

An Alternative Method for Anatomy Training: Immersive Virtual Reality

Ramazan Kurul,¹ Muhammed Nur Ögün,^{2*} Ayşe Neriman Narin,¹ Şebnem Avcı,¹ Beyza Yazgan³

¹Department of Physical Therapy and Rehabilitation, Faculty of Health Sciences, Bolu Abant İzzet Baysal University, Bolu, Turkey

²Department of Neurology, Faculty of Medicine, Bolu Abant İzzet Baysal University, Bolu, Turkey

³Department of Physical Therapy and Rehabilitation, Faculty of Health Sciences, Gazi University, Ankara, Turkey

The aim of this study was to investigate the effect of immersive three-dimensional (3D) interactive virtual reality (VR) on anatomy training in undergraduate physical therapy students. A total of 72 students were included in the study. The students were randomized into control ($n = 36$) and VR ($n = 36$) group according to the Kolb Learning Style Inventory, sex, and Purdue Spatial Visualization Test Rotations (PSVT-R). Each student completed a pre-intervention and post-intervention test, consisting of 15 multiple-choice questions. There was no significant difference between the two groups in terms of age, sex, Kolb Learning Style Inventory distribution, and the PSVT-R ($P > 0.05$). The post-test scores were significantly higher compared to pre-test scores in both the VR group ($P < 0.001$) and the control group ($P < 0.001$). The difference between the pre-test and post-test results was found to be significantly higher in favor of the VR group ($P < 0.001$). In this study, anatomy training with a 3D immersive VR system was found to be beneficial. These results suggest that VR systems can be used as an alternative method to the conventional anatomy training approach for health students. Anat Sci Educ 0: 1–9. © 2020 American Association for Anatomy.

Key words: gross anatomy education; physical therapy education; undergraduate education; spatial processing; virtual reality

INTRODUCTION

Anatomy training is the basis of health education. Slideshows with two-dimensional (2D) images are often used during anatomy training. The three-dimensional (3D) perception of organs and structures is essential for successful and effective anatomy training. For this purpose, cadavers, synthetic reconstructions, silicon, or plastic models are used (Moro et al., 2017a). The traditional view is that cadaver dissection is the best learning method for anatomy training. Cadaver dissection provides accurate information related to the shape and size of organs, bones, and muscles; however, dissection only provides a deconstructive perspective that reaches to the bone from the skin

(Bogomolova et al., 2020). Complex anatomical structures that are located in deeper layers are difficult for students to imagine and even harder for the students to perceive them. Moreover, students have to study using 2D images due to the limited amount of time they are allotted to work with cadavers and the fact that they work in groups, while working with cadavers (Moro et al., 2017b).

In the study by Melguizo et al. (2020), which was conducted on undergraduate physiotherapy students, it was found that anatomy is essential for physiotherapy education (Melguizo et al., 2020). Physiotherapy students and physiotherapists need to have a thorough knowledge of anatomical structures to understand the normal motions of the body. For this reason, anatomy education is crucial for the effective treatment of patients and for students to become competent physiotherapists (Shead et al., 2016). Various teaching methodologies, such as lectures, dissection, and 2D-3D computer images, are used in anatomy training. Although dissection is the most preferred teaching method, it becomes more challenging for routine use in the educational curriculum due to the ever-increasing number of educational topics (Sugand et al., 2010). In 2011, second-year medical students' understanding of anatomy and their knowledge of anatomy were evaluated, and it was found that the students who performed dissections obtained better results

*Correspondence to: Dr. Muhammed Nur Ögün, Department of Neurology, Faculty of Medicine, Bolu Abant İzzet Baysal University Hospital, 14280, Bolu, Turkey. E-mail: dr.mogun@gmail.com

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(Shead et al., 2016). Visualizing a three-dimensional concept with traditional anatomical teaching is difficult (Peeler et al., 2018). Therefore, using 3D models and simulations increases the perception of functional anatomy and the localization of structures (Serrat et al., 2014). There are studies that suggest cadaver dissection is vital for anatomy learning. According to students, dissection and direct manipulation significantly increase their musculoskeletal knowledge and their knowledge of practical applications compared to passive viewing (Dissabandara et al., 2015; Peeler et al., 2018; Triepels et al., 2018). The term passive viewing is a lecture type that student does not directly contact or experience the structures. Students with low spatial ability require more direct manipulation that provides an opportunity to experience the structures and helps to facilitate learning (Jang et al., 2017).

