The rest of the session was filled with assignments that the students performed in groups of two or three. The assignments were created in advance by the teachers and the researcher and focused on the structures tested in the following partial exam. The first part of the sessions was specific to the session, and all sessions ended with the same final assignment. Assignments were designed to stimulate cooperation and communication about anatomical structures in relation to each other. The students alternated to wear the VR headset. The other students read the assignment, compared the answers of the student in VR with anatomical atlases and other sources, and made notes. During the assignments flashcards with anatomical structures were used, so students repeated the same assignments but with different structures. Assignments are included in Appendix 1: Assignments.

Research team and reflexivity

Each session was led by two teachers. One of them was a teacher who also teaches the regular work groups (two teachers alternated each other). The other teacher was the author, involved in other anatomy courses as well. The open ended questions in the online questionnaire were used for qualitative analysis and were anonymously used. The researcher read the questionnaires and analyzed the data with another researcher from Human Movement Sciences. The second researcher was not involved in the VR sessions and was not involved in the earlier phases of the research.

Materials

The VR sessions took place at the Vrije Universiteit Amsterdam. For the VR sessions, twelve Meta Quest 2 headsets (11) were used. 3D Organon was used as an application (4). With this application, it is possible to look at and move around anatomical structures. An anatomical model of the full body is available, as well as models of specific regions. Various functions make it possible to create a specific model, adapted to the requirements of the assignment. For example, it is possible to fade structures, fade surrounding structures, show or remove names of structures, and it is possible to select systems (skeletal, muscular, vascular, etc.). Other functions include, for example, microscopic models of organs, animations of skeletal and muscular actions, and drawing.

To measure the learning effect on factual anatomical knowledge, the scores on the partial exams were used. The partial exams contained a total of ten questions, consisting of multiple choice and short open questions about factual knowledge of anatomical structures (origo, insertion, function, topography, etc.). The list of structures differed per partial exam. The first partial exam was mainly about the skeletal system, the second partial exam was mainly about the muscular system, and the third partial exam was about innervation and vascularity. The first partial exam was used as a pre-test.

To measure the engagement of the students the Multidimensional Scale of Student Engagement in a Higher Education Course was used (12). This scale consists of four dimensions: behavioral, social, emotional-cognitive and agentic engagement. Because this study follows the framework of Fredericks et al. (8) only the questions from the behavioral and emotional-cognitive dimensions were used. Additionally, there was an open ended question about the use of learning material, and two (control group) or eight (experimental group) open ended questions (Appendix 2: questionnaires (in Dutch)) about engagement.

Data Analysis

Both quantitative and qualitative data was retrieved during this study. Quantitative data was retrieved for both learning and engagement and were used for descriptive analysis. Learning effect was defined as the differences in scores on the partial exams between groups. The scores ranged from 1 to 10, with 10 being the highest. Qualitative data was retrieved only on engagement. The questionnaires were conducted digitally in Qualtrics and exported to Excel for data analysis. Table 2 shows an overview of the questions in the questionnaire and the data that comes from these questions.

Table 2: Overview questions and data

Question	Data
MSECC questions about engagement	Quantitative 6 point Likert scale (1 = strongly disagree/6 = strongly agree)
Open-ended questions about engagement	Qualitative written

Learning effect

Due to the small sample size we decided to perform two separate analyses.

- Analysis 1: the mean test scores for all partial exams were analyzed for both the experimental and control groups. All participants who missed one of the partial exams or did not attend to one of the VR workgroups (only for the experimental group) were excluded from this analysis.
- Analysis 2: the effect of the separate VR workgroups on the corresponding partial exam was analyzed. For the calculation of the mean score of partial exam 2 only students from the experimental group who attended VR workgroup 1 were included. For the calculation of the mean score of partial exam 3 only the students who attended VR workgroup 2 were included. Students who did not take the partial exam were excluded from the analysis.

Engagement

The open ended questions of the questionnaire were analyzed using thematic analysis, following the six steps from the paper of Braun and Clarke (13). 1) transcribing and familiarizing with the data, 2) initial coding, 3) searching for themes, 4) reviewing themes, 5) defining and naming themes, 6) producing the report. For coding ATLAS.ti Version 24.1.0.30612 was used. Both researchers familiarized with the data by reading all the transcripts and carried out an inductive preliminary coding scheme. A provisional coding scheme was designed collaboratively by both researchers, after which they coded all questionnaires separately. In the next phase they evaluated and revised the coding scheme. With the new coding scheme, the researchers revisited the original coding together. Eventually, the final themes were constructed collaboratively by both researchers.

