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Research Paper

The Perceived Benefit of a 3D Anatomy Application (App) in Anatomy Occupational Therapy Courses

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ABSTRACT
Conventional teaching methods, such as 2-dimensional PowerPoint presentations, are among the most common anatomy teaching tools. However, these methods do not allow depth perception of anatomical structures. Therefore, the purpose of this article is to report the incorporation and student's perception of a 3D anatomy app to an Occupational Therapy class as an enhanced anatomical learning technique. For methods, the Complete 3D Anatomy app was used to teach the upper extremity structures. The students used the Likert scale to answer a survey regarding the different anatomical teaching tools that were integrated into the course. The results indicated that 85% of the students reported the anatomy app was very helpful (85%-39/46), helpful (9%-4/46) or good (2%-1/46) in aiding their comprehension of complex anatomical structures. Similarly, 100% of the students considered the anatomy app to be beneficial. Therefore, we conclude that using the 3D anatomy app was a tool for the comprehensive learning of human anatomy. The selection of the 3D app demonstrates this by graduate students as the second-best teaching tool to learn anatomy. For future courses, we will incorporate and explore the benefits of a personal tablet/iPad with 3D apps for each student, along with a virtual dissection table for the human cadaver laboratory.

INTRODUCTION

Gross anatomy is traditionally learned from textbooks (Hammond, Taylor, & McMenamin, 2003), cadaver dissections (Houser & Kondrashov, 2018), and prosections. During instruction, the most common tool for presentations are screen projections such as PowerPoint presentations; although this method has its advantages, it remains a 2-dimensional surface that is unfavorable for depth perception, anatomical relationships, and clinical applications. Other tools, such as the 3D apps incorporated into the lecture and cadaver laboratory (Chakraborty & Cooperstein, 2018), can aid this issue by creating a tailored view and perspective during both components of the course.

The controversy with learning anatomy through textbooks is the shortcoming to capture depth perception and manipulate structure while seeking smaller structures such as arteries, veins, and nerves. Currently, there are several tools for the enhancement of learning and teaching in anatomy. For example, the incorporation of 3D virtual anatomy apps and anatomical models have generated excitement amongst students (Berkowitz et al., 2014). Studies have revealed that students often prefer the frequent use of innovative tools such as 3D anatomy apps to enhance the understanding of the class (Chakraborty & Cooperstein, 2018) and (Houser & Kondrashov, 2018). Furthermore, investigations demonstrated that the complement of a 3D application increases not exclusively the scholar's perceived benefits but also the comprehension of the anatomy for specialized courses (Ha, & Choi, 2019). The adoption of 3D apps has confirmed to be favorable for specialized programs such as neurovascular surgery (Bairamian, Liu, & Eftekhar, 2019).

Another fundamental obstacle for students is mastering the anatomical relationship of smaller structures in regions such as the head and neck. For this hardship, various professors had embraced the usage of virtual dissection tables successfully. For instance, 3D perspectives tools such as the anatomage table are exceptionally advantageous for manipulating and appreciating the relation and integration of small anatomical structures in the head and neck region (Brucoli et al., 2020). Virtual dissection tables have been shown to support the interpretation and comprehension of anatomy, the relationship between structures and capability to maneuver through the distinct structural layers in specialized occupations such as physicians (Brucoli, 2019) and radiologists (Ward, 2018). Augmented reality (AR) is another helpful accessory for the guidance and understanding of anatomy. AR systems have been demonstrated to be analogous to traditional textbooks for specialized courses such as radiology programs (Bork, 2019) and community college (Duncan-Vaidya, Stevenson, 2020).

There are divergent paths to teach and learn that could be incorporated into anatomy courses. A review by Iwanaga (2020) presented the various strategies to instruct in anatomy, referred to as cadaver dissection and prosection. Authors concluded from their examination that 3D apps, as accurately as other adjunct tools, are beneficial for understanding anatomy. Although there is no arguing for substituting anatomy dissection, applications are favorable, especially when face to face is not possible. Related to

cadaver dissection, 3D apps, and augmented reality has proven to benefit as an extension to cadaver dissection (Uruthiralingam, & Rea, 2020).