Computer-based simulations have been used in health education since the 1970s. Thanks to the development of technology, virtual reality (VR) systems have become inexpensive and easily accessible, and they can be integrated into medical education. Virtual reality refers to a combination of a broad range of computer-assisted hardware and software that includes non-immersive and immersive VR experiences (Fealy et al., 2019). Non-immersive VR uses an avatar to represent the user on a screen and this avatar provides interactions with the virtual environment and other users (Irwin and Coutts, 2015). Immersive VR is defined as an environment composed of interactive objects that replaces the user's body as an avatar and tracks positional changes and actions on different planes. The users experience the simulation as they are in the virtual environment, and they receive feedback from the VR, which creates the feeling of immersion. Immersive VR consists of four key aspects (a virtual world, immersion, sensory feedback, and interactivity) and requires either head-mounted devices or rooms that cover the users' field of view (Sherman and Craig, 2018). Immersive 3D VR consoles provide a more realistic view than non-immersive VR consoles. These consoles provide a 360-degree interactive experience and completely isolate the individual from the external environment (Laver et al., 2018). In addition to VR applications, Augmented Reality (AR) and Magic Mirror (MM) technologies can be used in medical and educational fields. Augmented Reality is a system that uses cameras to collect real-world images and combines real-world and 3D images, allowing users to interact with the combined virtual and real environment (Jamali et al., 2015). Magic Mirror is a type of AR that displays the user's mirrored image on a screen with augmented 3D images reflected by the user's body (Kugelman et al., 2018).

As with other quickly developing technology, VR technologies have developed rapidly and have begun to be used as a part of student-centered interactive health education in recent years (Maresky et al., 2019). In anatomy learning, VR applications represent a less expensive and promising alternative to cadaver dissection (Lee and Wong, 2014). There are also studies that suggest a 3D VR environment improves learning, especially among low spatial ability students (Jang, et al., 2017). The effectiveness of mobile-based VR devices in medical education also shows promise; however, due to motion sickness, users usually need to be stationary while using these devices (Moro et al., 2017b). In addition to education, VR systems have been used in therapeutic and diagnostic interventions in the field of medicine (Grantcharov et al., 2004; Gurusamy et al., 2009; Gurpinar et al., 2011). Virtual reality devices have been used in medical education and interventional and surgical procedures in medicine (Burdea and Coiffet, 2003; Grantcharov et al., 2004;

Gutiérrez et al., 2007). While conventional education methods aim to implement visual and auditory learning aspects, during VR training, interactive learning is provided along with practical work. Many educational studies have been conducted with VR because of the combined aspect of interactive learning and practical work of VR learning methods and its possible positive effect on learning skills (Nicholson et al., 2006; Ruiz-Parra et al., 2009). Because 2D atlases and course slides are inadequate in learning about 3D structures and because cadaveric studies are not common or frequent, researchers have focused on more easily accessible 3D learning methods in anatomy (Moro et al., 2017a). Actively interacting with a 3D structure in medical education is vital to understand physical constructs and to gain a sense of confidence and familiarity with the topic (Cooper and Taqueti, 2008). This is particularly important for students in the field of surgery or anatomy (Privett et al., 2010).

The application of immersive VR within undergraduate anatomy education in physiotherapy is mostly unknown and requires ample evidence to be implemented in the curriculum. The present study aimed to investigate the effects of direct manipulative anatomy training with an immersive VR system on undergraduate students' learning compared to lectures.

MATERIALS AND METHODS

Seventy-two students who accepted and fulfilled the inclusion criteria were included in the study. This study was performed in line with the Helsinki Declaration with permission from the ethical committee of Bolu Abant İzzet Baysal University (Clinical Researches Ethics Committee 201799-131). Inclusion criteria were stereoacuity of a Titmus test at 40 arc/s (Momeni-Moghadam et al., 2011) and willingness to participate. The students who had previous VR experience and/or already commenced head and neck region anatomy classes were excluded from the study.