All data were anonymously used during the research and are stored on researchdrive, a secure cloud storage. A key document which contains the names combined with the raw data is also stored on research drive with extra encryption. After the research, the data will remain in this storage up to 10 years. All data are only accessible to researchers.

Results

Learning effect

Analysis 1

In total, 29 participants were included (N_{exp} = 14; $N_{control}$ = 15). Figure 2 shows the mean test scores for both groups on the three partial exams. The mean scores are shown to be slightly higher for the experimental group (M_1 = 7.2, SD_1 = 1.3; M_2 = 5.5, SD_2 = 1.5; M_3 = 7.8, SD_3 = 1.2) than for the control group (M_1 = 6.5, SD_1 = 1.6; M_2 = 4.9, SD_2 = 1.8; M_3 = 6.8, SD_3 = 2.1) on the three partial exams.

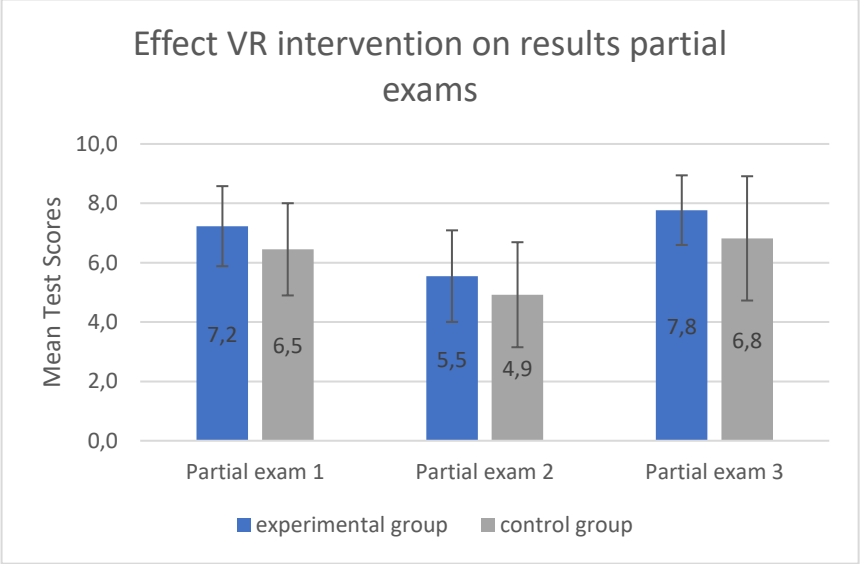

Figure 2: Effect VR intervention on partial exam results

Analysis 2

Figure 3 shows the results of the second analysis. A slightly higher score was observed for students who participated in VR workgroups. Especially for partial exam 3 this trend seems larger, where the mean score for the experimental group is 1.0 points higher (M = 7.8, SD = 1,2) than for the control group (M = 6.8, SD = 2.0).

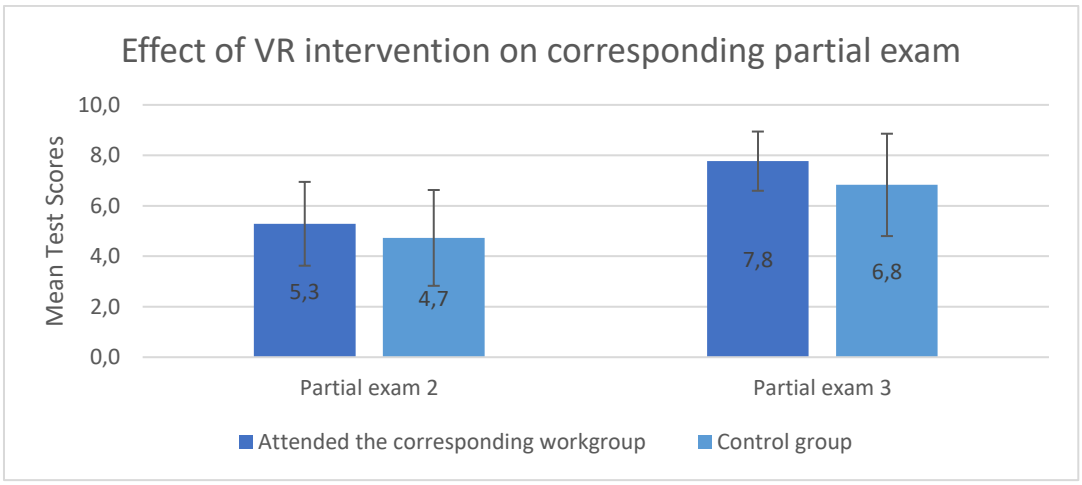

Figure 3: Effect of VR intervention on the result of the corresponding partial exam.