The anatomage and AR are accurate and useful tools in teaching anatomy; nevertheless, there are some downfalls worth mentioning. For instance, contrary to the anatomage table, 3-dimensional applications are portable and inexpensive. With the anatomage or AR, the accessibility to these tools will be tied to scheduled course hours rather than when students require further review.

Many of these studies alluded to above are steered on the instruction of anatomy to a more specialized status, such as surgeons, and neglect to engage scholars in earlier stages of their education. In past years we have demonstrated the advantages of additional anatomy instruction tools that have aided student's understanding of anatomy, which would, in turn, encourage students to pursue graduate studies (González-Solá, Hyder, & Rosario, 2019). We believe this type of work, using 3-D applications for a better understanding of anatomy, should be focused on the early stages of students' careers, such as undergraduate degrees and programs that are not expected to have an anatomy cadavers course; however, they are in the health care occupations. In this study, we propose an enhanced learning technique through a multimodal approach using anatomy 3D applications integrated into an Upper Extremity Anatomy course for occupational therapy (OT) students. Therefore, this inquiry aims to report and explore the perception of OT students related to the incorporation of an anatomy application in an upper extremity anatomy course.

METHOD

Participants

Forty-six students enrolled in the Master's in Occupational Therapy program (two males and forty-four females) at Texas Woman's University (TWU) during Summer 2018. The course the graduate students assessed is titled 'Upper Extremity Anatomy for Occupational Therapy" available to the Dallas, Denton and Houston campuses. This is an approved IRB protocol number 20269.

Equipment

As support for the lecture component and models, 3-dimensional animations ("Complete Anatomy" app, on an Apple iPad Pro) of different anatomical upper extremity structures were projected on large screen for students to visualize and improve their understanding of the anatomy content that would be covered during lecture and laboratory, as seen in Figure 1. The app was used to show students real-time muscle movement, insertion & origin, bony surfaces, and landmarks, along with nerve and blood supply of the upper extremities. Additionally, to enhance student comprehension of upper extremity anatomy and involvement, the virtual dissection tools were utilized during lecture as well as while examining on the pre-dissected cadavers.

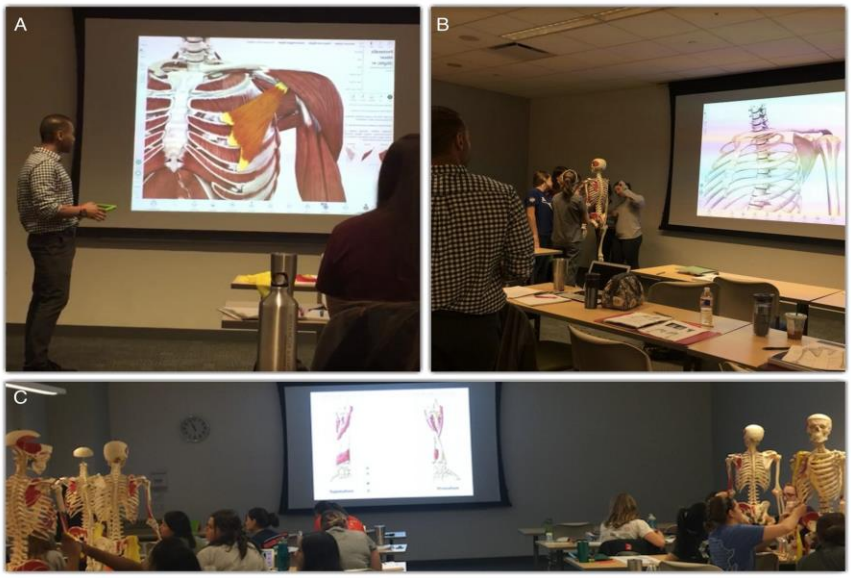

Figure 1. Occupational Therapy Anatomy Class Utilizing 3D Anatomy App. A) Professor explains the pectoralis minor muscle from an anterior view using Apple iPad Pro and 3D Medical App projected on the screen, B) Students finding the thoracic and shoulder skeletal structures shown with Apple iPad and 3D Medical App projected on the screen, and C) Students working with the skeletal models meanwhile the powerpoint shows the forearm's deep muscles.