The stereopsis is critical and very important for VR and anatomy training (Wainman et al., 2020). Binocular vision is necessary for 3D vision, which is referred to as stereoacuity and is assessed with a Titmus test. The test is performed with special glasses designed for this purpose, and a booklet is held at 40 cm away directly at eye level (Adams et al., 2009). The booklet contains different sized images overlapping each other, and when observed with glasses, 3D images appear (Birch et al., 2008). The Titmus test was used on all students as a part of the inclusion criteria. Students were asked whether they could see a 3D object in the form of a "yes" or "no" question while wearing the glasses. The test has three subsections, which evaluate low (3,000 arc/sec), medium (1,000-2,000 arc/sec), and high stereoacuity (20-900 arc/sec) with 3D images in the booklet (Clarke and Noel, 1990; Hahn et al., 2010).

In Turkey, undergraduate physiotherapy and rehabilitation students attend anatomy courses for two semesters in their first year. Each semester is 14 weeks long and the students attend a total of five hours of anatomy training each week (three-hour lectures and two hours of laboratory experience). The first semester focuses on bony skeleton, ligaments, tendons, fascia, muscles, vessels, nerves of extremities, and the torso. The second semester focuses on head-neck anatomy, visceral organs, and neuroanatomy. The anatomy lectures are given by anatomy professors in a lecture hall with slideshows and students use the plastic real-sized models of the related structure in laboratories and attend cadaver dissections. Two of the most accepted anatomical atlases are recommended to students to supplement their class materials.

Randomization Procedure

The students were divided into VR ($n = 36$) and control groups ($n = 36$) based on the Kolb Learning Style Inventory (LSI), sex, and the Purdue Spatial Visualization Test: Rotations (PSVT-R) scores with stratified randomization.

Kolb Learning Style Inventory. The Kolb LSI developed by David Kolb in 1976 measures learning to various degrees. According to Kolb, learning styles are divided into four categories: diverger, assimilator, converger, and accommodator (Chen et al., 2005; Kolb and Kolb, 2005). The learning style of each individual is a component of these four basic forms; however, recent reviews show that the Kolb LSI is not supported by well-designed studies, and only a few studies have shown statistically significant results for some subjects (Rohrer and Pashler, 2012). In this study, the Kolb LSI was used as part of the randomization procedure because it has been found that medical students' Kolb scores may change during their medical education (Gurpinar et al., 2011; Bitran et al., 2012; Hu et al., 2018).

The Kolb LSI consists of 12 items with four options. Each item has four sentences that corresponded to one of the four learning styles, such as "I learn best from..." sentence and each ending corresponds to the four learning styles (diverger, assimilator, converger, and accommodator). The students were asked to score the appropriateness of each sentence with a rank order (most suitable sentence as "4," the second suitable as "3," the third suitable as "2," and the least suitable sentence as "1"). Based on the scores given to each option, combined scores were obtained. Responses were aligned to X-Y axes so that the sum of points in each axis represents a score on one of the four categories. In the diagram provided, according to the combined scores, the point at which the two points intersect shows the most appropriate learning style for an individual (Fig. 1).

Purdue spatial visualization test: Rotations. This test is one of the most used mental rotation tests and was used to measure the 3D perception of students in this study. Purdue Spatial Visualization Test: Rotations was developed by Guay in 1977. The test consists of 30 items. The students were told

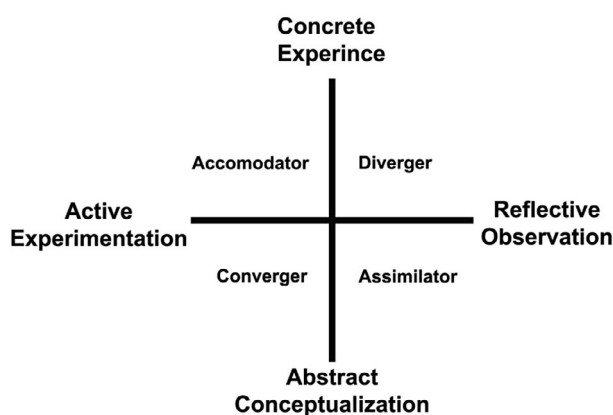


Figure 1.

On the vertical axis, the student either attempts to conceptualize an idea or theory (abstract conceptualization) or perceives experience through a new event (concrete experience). On the horizontal axis, the student can make an experience new and meaningful either by applying it (active experimentation) or reflecting on it (reflective observation). These two axes create four quadrants, each representing the four learning styles as diverger, accommodator, assimilator, converger (based on Kolb and Kolb, 2005).

to study how the object in the top line of each question rotated and select the correct rotation from the five multiple-choice questions (MCQs) by applying the same rotation to the object in the middle line. High scores indicate high spatial perception values (Guay, 1977; Bodner and Guay, 1997).

