

Augmented Reality for Veterinary self-learning during the pandemic: a holistic study protocol for a remote, randomised, cross-over study

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The objective of the study is to compare a smartphone AR self-learning application with a non-AR smartphone app teaching tool to see which one will more effectively support veterinary students' self-learning. To achieve this, participants will install a mobile application and use it as a self-learning support tool. Feedback will be obtained via a System Usability Scale (SUS) survey in the app at the end. But beyond this common questionnaire, the study will compare the training efficiency and training effectiveness between the AR mode and non-AR mode, exploring the impact on student's learning motivation and knowledge acquisition. This will be achieved by leveraging the remote nature of the experiment by recording the time taken within the application and future results of the participants who are Veterinary medicine undergraduate and postgraduate students from a university in Ireland and a veterinary medical university in UK.

Augmented reality, Veterinary education, Cross-over study, Remote study

1. INTRODUCTION

One of the most important components of veterinary training is to learn the anatomy of the animals. The traditional way of learning anatomy is from the study of animal cadavers. However, with increasing numbers of students and ethical restrictions on the use of animals, alternative methods are needed. Some of the solutions to reduce animal usage were the use of 2D images, books, or videos for veterinary training. In recent years, CT scans and 3D reconstruction brought a more flexible way to obtain anatomy information. Based on the scanned 3D models, the anatomy information could be visualised by students using Virtual Reality (VR) headsets(Xu et al. (2018)) for high immersion experience or by Light Field Displays (LFDs) for collaboration usage (Xu, Pan and Campbell (2020)).

Under the global pandemic situation, face-to-face teaching became hard, and the students had to take online courses and learn by themselves. Although VR could bring realistic experience for self-learning, it is still too costly for every student to have their

own headsets. In order to provide the students with low-cost self-learning experiences, prior research proposed two types of systems that allowed students to learn using their own devices such as PCs, tablets, or smartphones. One type of system register and display the 3D anatomy models in the real world through smartphone phone videos. Another type of system visualised the 3D model on a same position of the screen (referred to as "non-AR systems"). Both these systems are widely used for self-learning in recent years; however, it is still unexplored which system assists students in learning better. Therefore, a study was undertaken to compare the learning effectiveness of non-AR and AR-based mobile vet self-learning applications.

This experiment aims to exam both AR and non-AR applications in knowledge acquisition for the students. Moreover, the study will compare the smartphone AR teaching tool with a non-AR smartphone app teaching tool to see which one performs better and will explore the difference between the AR mode and the traditional application.

In a holistic approach, the participants are informed of the full protocol through the application, and in addition to the traditional questionnaire approach to review an AR application; time of the users' interactions with the application is recorded, thus allowing an overview of their interactions with the application.

2. RELATED WORK

In the past, books and pictures were the most common learning materials with the exception of course of real cadavers. According to the research (Theoret et al. (2007)), these materials were of course easier to access but did not provide the same level of learning outcomes that traditional cadaver-based teaching method could achieve. After VR was utilized for anatomy visualization, researchers compared the learning impact between VR-based learning method, 2D-based materials, and traditional cadaver-based methods. The VR-based visualisation methods are superior for veterinary teaching than the 2D-based materials (Zhao et al. (2011)). Moreover, the VR-based methods can provide a similar learning experience (Codd and Choudhury (2011)) for the students as the cadavers while making the students feel more relaxed (McCool et al. (2020)).

The AR-based learning tools are also known as "hand-held Augmented Reality (AR) applications" because they capture real-world video through students' smartphones or hand-held tablets. The AR application allows the students to place the 3D anatomy model in the real world space, which may bring them substantial engagement (Xu, Kilroy, Mangina and Campbell (2020), Christ et al. (2018)). Non-AR learning tool allows students to interact with 3D models by scaling and rotating them (Xiberta and Boada (2019)), which makes it easier for students to manipulate the 3D models but also produces less immersion.

3. METHODS

3.1. Preparation for Experiment Design

Due to the global pandemic situation, it is not possible to conduct a face-to-face experiment. This remote cross-over study is designed to gather the data safely from the participants and support participants' self-learning processes when studying from home. A device statement checking form (Table 1) was sent out to collect device capabilities and participation willingness information to guarantee the

¹https://developers.google.com/ar/discover/supported-devices#google_play

Questions	Options	n
Are you willing to participate in this remote experiment?	Yes	13 (76.5%)
	No	1 (5.9%)
	Maybe	3 (17.6%)
Do you have access to a smartphone?	Android	4 (23.5%)
	iOS	13 (76.5%)
	Both	0 (0.0%)
	No	0 (0.0%)
If so, please provide your phone's manufacturer and model. (e.g. iPhone 8)	N/A	N/A
Is your smartphone on the list? ¹	Yes	16 (94.1%)
	No	1 (5.9%)

Table 1: Device Statement Checking Questionnaire

study is well designed and easily delivered to all the potential participants. Because the remote data collection process would not collect any respondent's personal data, exemption from full ethical review was granted on February 11, 2021 by the Office of Research Ethics with the Research Ethics Exemption Reference Number (REERN): LS-E-21-28-Kilroy.