Human Cadaver Laboratory

The Texas Woman's University School of Physical Therapy has a fully equipped human cadaver laboratory. The OT upper extremity anatomy professor coordinates the lab for the students of the department mentioned above. The human cadaver laboratory has ten cadaver tanks holding ten cadavers which were previously dissected by Physical Therapy students during their anatomy course, taught during the Fall semesters. The cadaver lab coordinator preserves the ten thoroughly dissected specimens to teach courses.

Additionally, the cadaver laboratory is equipped with a large screen projector similar to the lecture room, where the iPad with the 3D app is connected to perform the prosection component of the course.

Course Schedule

The upper extremity OT anatomy course was divided according to the different major joints (shoulder, elbow, wrist), from proximal (shoulder) to distal (hand and wrist) (Table 1). The lecture portion was designed to cover each anatomical region through PowerPoint presentations that were further explained and demonstrated via the 3D perspective (Figure 1). The 3D view of the current region was then open for discussion through questions from the anatomy professor. These reviews had discussions, identification, function, and muscle origins, and insertions that were then asked to be shown within this 3D app tool. Following the discussion for each main joint and their related structures, students participated in prosection in the human cadaver laboratory. Every prosection session was combined with the 3D perspective approach, similar to the lectures.

Table 1. Course Schedule

Day 1	Introduction to class and review of the shoulder and upper arm and surface anatomy Anatomy Lab for shoulder and upper arm Biomechanics and Manual Lab for the shoulder joint Review of elbow anatomy and surface anatomy Anatomy lab for elbow and forearm Biomechanics and Manual lab for elbow joint
Day 2	Review Wrist and Hand anatomy and surface anatomy Anatomy Lab for the Wrist and Hand Biomechanics and Manual lab for the wrist and hand Anatomy lab to review with 3D app and models Practice quiz
Day 3	Anatomy Lab to review with 3D app (lecture room, half of the group) and prosection (cadaver lab, half of the group) Case study presentations Review of manual therapy lab/putting it together Case study presentations Upper quadrant exam with clinical applications in the anatomy lab
Day 4	Review in cadaver lab

Five objectives were designed specifically for this course. These objectives have different levels of difficulty, from identification to integration of structures or topics related to the upper extremity (Table 2).

Table 2. Course Objectives

1. Identify and describe relevant gross anatomical structures of the upper limb.
2. Describe the relationship between normal surface anatomy to underlying musculoskeletal and related neurovascular structures in the upper limb.
3. Palpate the subcutaneous tissue, periarticular tissue, bone, and related neurovascular, neuromuscular, and integumentary structures of the upper limb.
4. Perform selected regional examination procedures and visualize disorders of the upper limb.
5. Integrate anatomical dysfunctions to the clinical manifestations of selected disorders that affect the musculoskeletal system, and related components of the neurovascular and neuromuscular systems.

Survey

Upon course completion, the students were provided the opportunity to voice feedback and their impressions regarding this combined teaching technique (Table 3). The questions were tailored to examine the student's perception of integrating the app into the course via a Likert scale (Albaum, 1997), their preference of the different tools presented during the course, as well as their opinion on integrating this tool in future courses.

Table 3. Student's response to survey and percentage

Question	Options	Responses	Percentage %
1. In a scale of 1-5 (1= not helpful, 5 very helpful) did the ipad-anatomy app help you understand some of the anatomy you saw in the cadaver lab?	1. Very helpful	39/46	85%
	2. Helpful	4/46	9%
	3. Good	1/46	2%
	4. Somewhat helpful	0/30	0%
	5. Not Helpful	0/30	0%
2. From the teaching tools demonstrated in the activity, please choose the ones you liked more:	A. Ipad-Anatomy App	25/46	54%
	B. Hands-on prosection	34/46	74%
	C. Anatomical Models	8/46	18%
	D. Lectures	11/46	24%
3. Do you think the Ipad-Anatomy App is a helpful tool for OT Upper Extremity Course?	A. Yes	46/46	100%
	B. No	0/46	0%

Data analysis

An anonymous survey was distributed through Socrative, an online quiz/test platform, (Socrative, 2019). The data gathered from completed surveys was compiled into an Excel spreadsheet, where descriptive data, averages, and percentages were analyzed by SPSS version 20.