Sex. Some studies have reported sex differences in scores of Mental Rotation Tests (MRT). The reported difference in spatial perception test scores between males and females resulted from the activation of different brain regions during tests. Due to this reported difference between men and women, sex distribution was taken into consideration during randomization (Voyer and Bryden, 1990; Hugdahl et al., 2006).

Outcome Assessment

A 15-question quiz was given to the students before and after the VR session and lecture. The students were given one minute for each question, a total of 15 minutes to complete the quiz.

Anatomy quiz. A 15 MCQs quiz, including questions about the anatomical structures of the head and neck region, was chosen from the anatomy and palpation lecture's question pool. The quiz was modified with the consideration of Bloom's taxonomy, but the evaluation and synthesis levels were excluded as they cannot be tested with MCQs. The questions were rated by a committee of four professors experienced in the field of head-neck anatomy between 1 and 4 scores (1 = Knowledge, 2 = Comprehension, 3 = Application, and 4 = Analysis). Bloom levels 1-2 are combined as lower-order and 3-4 as higher-order to increase interrater reliability. A total of 15 questions (eight from lower-order and seven from higher-order) were randomly chosen with an internal consistency of interrater reliability $\alpha > 0.7$ (Thompson and O'Loughlin, 2015). Pre and post-tests have consisted of the same questions, and a change in a 20% difference between the pre and post-tests was considered meaningful (Nicholson et al., 2006). The data used for reliability and validity analyses were obtained from a pilot study. The sample of the pilot study did not include the present study.

Likert scale survey. After the VR session, students' perceptions of the VR experience were rated with a five-point Likert scale item. A five-point Likert scale was used to evaluate agreement with "I enjoyed studying anatomy with virtual reality" and "It is easy to understand the location of structures with virtual reality" statements (1 = Strongly disagree to 5 = Strongly agree) (Hu et al., 2009).

Interventions. In this study, 3D Organon Anatomy[®] (Medis Media, Queensland, Australia) was used for anatomy training. Immersive 3D glasses (Oculus Rift[®]; Oculus VR, Irvine, CA) were used for VR training (Fig. 2). The anatomical region used for training was determined as the head and neck region because the second-semester students had not learned about the anatomy of the head and neck region. A presentation was prepared by taking pictures of the region used for training in a VR environment from different angles from superficial muscle groups to deep groups and bone structures. This presentation was approved by a professor with ten years of experience in manual therapy and musculoskeletal palpation. The students were given five minutes to become oriented to the application and the interface. The researcher did not provide any support unless the students experience navigation problems during the application. The evaluations were performed by a third researcher who was blinded to group allocation. The students answered 22 Yes/No questions regarding any adverse effects related to head-mounted devices based on the reference study (Ames et al., 2005).

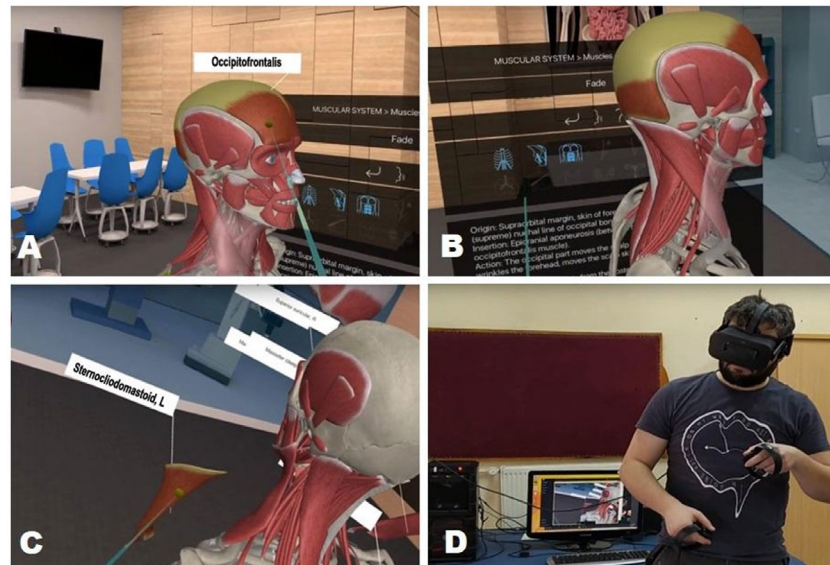


Figure 2.

