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VIRTUAL REALITY AS A TEACHING AID FOR ANATOMY

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Abstract

Within medical education virtual reality (VR) environments have been used routinely for training and assessing medical skills whereas they remain less developed in other fields where knowledge of human anatomy may also be required. A full understanding of human anatomy requires students to learn many specific terms and typically traditional assessments in this area reward recall over contextual understanding. Therefore, the aim of this study was to determine whether using VR as an immersive learning opportunity could help students to engage with anatomy material and subsequently whether it may impact their achievement in related assessments. Students studying a level 4 (first year undergraduate) anatomy module as part of a Medical Engineering undergraduate degree (N = 42) were recruited to the study. Data collection consisted of a crossover repeated-measures design where students completed an assessment of their knowledge of the skeletal system before and after using the VR platform and before and after studying from a set of written notes in a randomised order. Students also completed a questionnaire regarding their thoughts about the VR task and its part in their learning. Within the VR platform students completed an individual task where they were required to assemble a human skeleton using a controller and starting from the skull. They were given hints and tips throughout if needed and on completion were given a score based on their time to correctly assemble the skeleton and number of hints needed. Results of the study showed that students had a (non-significant, $P = 0.141$) improvement in their learning in the short-term ($10 \pm 15\%$) over text book use alone ($0\% \pm 12\%$). In the longer term those who participated in the study performed significantly better on the end of module examination ($P = 0.012$) suggesting measurable learning gain from the experience more widely. Questionnaire results show that students felt VR belonged in higher education settings (100%) and that it helped their attainment on the end of module exam (71%). The main benefit students saw in using VR for this anatomy material was that it 'gave a clearer visual perception of the bones' (83%). The study concluded that students showed a measurable learning gain using a VR platform and that students want to see more VR in their higher education provision. Universities should consider facilitating VR platforms for appropriate educational material.

Keywords: Virtual Reality, Gamification, Technology Enhanced Learning, Anatomy, Medical Engineering.

1 INTRODUCTION

In human anatomy the body is studied in terms of its structures. While in medical education settings anatomy has been typically taught using dissection [1], in other related disciplines, where a knowledge of human anatomy is also required of students, delivery of the material has been more traditionally lecture based [2]. Students perceive anatomy to be challenging [3] largely due to the volume of specific terminology and content needed to cover the required material. This often leads to students memorising rather than contextualising the material. This is perhaps confounded by the types of assessments typically used to measure students understanding in this field where recall is often rewarded over a deeper understanding. Regardless, surface learning of this important underpinning topic limits transferability for practical application [4]. A number of research studies have investigated various approaches to solving this problem using strategies such as body painting ([4], [5], [6]) and three-dimensional wax models [7] both of which highlight the need for students to understand and visualise anatomical structures three dimensionally. A more recent study in 2014 investigates the use of Augmented Reality for anatomy education where findings showed students had a better "spatial understanding" and overall better test scores than those in a control group [8].

Virtual reality (VR) as a technology has become increasingly popular since its early uses as simulation for both flight and medical training [9]. Immersive VR refers to a VR environment where real-world surroundings are replaced with an artificial environment in which users can suspend reality and fully engage with the created environment, typically this is done using a head mounted display.

The use of VR in an educational setting is growing rapidly, largely due to the increasing availability of lower cost technology and improved internet speeds, however, fully immersive VR remains behind that of desktop systems [10] despite its advantages in terms of active learning and ability to offer both experimental and experiential experiences [11].

The aims of this study were, firstly, to assess the effects of a specifically developed immersive VR platform on student's understanding of the human skeletal system and attainment in a related assessment and secondly, to determine student's opinions on the platform and the use of VR in higher education more widely.

2 METHODOLOGY

2.1 Participants

The study participants were taken from a cohort of 42 first year undergraduate students studying Human Anatomy as a core module on a Medical Engineering degree scheme at a UK University. Study involvement was voluntary and not a summative component of the module. As such, 9 students (21%) chose to take part in the study. All participants provided written informed consent after receiving information about the study and whilst the study was outlined to students during a lecture the module lecturer was not aware as to which students had agreed to participate.