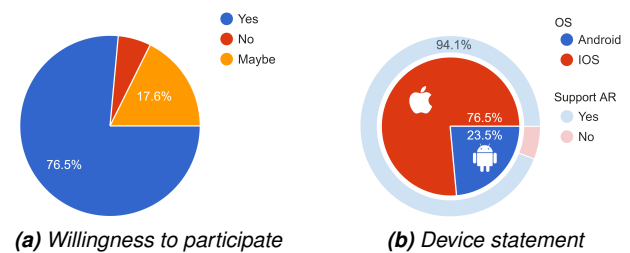


Figure 1: Result of responses

A google form requesting details of access to AR-compatible devices was sent out on February 19, 2021, to undergraduate and graduate veterinary students. The last response was handed in on March 1, 2021. During this period, the research group received 17 responses in total. The results are shown in Figure 1. Over three-quarters of the students are willing to participate in this remote experiment (Figure 1a), indicating that students are interested in trying out the AR app generally. Over three-quarters of the students hold iOS smartphones, while the rest have access to Android

smartphones. Only 5.9% of respondent's devices cannot support AR (Figure 1b).

These results indicate that most mobile devices have the capacity to run the AR algorithm. However, as multiple platforms devices would be involved, the study needs a solution supporting cross-platforms to maximise the participating opportunities. Eventually, the research group decided to implement the AR function by using AR Foundation package², which enables multi-platform deployment (ARCore³ for android devices and ARKit⁴ for iOS devices) in the Unity Engine.

The experiment invitation will be sent out to not only UCD but also Royal Veterinary College, London, UK, so that the study is expecting more than 17 participants.

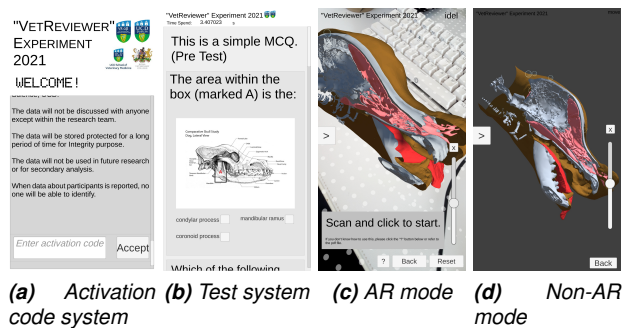


Figure 2: App User Interfaces

3.2. Software Implementation

3.2.1. System Overview

An app was developed to support students' self-learning processes under the pandemic crisis. Participants will be able to check the 3D canine model generated from a CT scan and acquire knowledge from labelled segmentation. The model generation process follows the workflow in Xu et al. (2018)'s research. The installation package can be accessed on Apple Store and Google Play Store after being reviewed officially as open testing. This method provides a safer environment for the participants' devices to test. The app has the following features:

- Activation code system. (Figure 2a)
- Teaching system. (Figure 2c and 2d)
- Embedded test & questionnaire. (Figure 2b)
- Usage tracking system.

²<https://docs.unity3d.com/Packages/com.unity.xr.arfoundation@4.2/manual/>

³<https://developers.google.com/ar>

⁴<https://developer.apple.com/augmented-reality/>

The information sheet is displayed for the participant after they launch the app. Each participant will be assigned a unique activation code for enrollment. As the software is published on the application store for open testing, other passersby can also download the app to their devices. The activation system (Figure 2a) will prevent the user who has no relevant background knowledge from enrolling in the study to ensure the data are valid for future analysis.

The test system (Figure 2b) handles the pre-test, two post-tests and questionnaire during the experiment. It will randomly select ten questions from the question bank (12 anatomy questions, four physiology questions, and two embryology questions) with shuffled choices for each test. Once the participant submits the result, the data will be sent to a spreadsheet through the internet.

The teaching system (Figure 2c) allows the user to explore the bony structure of a canine head by rotating it, zooming it, and moving it. The user can slice the virtual 3D model in three different directions or tap on the highlighted area to see a detailed description. Moreover, the model can be switched from the whole head to the skull for more specific information. The usage tracking system will record the time used in each mode and test. The time data will be stored locally on the device and submitted at the end of the experiment. The system will not store the specific timestamp for the individual user. It will only store the sum-up of the time to avoid infringing the user's personal data.