Using the 3D Organon Anatomy® application for interactive anatomy training. A, Highlighting the occipitofrontalis muscle with the controller; B, Studying highlighted muscle's origin, insertion, function and nerve from the background information text; C, Detaching the sternocleidomastoid muscle and exposing the 3D structure of muscle while revealing the partially hidden underlying muscles to experience a layer-by-layer dissection; D, Third-person perspective of sternocleidomastoid muscle's direct manipulation with head-mounted virtual reality (VR) device and touch controllers.

While the control group attended a 30-minute presentation of images used in VR, the VR group received a head and neck region anatomy training for 30 minutes using a 3D virtual reality device. The students selected the related structure from the information screen and interactively studied the structures. Due to the features of the software, students not only visually examined the layers of the anatomical region but also had the opportunity to read supplementary theoretical information about the structure they viewed on the screen.

Statistical Analysis

All statistical analyses were performed using the SPSS statistical package for Windows, version 20.0 (IBM Inc., Armonk, NY). The chi-square test was used to compare the distribution of sex and the Kolb LSI between the VR and control groups. The Shapiro-Wilk test was used to test for the normal distribution of continuous variables. Normal distribution was observed for age, pre-test and post-test results, and PSVT-R scores in both groups. The paired sample t-test was used for analyzing changes in the pre-test and post-test results for each group. The independent t-test was used to analyze the differences between the

post-test and pre-test scores and to analyze the adverse effects for both groups. The interrater reliability of Bloom's taxonomy was assessed using Krippendorff's alpha due to the dichotomous/nominal nature of classification (Krippendorff, 2003). The content validity of the quiz was assessed by an expert committee and internal consistency was assessed with Cronbach's alpha. The appropriateness of the factor analysis was tested with Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity. A *P*-value of less than 0.05 and $\alpha > 0.07$ was considered statistically significant. To achieve $\alpha < 0.05$ and $\beta = 80\%$, according to Nicholson and colleagues' study, 26 students were required for each group (Nicholson et al., 2006).

RESULTS

Seventy-two students, who met the inclusion criteria, were included in this study. There was no significant difference between the two groups in terms of age, the PSVT-R (Table 1), or sex and Kolb LSI distribution ($P > 0.05$) (Table 2). The students' age was between 18 and 22 years (mean age 19.15 ± 0.79). There were 52 (72.22%) female and 20 (27.78%) male students. The students' PSVT-R scores were normally distributed

Table 1.

Baseline Characteristics of Students in the Virtual Reality and Control Groups

Characteristics	Virtual Reality Group; n = 36 Mean % ($\pm$ SD)	Control Group; n = 36 Mean ($\pm$ SD)	t-test	P-value
Age in years	19.19 ($\pm$ 0.74)	19.11 ($\pm$ 0.85)	0.440	0.661
PSVT- R	14.19 ($\pm$ 4.61)	13.97 ($\pm$ 4.83)	0.200	0.842

PSVT-R, Purdue Spatial Visualization Test Rotations (Minimum score 0 - Maximum score 30); $P < 0.05$.

Table 2.

Distribution of Sex and Kolb Learning Style Inventory styles of Students in the Virtual Reality and Control Groups

Characteristics	Virtual Reality Group; n = 36 N (%)	Control Group; n = 36 N (%)	χ^2 -test	P-value
Sex				
Female	29 (80.6)	23 (63.9)	2.492	0.114
Male	7 (19.4)	13 (36.1)		
Kolb Learning Style Inventory				
Accommodator	3 (8.3)	5 (13.9)	1.567	0.665
Diverger	7 (19.4)	8 (22.2)		
Converger	6 (16.7)	8 (22.2)		
Assimilator	20 (55.6)	15 (41.7)		

χ^2 : chi-square test; Independent samples t-test; $P < 0.05$.

with a mean score of $46.93 \pm 16.53\%$. Also, the students' PSVT-R scores were analyzed for the difference in sex and it was found that there was no significant difference between scores of female ($46.33 \pm 15.3\%$) and male ($48.5 \pm 16.76\%$) students ($P = 0.604$).