2.2 Study Design

The study was a randomized crossover design where students completed an assessment of their knowledge of skeletal anatomy before and after using the virtual reality platform and before and after studying from a set of written notes in a randomized order. The testing for study took place in week 8 of an 11-week teaching semester where students had covered module content around the skeletal system in weeks 3-5. The module was assessed via an end of module examination which took place approximately 7 weeks after the testing for the study. Following completion of the module participants were asked to complete a questionnaire around their opinions of the VR anatomy platform and their attitudes towards the use of VR in higher education more broadly.

2.3 Procedures

After College Research Ethics Committee approval was granted, the study was outlined to students during a lecture. Participants then attended one single testing session, prior to which they gave written informed consent to participate in the study. On arrival at the testing session all participants completed a baseline multiple choice test to establish their existing knowledge of the human skeletal system. The test consisted of 20 questions (200 maximum score) and participants were not given feedback regarding their responses. Following this, participants were randomly allocated to complete either the VR anatomy platform task or to study from a set of written notes for a 20-minute period. After completing this first task participants were then re-tested using a similar set of multiple choice questions before carrying out the second arm of the trial and repeating the test a final time.

The task assigned to study participants in the VR anatomy platform was to assemble a human skeleton, beginning with the skull, from the series of bones which lay on the floor around them in the virtual environment. The level of detail in the task was commensurate with the detail students were required to know on the module more widely so that some bones were grouped together rather than needing to be individually identified and attached (e.g. bones of the skull, individual vertebrae, carpals, tarsals, phalanges). The task had an element of gamification in that points were awarded for time taken to complete the task (fastest times = highest points) and the number of errors in placement of the bones (incorrect attempts = points deduction).

2.4 Data Analysis

Initially all data was assessed for normality using the Shapiro-Wilk test. Given that all data was normally distributed, pre- mid- and post-trial test scores were analyzed using a One-way Repeated-measures ANOVA. Independent samples T-tests were used to compare performance on the end of module examination between those students who had completed the VR platform and those who had not. Paired samples T-tests were used to compare student's performance on the Anatomy module against their performance on the remaining 5 modules sat during the same semester of teaching. Data

is presented as mean (\pm SD). Significance was set at $P < 0.05$ and all data was analyzed using IBM SPSS Statistics (version 22.0). Open-ended questions about the VR anatomy platform and use of VR in higher education more broadly were analyzed using descriptive statistics.

3 RESULTS

3.1 Short-term Data

Participants took on average 21.2 ± 10.9 minutes to complete the task in the VR platform. One participant failed to complete the VR task in its entirety. Student's performance on the skeletal system quiz after using the VR improved by $10 \pm 15\%$ with a $0 \pm 12\%$ improvement when studying from written notes. However, no statistically significant difference was seen in test scores across the study ($F(2, 15.5) = 2.219, P = 0.141$) (Fig 1.).