Engagement

16 participants in the experimental group and 11 participants in the control group completed the MSECC questionnaire on engagement. The items and the mean scores are displayed in Table 3. Overall, the scores range from 3.6 to 5.3 on a 6 point Likert scale. The experimental group ranges from 3.8 to 5.3 and the control group from 3.6 to 5.2. Due to a small sample size, no statistical comparisons between the groups were made. Overall a small positive trend for the experimental group is shown in Table 3, but the differences with the control group are very small.

Table 3: Results MSECC. B = behavioral engagement, EC = emotional-cognitive engagement.

Item	Question	Experimental group		Control group	
		Mean	SD	Mean	SD
B1	I paid attention in this course.	5.3	0.6	5.2	0.6
B2	I devoted a lot of time to this course.	5.0	0.6	4.9	0.5
B3	I made an effort to understand the complex notions of this course.	4.9	0.7	4.6	0.5
B4	I really wanted to master the content of this course.	4.9	0.6	4.6	0.5
B5	I gave my best in this course.	4.9	0.7	4.8	0.8
B6	I reviewed my course notes to make sure I had mastered the content.	4.1	1.0	4.3	1.0
EC1	I found ways to make this course relevant to me	4.6	0.7	4.6	0.7
EC2	I was intrigued by the activities in this course.	4.9	0.8	4.5	0.9
EC3	I was interested in this course	5.2	0.8	4.8	0.6
EC4	I enjoyed this course	4.8	0.8	4.7	0.6
EC5	I was looking forward to participating in the activities of this course.	4.8	0.8	4.4	0.7
EC6	I have tried to apply the content of this course to other professional or personal situations.	4.5	0.7	3.9	0.7
EC7	I was keen to explore related subjects during this course.	3.8	0.9	3.6	0.7
EC8	I developed better judgment skills in this course.	3.8	1.0	3.8	0.8
EC9	I felt completely absorbed in the activities of this course.	4.0	1.0	4.1	1.0

Thematic analysis

Table 4 shows the final coding template for the thematic analysis. All codes could contain both positive and negative quotations. In the analysis a distinction was made between the positive and negative quotes.

Table 4: Coding template for analysis.

Theme	Codes	Explanation	Illustrative quote
Social aspects	Interacting with other students	Everything about collaboration or other social interactions	"With virtual reality I found it extra helpful that you could work together and also help each other out."
	Pleasure	Everything about fun, interest or other positive emotions	"I thought it was interesting and fun to do."
Learning strategy	Activating effect VR	The stimulating effect of VR on engagement and learning	"And I also listened to the explanations and did the assignments well."
	Self-study with VR	Everything about VR in in the context of using VR during self-study, without the assignments or teachers.	"I think the working group has added a lot, because of the assignments you start to study the structures in a more targeted way. Without instructions would also have been useful, but I think less efficient."
	Interaction with the VR application	Everything about the user experience of the VR software. For example the interaction with the anatomical model.	"The atlas clearly shows all the information per muscle or structure and many pictures of how everything relates to each other, which is very nice. This is also the case with VR, but then you can also rotate the structures, which helps."

	Comparison VR and other learning materials	How VR compares to the other available learning resources.	"Complete anatomy is also nice, although I think VR works better then."
Learning resources	Diagnostic use	Quotes about VR being used to test students' current knowledge	"For me, the VR sessions felt like a test to see how well I had already learned. Sometimes I already knew things by heart and other times I had to look it up."
	Used as preparation	Quotes about VR being used as a preparation for the other learning activities	"By knowing the anatomy and functions better, the working groups also went better."
	Activating assignments	Quotes about the assignments, apart from VR as a tool	"The working methods ensured that you were time-bound, so there was a good pace."
	Prior knowledge required	Quotes about the prior knowledge needed before successful use of VR	"For the VR sessions, you actually need to know at least the location of the structures, and that helps to get started with the learning material in time."

Table 5 shows the results of the thematic analysis. The prevalence of the quotations is reported by the total number of quotations per code and by how many students the code was mentioned. 14 students in the experimental group completed the questionnaire and were included in the analysis. Quotes are marked as positive or negative regarding the description of the code when relevant.

Table 5: Results thematic analysis.