The Krippendorff's alpha calculation was used to assess inter-rater reliability. The results of the first four levels of Bloom's Taxonomy achieved good interrater reliability ($\alpha = 0.744$), while dichotomizing levels as "low-order"- "high-order" decreased differences and achieved high interrater reliability ($\alpha = 0.801$). Cronbach's alpha calculation was used to assess internal consistency. The results indicated an acceptable level of internal consistency for the quiz ($\alpha = 0.753$).

Both groups' post-test scores increased compared to the pre-test; however, the VR group showed a significant increase compared to the control group ($P < 0.001$). The VR group scored a mean score of 33.86% and the control group received a mean score of 39.4% from the pre-test. The post-test results for the VR group increased to a mean score of 70.13% , and the control group scores increased to a mean score of 50% . The paired sample t-test results showed that post-test scores were significantly higher compared to pre-test scores in both the VR group ($70.13 \pm 14.73\%$ vs. $33.86 \pm 14.86\%$, $P < 0.001$) and the control group ($50.0 \pm 20.46\%$ vs. $39.6 \pm 14.72\%$, $P < 0.001$).

The post-test results showed an increase of more than 20% in both groups compared to the pre-test results. The pre-test results increased by 107% for the VR group and by 26% for the control group (Table 3). The difference between the pre-test and post-test results was found to be significantly higher in favor of the VR group ($33.26 \pm 22.86\%$ vs. $10.33 \pm 10.13\%$, $P < 0.001$) (Table 4).

The students from the VR group reported significantly more adverse effects than the control group ($P < 0.001$). Although the VR group showed more adverse effects than the control group, there was no significant difference between groups according to the chi-square test, except the concentration difficulty symptom, which was found to be more significant in the control group ($P = 0.047$) (Table 5).

A Pearson correlation was run to determine the relationship between PSVT-R scores and quiz scores of the VR group. There was no statistically significant correlation between PSVT-R scores and quiz scores ($r(34) = -0.23$, $P = 0.896$).

The student perceptions of the VR session group were assessed with a five-point Likert scale. 88.8% of students answered "I agree" or "I strongly agree" to the "I enjoyed studying anatomy with virtual reality" sentence with a mean score of 1.69 ± 0.92 . In addition, 83.3% of students answered, "I agree" or "I strongly agree" to the "It is easy to understand

Table 3.

Comparison of Pre- and Post-Test Results between the Virtual Reality and Control Groups

Groups	Pre-test Mean % ($\pm$ SD)	Post-test Mean % ($\pm$ SD)	t-test	P-value
Virtual Reality Group; n = 36	33.86 ($\pm$ 14.86)	70.13 ($\pm$ 14.73)	-9.511	<0.001
Control Group; n = 36	39.40 ($\pm$ 14.65)	50.00 ($\pm$ 20.46)	-6.139	<0.001
Effect Size	0.388	1.129	-	-

t, paired samples t-test; total number of questions in the quiz = 15; $P < 0.05$.

Table 4.

Independent Sample t-test Result of Mean Differences between the Virtual Reality and Control Groups

Assessment	Virtual Reality Group; n = 36 Mean % ($\pm$ SD)	Control Group; n = 36 Mean % ($\pm$ SD)	t-test	P-value
Quiz	33.26 ($\pm$ 22.86)	10.33 ($\pm$ 10.13)	-6.212	<0.001

t, independent samples t-test;; total number of questions in the quiz n = 15; $P < 0.05$.

the location of structures with virtual reality” sentence with a mean score of 1.83 ± 1.05 . Students’ verbal feedback examples included: “*Being able to handle and inspect structures separately helps me to understand the anatomical structures*” and “*Instead of spending the same time for each structure in the lecture, I can focus on the hard to understand structures and study the related information in-depth.*”

DISCUSSION

In this study, it was found that anatomy training using a 3D immersive VR system improved the test results of first-year undergraduate physical therapy students. This outcome shows a high potential for the effectiveness of immersive VR in the supplementation of anatomical education.