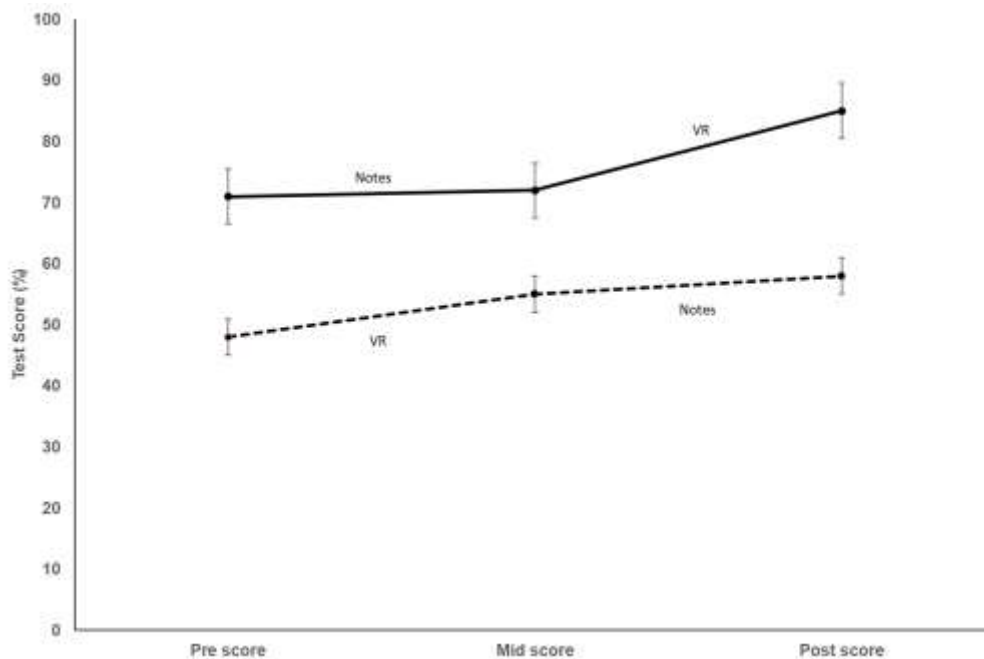


Figure 1: Skeletal system test scores at each time point of the trial. Mean values displayed (\pm SEM)

3.2 Longer-term Data

When comparing end of module examination performance, those who participated in the study and experienced the VR task performed significantly better than those students who did not ($69.1 \pm 7.7\%$ and $52.5 \pm 18.3\%$ respectively, $P = 0.012$). Those who agreed to participate in the study did however perform better on all modules sat during the same semester of study ($69.2 \pm 8.8\%$ and $57.7 \pm 14.4\%$ respectively, $P = 0.028$). When comparing performance on the Anatomy module with broader performance across the other modules studied those who completed the VR task maintained their overall module average on the anatomy module ($-0.16 \pm 10.00\%$, $P = 0.964$), whereas, those who did not complete the VR task performed significantly poorer on the anatomy module than their combined average of the other modules sat ($-5.21 \pm 13.25\%$, $P = 0.031$).

3.3 Questionnaire Data

Table 1. shows the responses given by participants to the questionnaire administered at the end of the module. Responses were positive with 100% of participants ($N=7$) agreeing that virtual reality apps have a place in university education and several responses to open-ended questions asking for more opportunities to carry out such tasks (“I would like to use this often in various modules if possible!”, “The regular use of this”, “I’m happy our course had this opportunity. Would be glad to participate in something like that again :)”).

Table 1: Questionnaire responses (N=7)

| Question | Responses (%) |
|--|--|
| <i>Have you experienced virtual reality apps before?</i> | Yes (0%) No (100%) |
| <i>Do you feel virtual reality apps have a place in your university education?</i> | Yes (100%) No (0%) |
| <i>What (if any) benefit do you think the app had on your learning?</i> | Highlighted areas unsure of (16.7%) Gave a clearer visual perception of the bones (83.3%) |
| <i>Do you feel participating in the virtual reality project has helped your attainment on this module?</i> | Yes (71.4%) No (0%) Don't know (28.6%) |
| <i>Do you have any comments about your experience of using the VR anatomy app?</i> | <p><i>"I'm happy our course had this opportunity. Would be glad to participate in something like that again :)"</i></p> <p><i>"It was interesting and quite fun. It gave a clearer image of how the bones fit together. "</i></p> <p><i>"Needed more bones to learn about"</i></p> <p><i>"It was a good experience however many of the questions that were asked in the test did not relate to what was in the VR"</i></p> <p><i>"I would like to use this often in various modules if possible! "</i></p> |
| <i>What would you like to see done differently?</i> | <p><i>"everything was okay"</i></p> <p><i>"More bones"</i></p> <p><i>"The questions in the online test did not marry up well with the exercise of constructing the skeleton. "</i></p> <p><i>"The regular use of this"</i></p> |
| <i>Are there any other areas of anatomy (or more widely) that you would like to see in VR?</i> | <p><i>"I think it would be interesting to look deeper in systems, for example I'm expecting cardiovascular and respiratory systems being pretty hard. If we would have VR exercise to make content clearer, would be perfect."</i></p> <p><i>"Muscles! urinary system! Digestive system!"</i></p> <p><i>"Yes, maybe the next anatomy module"</i></p> |
| <i>Any other comments or useful feedback you'd like to offer?</i> | <p><i>"thank you :)"</i></p> <p><i>"Great experience!"</i></p> |