Themes	**Codes**	**Prevalence**	
		Quotations	*Students*
Social aspects	Interacting with other students	N = 21 Positive: 21	N = 10
	Pleasure	N = 31	N = 14
Learning strategy	Activating effect VR	N = 43 Positive: 39 Negative: 4	N = 14
	Self-study with VR	N = 14 Self-study > VR session: 4 Self-study ≤ VR session: 10	N = 13
	Interaction with the VR application	N = 14 Positive: 14 Negative: 0	N = 11
	Comparison VR and other learning materials	N = 12 VR > other resources: 8 VR ≤ other resources: 4	N = 9
Learning resources	Diagnostic use	N = 22 Positive: 21 Negative: 1	N = 9
	Used as preparation	N = 1	N = 1
	Activating assignments	N = 19 Positive: 19 Negative: 0	N = 10
	Prior knowledge required	N = 4	N = 4

Behavioral Engagement

Behavioral engagement entails behavior like attention, concentration, effort and asking questions (8). Most codes from the results could be accommodated under behavioral engagement. The most illustrative code for this concept is the activating effect of VR (mentioned 43 times, 39 times positively), in which students mention that they asked questions, they listened carefully, and worked attentively. ["The VR sessions made me more engaged. In this active way, it is much nicer to learn than just reading a book."] They were motivated to engage with the learning materials due to VR. ["Yes, my motivation was higher and I enjoyed working on the learning material more. As a result, I have been more engaged with the learning material and have put more time into it."]. Also, the quotes about the interaction with students and the interaction with the VR application show engaging behaviors like consulting, collaborating, and creating overview.

Some observations need to be made. First, the activating effect may not completely do the VR, but could also be influenced by the assignments. The students mentioned that the assignments activated their learning and motivation (n=19). ["Especially the 30 seconds at the end of the lessons, made us fanatical so that we really got to work with the learning material well and passionately, which is very nice to repeat everything."] This observation is strengthened by the mentions that the VR sessions contribute more to their engagement than self-study with VR would (n=9), although they never experienced self-study during the study. ["I think the design of the working group is very useful when using the VR headsets. Personally, I liked to ask for help when I didn't understand something and this helped me a lot."]

Second, it is important to mention that the activating effect of VR could also be due to the possibility to collaborate with other students. Interacting with students was mentioned a lot (n=21) and shows that students really liked sharing the experience, the atmosphere of the VR sessions, collaborating, and learning through explanation. ["By working together and being able to explain things to each other, I feel like I've learned a lot from this."].

Emotional Engagement

The emotional engagement of students is mostly illustrated by the codes pleasure and interaction with students. Emotional engagement refers to affective reactions in class (8). Pleasure was mentioned a lot (n=31) and showed that the students liked to work together, had fun, showed interest and thought that the VR sessions were a relevant way to study for their exams. They mentioned it as a more fun way to learn. ["VR seemed like a fun way to understand and learn the subject matter, so I tried harder to get the best out of it."]. The interaction with other students improved the pleasure during the VR sessions. ["It's also fun to work on it together, which gives more pleasure."].

Cognitive Engagement

Students sometimes preferred VR over other learning materials (n=8), but not always (n=4). VR was mainly compared to 3D models. Where the two were mostly equally appreciated, VR offers more interaction with the anatomical structures (grabbing, turning, etc.) as shown in the code “interaction with the VR application” (n=14). ["The digital models were very useful because you could look at the structures from multiple angles. The great thing about VR was that you could easily view and move the structures."]

Cognitive engagement means that the student is eager to accomplish the learning goals, rather than just trying to pass the exam (8). It was striking to see the multiple mentions of the diagnostic use (and preparatory use) of VR by the students (n=22; n=1). The students really liked the VR sessions because they could prepare for the exam. ["To be honest, I don't really use VR to learn. I'm trying the vr classes to know the structures and origo and insertion, so that this vr moment is still a repeat moment and to test which structures I couldn't pinpoint the location of."] It is important to note that the VR session always took place one day before the exam. Some students mentioned that VR is only useful when you have prior knowledge of anatomical structures, but this was only mentioned 4 times.

Discussion

Learning effect

The first purpose of this study was to gain insight into the effect of virtual reality on learning in an anatomy course of Human Movement Sciences. A small trend was seen for the learning effect, where the test results for the experimental group are slightly higher. These results are similar to the results of previous studies (5–7). Notable is the fact that the test results of the first partial exam were also slightly higher for the experimental group, but no VR sessions were before that exam. This could be due to a selection bias, because the students from the experimental group attended all sessions.