An important feature of VR is the high level of user enjoyment. In a study by Telner et al. (2010), 90.5% of participants self-reportedly agreed or strongly agreed with the statement, “I learn more when I have fun.” Enjoyment is believed to be an essential factor in case-based learning (Telner et al., 2010). Some studies reported that most students have high enjoyment rates while learning anatomy with VR (Vuchkova et al., 2011; Maggio et al., 2012; Moro et al., 2017a). In this study, 88.8% of students agreed or strongly agreed with the enjoyment state, similar to the previously mentioned study. Self-directedness is one of the key ingredients in addition to enjoyment in the success of problem-based learning in medical education (Neville, 2009; Niehorster et al., 2017). In this study, 83.3% of students reported that being able to interact with the structures helped them to understand structures.

In a study by Bairamian et al. (2019), using direct manipulation 3D-printed and VR angiogram, the two models were compared between neurosurgeon trainees, and the post-test results were significantly higher for the VR group than for the 3D-printed model group; however, the depth perception was higher for the 3D-printed model group (Bairamian et al., 2019). A systematic review reported that interactive AR sessions are more effective than passive learning (Akçayır and Akçayır, 2017). In a study by Jang et al. (2017), that was conducted with medical students in the first four years, and it was found that interactive direct manipulation in a 3D VR environment was more effective than passive viewing for learning in anatomy education (Jang et al., 2017). One of the most useful aspects of VR devices is that it allows the user to interact with the environment. The design of the present study, similar to Jang et al.’s (2017) study, allows the participant to interact with and observe anatomical structures. In this study, it was found that the pre-test results of both groups were similar, which supports randomization. Also, both groups’ post-test scores increased significantly. However, the VR group scores increased significantly more than the control group. It is clear that the

VR group achieved a higher degree of learning from the session and this may be caused by the immersive nature of the application or the direct manipulation of structures.

One of the issues that should be considered in studies with VR is the 3D perception of individuals. Individuals with a high perception of 3D benefit the most from VR training that requires 3D perception (Maeda and Yoon, 2013). Women’s perceptual skill working in 3D has been reported to be lower than men in several studies (Peters et al., 1995; Bosco et al., 2004; Maeda and Yoon, 2013; Langlois et al., 2017); however, it was found that they use different parts of their brains for perceptual skills. Therefore, sex was taken into consideration in the randomization. In this study, 3D perception scores of students, measured using the PSVT-R and PSVT-R scores were taken into consideration during the randomization. Thus, the distribution of students’ perceptions of 3D was homogenized with sex and LSI scores.

In a recent study by Maresky et al. (2019), the effect of 3D immersive VR on cardiac anatomy training was investigated and 3D immersive VR was found to be superior to conventional anatomy training methods, which is consistent with results of this study (Maresky et al., 2019). In addition to VR, AR and MM systems are alternative methods used in anatomy education. These are screen-based non-immersive systems that enable users to experience anatomical structures in combination with medical images in relation to their bodies (Chien et al., 2010; Ma et al., 2016; Kugelman et al., 2018). In a study by Bork et al. (2019), in which MM and AR had been integrated into gross anatomy courses and their impacts on student’s learning and perceptions were investigated. The post-test results of the MM group were significantly increased compared to the pre-test results, but no significant difference was found in the AR group. In addition, the group with low MRT scores received more benefits from MM compared to AR (Bork et al., 2019). In a study by Paech et al. (2018), in which both methods were non-immersive, the interactive group achieved a higher post-test result; however, the students’ MRT scores were not taken into consideration (Paech et al., 2018). In this study, there was no correlation between PSVT-R scores and quiz scores. The findings of this study contradict with Bork et al.’s (2019) study (Bork et al., 2019). Therefore, further studies are needed to determine the effects of spatial ability on both AR and VR anatomy training.

In another study investigating the effectiveness of VR tablets and AR training methods were compared and no difference was found between the groups. However, it was found that VR increases the immersion, enjoyment, and engagement of students along with increased adverse effects with the VR usage (Moro et al., 2017b). Other studies have reported cybersickness-related symptoms while using VR

Table 5.