RESULTS

The results demonstrated that 85% of the students reported the anatomy app was very helpful (39/46), whereas, 9% mentioned the 3D app was helpful (4/46) or 2% good (1/46) in aiding their comprehension of complex anatomy structures, as seen in Figure 1. As anticipated, the anatomy app was preferred second to hands-on prosection as a teaching tool. Moreover, 100% of the students considered the anatomy app to be a helpful tool in OT anatomy related courses.

The course schedule and objectives are observed in Appendix 2 and 3. Finally, course 3D app demonstration and study sessions are shown on Appendix 4, as well as sample 3D app anatomical structures for study are included on Figure 2.

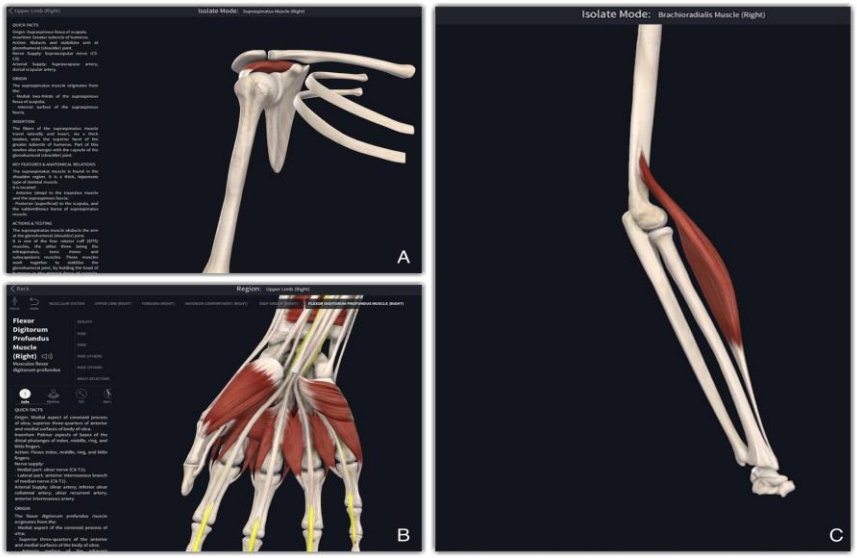

Figure 2. Complete Anatomy 3D app examples. A) Supraspinatus muscle, anterior view (shoulder). B) Flexor digitorum profundus muscle highlighted distally, anterior view (hand). C) Brachioradialis muscle, lateral view (elbow).

DISCUSSION

In the current report, we incorporate a 3D anatomy tool as an adjunct for an upper limb anatomy course. Thus, we collected and presented the perceived benefit and feedback of the students that partake in the course to better understand the view and impressions of said students with this added technology. Based on the responses of the graduate student, the addition of the 3D anatomy application was valuable and a success.

As educators in anatomy courses, we designed the objectives (course objective 2, Table 3) and expect students to describe the relationship between normal surface anatomy to underlying musculoskeletal and related neurovascular structures. However, teachers often encounter several issues while attempting to demonstrate multidimensional anatomical structures with 1-2-dimension tools, such as screen projected PowerPoints during lectures. While attempting to demonstrate depth perception among different anatomical regions, anatomy professors can perceive the apparent disconnect among students between the "flat" projected structures and the actual human cadavers. The primary concern with this is that students in clinical programs will eventually work with people in clinic settings and not the image on a computer screen or book, making it necessary to address this disconnect (Smith et al., 2013).

Therefore, to bridge the gap between the 2D flat structures, the anatomy of human cadavers, and real people in clinical settings, this report delineates the benefits and student perceptions adapting or utilizing anatomy 3D application tools. The 3D app strategy was used as an adjunct to the conventional lecture (PowerPoints) and cadaver prosection sessions during an Upper Extremity Anatomy course for OT students.

The overall results for incorporating the anatomical 3D perspective were positive and in approval of utilizing this approach as a supplement to the upper extremity course. The survey of the 3D app demonstrates graduate students' perspective on inclusion of the app as the second-best teaching technique in learning anatomy (see Table 1) recognizing human cadaver prosection as the most favored selection. Among the students, the integration of the 3D perspective was appropriate in understanding the different structures, depth perception, anatomical relationships and orientation of the upper extremities.