4 CONCLUSIONS

The initial aims of this study were to assess the effects of an immersive VR platform on student's understanding of the human skeletal system and attainment in a related assessment and secondly to gauge student's opinions on the platform and the use of VR in higher education more widely. Results

showed that in the short-term 21.2 ± 10.9 minutes of VR resulted in a $10 \pm 15\%$ improvement in test scores immediately following the VR experience. Whilst this was statistically not different to the $0 \pm 12\%$ change seen following 20 minutes of study from a set of notes ($P = 0.141$), an improvement that represents a full grade boundary for most students is not minimal in its potential impact.

In the longer-term (approximately 7-weeks following the VR task) the students who participated in the VR task performed significantly better than students on the same module who had not participated ($P = 0.012$). Initially this seems unsurprising as students self-selected to participate for the study which was additional to scheduled module content and was optional. However, to investigate the long-term impact of the VR task on students' attainment further, students marks on the end of module examination were compared to each individuals average of the other 5 modules they sat during the same semester. As is typically seen in those studying medical engineering, the majority of students performed worse in anatomy than in their other modules ($-5.21 \pm 13.25\%$, $P = 0.031$), however, those who had participated in the VR task were able to maintain a more consistent module mark ($-0.16 \pm 10.00\%$, $P = 0.964$) suggesting a benefit above and beyond them being just the 'better' students. This finding is consistent with those of a 2014 review which concluded that VR based games had a similar effect on student learning whether they were assessed immediately or after the passing of time [10]. One potential explanation for this finding could be related to the spatial understanding required to complete the VR task. It has been suggested that VR learning environments allow learners to acquire knowledge with less cognitive effort than a more traditional learning process [12] and it has been shown that 'games' in VR have the highest level of 'learning outcome gains' over simulations and virtual worlds [10]. The suggested instructional principles promoted by immersive VR [11] map closely to the VR task used in the current study. It has been suggested that when constructivism is applied to VR learning students learn from interaction with artificially real environments, from problem solving to promote creativity, through enhanced motivation and through VR used as a scaffold to their wider learning [11].

In addition to the learning gain, importantly, the secondary aim of the study also revealed positive attitudes from the students towards using VR. Promisingly, 100% of the students agreed that VR applications have a place in higher education. Whilst there are some obvious issues in terms of the practicalities of this i.e. the need for more lecture time, cost implications and technical skill needed for VR development, rolling out VR on a wider scale is rapidly becoming feasible. Higher education institutions risk being left behind the pace of advancing computer-based technologies if VR is not utilised more as an educational tool.

This study was not without its limitations. The primary issue related to the underpowered nature of the data due to under recruitment of students. An initial assumption was made that the majority of the students enrolled on the module ($N = 42$) would opt to participate in the research given that it had potential to help their understanding and had no stakes attached to it in terms of negatively affecting their mark. Secondly, no familiarisation to the VR equipment was offered to the students and 0% reported having used VR prior to the study, consequently there was a significant degree of novelty to the task they were being asked to complete. Extensive research has shown that when a task is perceived as novel there is an improved depth of information processing and increased ability to recall information seen as novel [13]. The extent to which exposure to VR will remain novel for our students is likely to diminish rapidly over the coming years but in a research context the likely impact of this novelty cannot be overlooked.

In conclusion, the main findings of this study were that students showed a measurable learning gain using an immersive VR platform to engage with the assembly of a human skeleton. Promisingly students also valued the experience and want to see more VR in their higher education provision. Universities should consider facilitating the development and use of VR platforms for appropriate educational material.

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