Reports of Adverse Effects in the Virtual Reality and Control groups

Symptoms	Virtual Reality Group; n = 36 N (%)	Control Group; n = 36 N (%)	P-value ^a
General Symptoms			
Fatigue	3 (8.3)	1 (2.8)	0.310
Boredom	1 (2.8)	4 (11.1)	0.169
Drowsiness	2 (5.6)	0 (0.0)	0.156
Headache	1 (2.8)	0 (0.0)	0.321
Sweating	2 (5.6)	0 (0.0)	0.156
Disorientation/Claustrophobia	1 (2.8)	0 (0.0)	0.321
Nausea	2 (5.6)	0 (0.0)	0.156
Dizziness	3 (8.3)	0 (0.0)	0.083
Stomach awareness	3 (8.3)	0 (0.0)	0.083
Exhilaration	2 (5.6)	3 (8.3)	0.649
Concentration difficulty	1 (2.8)	6 (16.7)	0.047 ^b
General discomfort	6 (16.7)	2 (5.6)	0.137
Ocular Symptoms			
Tired eyes	4 (11.1)	3 (8.3)	0.696
Irritated eyes	0 (0.0)	3 (8.3)	0.079
Watery eyes	1 (2.8)	0 (0.0)	0.321
Dry eyes	1 (2.8)	2 (5.6)	0.562
Eyestrain	6 (16.7)	2 (5.6)	0.137
Hot/Burning eyes	1 (2.8)	0 (0.0)	0.321
Blurred vision	3 (8.3)	0 (0.0)	0.079
Difficulty focusing	1 (2.8)	4 (11.1)	0.169
Double vision	3 (8.3)	0 (0.0)	0.079
Vision discomfort	7 (19.4)	2 (5.6)	0.077
Total Symptoms	54 (62.8)	32 (37.2)	<0.001

^aChi-square test; ^bP < 0.05.

(Mosadeghi et al., 2016). It has been reported that experiencing cybersickness has an impact on immersion. Therefore, cybersickness reduces the effectiveness of VR (Servotte et al., 2020). In this study, it was found that the VR group showed more adverse effects, but this was not statistically significant. Adverse effects might have affected students' immersion; therefore, the effectiveness of the session, thus quiz scores, might have been affected.

Limitations of the Study

In the light of Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity results, a higher number of students would further support the findings. The content validity of the quiz was assessed, but validity was not verified with a valid test. The same quiz was applied before and after the session. Therefore, the motivation of students might have affected the results. For

example, positively motivated students might have tried to memorize the questions and they might have focused on these topics during the lecture or using VR.

CONCLUSIONS

Virtual reality systems can be used as an alternative to cadavers for anatomy training for health students. In the present study, it was shown that anatomy training with a 3D immersive VR system might be a suitable alternative to conventional training methods. The VR system, which facilitates learning about the 3D structures of the muscles and the skeletal system, can be a unique and powerful alternative for health science anatomy education. This finding shows great promise for future applications utilizing VR, which are expected to become unique and powerful learning tools within health sciences and medical curricula.

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NOTES ON CONTRIBUTORS

RAMAZAN KURUL, Ph.D., is an assistant professor of physiotherapy in the Department of Physical Therapy and Rehabilitation, Faculty of Health Sciences, University of Bolu Abant İzzet Baysal in Bolu, Turkey. He teaches palpation techniques and manual therapy and has a special interest in virtual reality applications on physiotherapy.

MUHAMMED NUR ÖĞÜN, M.D., Ph.D., is an assistant professor of neurology in the Department of Neurology, School of Medicine, University of Bolu Abant İzzet Baysal in Bolu, Turkey. He teaches anatomy of head and neck to medical students and neurology residents.

AYŞE NERİMAN NARİN, Ph.D., is a professor of intra-curricular education of physiotherapy in the Department of Physical Therapy and Rehabilitation, Faculty of Health Sciences, University of Bolu Abant İzzet Baysal in Bolu, Turkey. She teaches musculoskeletal anatomy and kinesiology of the locomotor system to physiotherapy students.

ŞEBNEM AVCI, Ph.D., is a professor of intra-curricular education of physiotherapy in the Department of Physical Therapy and Rehabilitation Faculty of Health Sciences, University of Bolu Abant İzzet Baysal in Bolu, Turkey. She teaches head anatomy and muscle motor points to physiotherapy students for electrotherapy applications.

BEYZA YAZGAN, M.Sc., is a graduate (Ph.D.) student in the Department of Physical Therapy and Rehabilitation, at Faculty of Health Sciences, University of Gazi in Ankara, Turkey. She is investigating the role of visuospatial capabilities on palpation techniques.

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