For that reason, the second analysis was performed where the effect of attendance to the corresponding VR session on the test results was measured. Here is also a small trend visible, especially for the third partial exam. An explanation for this difference could be that the students were more familiar with the partial exams and also knew more about the possibilities of VR. The higher test results for the experimental group do not necessarily need to be due to the VR sessions. This could also be explained by the extra opportunity to practice. This is also mentioned by students in the questionnaire, where diagnostic use was a prevalent code.

Engagement

The second purpose of this study was to gain insight into the effect of virtual reality on engagement. Previous studies mentioned small or no differences in learning effect with VR interventions, but the learning experience, among which engagement, was found to be better in these studies (6,9). In this study the engagement was compared between the intervention- and control group, but only a really small trend was visible. A larger sample size is needed to confirm this.

The thematic analysis expressed the experience from students and helped structuring the advantages and disadvantages of virtual reality from a student point of view. While for learning only a small trend is visible, the presence of engagement is promising considering engagement builds on itself once established and could influence learning and achievement in a later stage or in another context (8). Behavioral engagement seems to increase, illustrated by the activating effect of VR. This is a promising outcome given the fact that behavioral engagement is correlated with achievement. But, engagement is a multidimensional construct so emotional and cognitive engagement are also important (8,10). Whether the students were cognitively engaged is questionable, because they mentioned often that they used the VR sessions diagnostically, where cognitive engaged students would show eagerness to complete the learning goals rather than just passing the exam (8). Students were emotionally engaged, but it is not sure if this was fully to be explained by virtual reality. Also the interaction with other students could be of influence.

Strengths and limitations

A strength of this study was the randomized controlled trial design. An advantage of this design was that the students in the control group were also eager to participate, like the students in the intervention group. A limitation was the small sample size. It appeared to be difficult to recruit enough participants to execute this RCT design properly. Because of the small sample size, the results are presented as a descriptive analysis, and this would have been more insightful when letting all students participate in the VR sessions. Especially the response rate of questionnaire of the control group was very low, which made a comparison difficult.

Another limitation is the fact that students from both groups scored higher on the first partial exam than on the second and third partial exam, while the first partial exam was meant act as a pre-test. This was based on the assumption that the three partial exams were equally difficult, but this appeared not to be the case. It could be possible that the first partial exam was easier compared to the other partial exams because of the learning content, which means that this was not a proper pre-test. Students who attended the VR session scored slightly higher on the corresponding partial exam, but this could be biased. When a

student was too sick to attend the VR session, the student was probably also not able to study properly for the exam.

The open ended questions in the questionnaire were designed based on the framework of Fredricks (8). This resulted in answers that could be connected to the three dimensions of engagement, but it did not reveal the underlying reasons for engagement. Interviews or focus groups would have given even more meaningful insights about the engaging effect of virtual reality.

Conclusion & advice

In conclusion a small positive trend is visible in learning and engagement in the VR intervention group compared to the control group, but future research in other courses related to anatomy with more participants should confirm this. Our results suggest that virtual reality seemed to activate students and stimulated their behavioral engagement. Also the emotional engagement was affected positively. Only cognitive engagement was debatable, given the fact that students used the VR sessions to prepare for the exams rather than accomplish the learning objectives. Given the results of the thematic analysis, it would be interesting to further explore the causalities of this behavioral engagement. This study did not yet tell us if the activating effect was due to virtual reality or was partly affected by interaction with peers and collaborative assignments. It would be insightful to explore this by performing interviews or focus groups with students.

This study shows that virtual reality could positively add to certain aspects of engagement and could thereby be a beneficial addition to the course. However, there're also some effects on engagement that should be further explored to be sure if those effects are preferable. Together with the fact that the learning effect is still not evident, virtual reality should not replace educational activities in the course like dissecting or in vivo work groups. It could be a positive addition to the course if the activities are voluntary, the sessions are supervised by teachers and contain activating assignments. That way, it could positively contribute to deeper understanding and better insight in anatomical structures and their functions.

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Appendix 1: Assignments

At the beginning of the session, the students will form groups of two or three. Within the groups, it is necessary that the students study the same region. All subgroups will get a set of flashcards corresponding to their region and the partial exam corresponding to this session. This set of flashcards contains all the structures in the list that students need to know for the partial exam.

To start, students first make a clear division of roles. During the VR session, the roles will be switched multiple times. In the case of a group of two students, roles B and C can be combined.