As previously stated, cadaver dissection is a unique and unparalleled experience (Ghosh, 2015). However, anatomy supplements, such as the application mentioned above, are vital in aiding student's comprehension, reducing the gap created by the lecture and 2D images while minimizing the time required in connecting concepts within the lecture and the anatomy lab (Krause et al. 2015). It is important to note that human cadavers often have inconsistencies. By integrating the 3D app with an upper extremity focus into the Institution's gross anatomy course, the future OTs are given the opportunity to study each anatomical structure unambiguously. In providing students with a virtual, 3D image in comparison to a 2D image in every anatomical region (shoulder, elbow and hand/wrist, Appendix 5) of the upper extremity, they are provided an advantage in comprehensively viewing anatomical structures that are not always explicitly observable in cadavers or noticeable in lectures.

Human cadavers are unequivocally irreplaceable (Ghosh, 2015), and the students agreed on the importance of human cadaver prosection above any other teaching approach, so the intent for commissioning the 3D perspective with the app was as an adjunct to cadaver prosection (González-Solá, Hyder & Rosario, 2019). Technology such as this serves as useful educational and learning tools when used in conjunction with existing instructional methods. Similar to this report (Berkowits et al. 2014), students from various academic backgrounds had expressed the utility of having such tools available in their courses and the positive impact on their education, but as an addition, not a substitution.

The 3D perspective allowed students to experience upper extremity gross anatomy with greater depth, which led to higher participation, further informing us that the 3D tool helped in providing a greater understanding of the human body (Brucoli et al. 2018). Even with methodological differences between the present study, Chakraborty and Cooperstein (2018) reported similar findings to ours. An anatomy app embedded into the course enabled a better understanding of anatomical concepts and is of great benefit to the in-depth instruction of graduate students (Raney M, 2014). The OT students reported learning anatomical structures with the 3D upper extremity app have aided them in gaining a more thorough viewing, understanding, and experience in the upper extremity gross anatomy, ultimately increasing the confidence in their knowledge and ability to treat as future OTs. Hence, the students' report of 3D approaches to anatomy should be incorporated into other anatomical/clinically related courses within the OT curriculum.

Following the incorporation of the 3D technology into the upper extremity lecture and lab, there has been a noticeable increase in excitement and motivation to learn anatomy; this can be attributed to the 3D perspective providing students with the "full picture" in a concise manner, as previously reported in similar settings (Berkowitz et al., 2014).

Some examples of student's feedback were: "Thank you so much for allowing me to visualize everything and increase my knowledge even more in the anatomy aspect. I loved all the different tools used and wish we could take this the summer before OT school. It would have helped a lot,", "The iPad anatomy app made it very easy to visualize muscles, nerves, tendons, etc. before taking part in the prosection. It also makes it quick and easy to see everything from various angles,", and finally "I absolutely felt that the iPad [app] anatomy program was beyond helpful and efficient in our learning of the anatomy.". These comments paired with the results were extremely positive and encouraging for us to conclude that the use of 3D anatomy apps are beneficial for the OT students.

CONCLUSION

Since course assessment changed from individual test (Summer 2016) to group test (Summer 2017-18), we were unable to make a quantifiable comparison of Pre and Post 3D app. However, utilizing the 3D app approach has proven to be a substantial accompaniment to traditional instruction methods for OT students since being incorporated into the anatomy lecture and cadaver laboratory (Summer 2017-2018). There are other considerations to include tablets or iPad stations where students can individually locate and review structures necessary to best engage with and visualize the upper extremity anatomy. We also find the interaction

with a virtual dissection table like the anatomage (González-Solá, Hyder & Rosario, 2019) is paramount for students in this program since they have only the opportunity to partake in prosection of the upper extremity.

This study recommends incorporating tools like the 3D anatomy apps into every anatomy related course regardless of the level or major the students are enrolled in. Combining the 3D anatomy apps with conventional teaching strategies (Alsharif et al. 2018; Lewis et al. 2014; Berkowitz et al. 2014) into graduate OT anatomy courses appears to increase participation and success rates for the comprehensive learning of human anatomy.

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