- Student A: puts on the VR headset and ensures that they have the complete anatomical model in front of them;
- Student B: has an anatomical atlas and uses this to help;
- Student C: has the flashcard jar and makes notes.

First part session 1

This second session focusses mainly on muscles and their functions.

Student C starts the assignment by randomly selecting a flashcard and saying this muscle out loud. Student A and Student B immediately start working on this selected muscle:

- Student A looks up the muscle in the anatomical model. Once this is found, the origin and insertion of the muscle can be found.
    - Tip: information about structures can be found in the right menu.
- Student B looks at the muscle in an anatomical atlas to get an idea of what is seen in the VR headset.
- Student A speaks out loud about the origin and insertion of the selected muscle.
- Student B and C consult with each other to explain the function components of the muscle based on: origin, insertion, and image from anatomical atlas. They pass on the final answer to Person A. Person A checks this using a small menu of the selected muscle.
- Only anatomical language is allowed to be spoken during the assignment.
- Optional: person A can still go to actions and analyze the movements.

First part session 2

This session is about vascularity, innervation, and muscles. Because this is the last session, all other structures have already passed, so these structures will also reoccur. During this first activity, there are two possible assignments. Students can alternate between the two assignments, every time with a new flashcard and different student roles.

1. Student A puts on the VR headset. Student C reads one of the flashcards. Student A searches for this structure and tries to describe the structure as specifically as possible (origo, insertion, the course, other related structures, function). Students B and C try to draw the structure based on this description. Afterwards, they evaluate the drawing, comparing it with an anatomical atlas and VR (student B and C can put on the headset as well).
2. During this assignment, the slicing function in 3D Organon will be used. Student C will read a flashcard and student A will search for this structure using the slicing function. To do this, factual knowledge about this structure is required. Student A and B will have to guide student A. They have with communicate to student A where this structure is to be found. If student A thinks to have found the structure, students B and C will check this by looking at the slicing result in VR.

Final assignment for both sessions

This assignment consists of three rounds. Every round, another student of the subgroup will wear the VR headset.

- Per round, one of the structures on the structure list of the following partial exam will be shown on the PowerPoint per region. One structure for the upper extremity, one structure for the lower extremity, and one for the core.
- The student with the VR headset will grab one of the flashcards and put on the headset. This student has to describe to the other students in the subgroup how this structure is related to the structure in PowerPoint. This must be done in anatomical correct language. For example, this structure is superficial to...
- The other students have to guess the structure. They can use their notes from the previous assignment, but they cannot use their atlas.
- The goal is to guess as many flash cards as possible.

Appendix 2: questionnaires (in Dutch)

Vragen voor beide groepen

MSECC: items B1-B6, EC1-EC9

Q1: Licht hieronder kort toe welke leermiddelen je het meest hebt gebruikt en waarom. Als je overige leermiddelen hebt gebruikt, ook graag hier vermelden.

Q2: Hebben de VR sessies invloed gehad op jouw betrokkenheid/bevlogenheid met de cursus? Licht toe.

Q3: Hoe heb je je tijdens de VR werkgroepen voorbereid op de deeltoets? Geef hierbij voorbeelden. Denk hierbij aan de motivatie die je hebt om te studeren voor de theoretische leerstof, de moeite die je stopt in het studeren en beschrijf je studiestrategieën.

Vragen voor experimentele groep

Q4: Hoe zou je jouw verbale- en non-verbale gedrag in de VR-werkgroepen beschrijven? Geef hierbij voorbeelden. Denk hierbij aan het stellen van vragen, meedoen aan discussies, aandachtig luisteren, etc.

Q5: In hoeverre was je emotioneel betrokken/bevlogen met de VR-werkgroepen? Licht toe en geef voorbeelden. Denk hierbij aan interesse, plezier/verveling, verbondenheid met en relevantie van de leerstof, verbondenheid met studenten en docenten, etc.

Q6: Beschrijf hoe de werkvormen hebben bijgedragen aan jouw waardering van de VR werkgroepen. Zou je de VR werkgroepen even waardevol vinden als je alleen zelfstandig de VR bril had gebruikt, zonder instructies?

Q7: Zijn er nog dingen die je kwijt wil over de VR werkcolleges die niet in de vorige antwoorden naar voren zijn gekomen?

Q8: Wat vind je goed aan de gehele cursus, met betrekking tot het onderwijs gerelateerd aan de deeltoetsen?

Q9: Wat zou je willen aanpassen/verbeteren aan de gehele cursus, met betrekking tot het onderwijs gerelateerd aan de deeltoetsen?