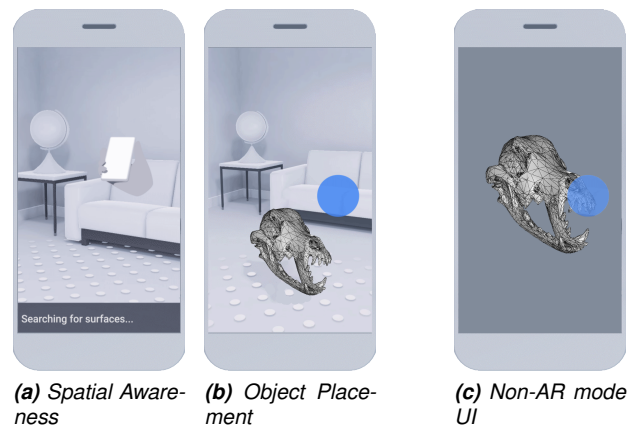


Figure 3: (a)(b)In AR mode, user needs to rotate the device to search for surfaces; then, place the virtual object on the detected surface for manipulation. (c) In non-AR mode, user can directly manipulate the virtual object.

3.2.2. AR mode

In addition to those features, the AR mode will enable the plane detection function to place the model on a physical reference, and the user can observe it from different angles (Figure 3a, 3b). Compared to

the traditional mobile app, AR has the potential to better support the learning process by enhancing the presence of the virtual object and by precise control of the view perspective.

3.2.3. Non AR mode

The non-AR mode carries over all the functions, including the activation code system, teaching system, embedded test and questionnaire system, and usage tracking system, from the AR mode (Figure 2d, 3c), being the control to the AR mode. In other words, the non-AR mode will only cut down the AR feature, in which a user cannot change the virtual camera's position by moving the device and feel the presence of the virtual model to the physical environment.

3.3. Study Setting

This is a randomised, 2-way cross-over study protocol. This study will be conducted remotely by using students' mobile devices.

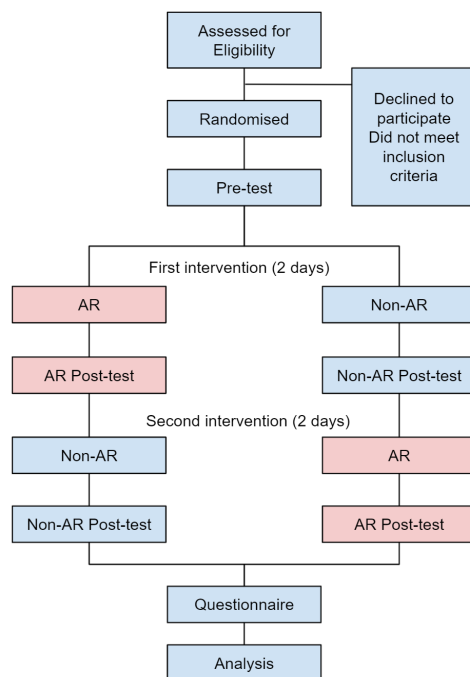


Figure 4: Enrollment, Randomization, and Retention of Study Participants

The study consists of two intervention periods of two days with no washout period (Figure 4). The study's objective is to compare the training efficiency and training effectiveness between the AR mode and non-AR mode, exploring the impact on student's learning motivation and knowledge acquisition.

The hypothesis is shown in Table 2.

This protocol has been reviewed and approved by a recognised ethics review board at UCD. The Office of

Research Ethics accepted the exemption from a full ethical review with the Research Ethics Exemption Reference Number (REERN): LS-E-21-28-Kilroy.

3.3.1. Primary Outcomes

Regarding the learning efficiency and effectiveness, this study will determine whether the mobile application can support students' self-learning processes during the pandemic based on pre-test and post-test results (Score and time). Moreover, this study will compare the AR mode and non-AR mode's post-test scores and times in order to evaluate the AR feature in supporting self-learning.

The System Usability Scale (SUS) survey (Brooke (1996)) will assess the usability of both AR mode and non-AR mode, determining which mode is easier to use. This study will also observe the user's preference toward different modes.

3.3.2. Secondary Outcomes

A standard questionnaire gathering user's gender, age, study year, current tablet AR experience, AR and non-AR preference, and feedback will be sent out along with the SUS survey.

The usage time will be recorded for further analysis. The AR mode will need extra time to set up before the model is generated. The users will need to learn how to use the AR mode. Because of this, the longer usage time cannot represent the user's preference. However, if the AR usage time is shorter than the non-AR, it is reasonable to say that the user would prefer to spend more time on the non-AR mode. However, the preference should be interpreted by combining the time used and the questionnaire result.

3.4. Randomisation and Blinding

The system generates activation codes for the enrollment process. The participant will be randomly assigned to one study group according to the activation code. The exact number of codes for two study groups will be shuffled using the spreadsheet's randomised algorithm and then sent to two researchers. The researchers will assign the code to every potential participant; thus, the group assignment will be fully blinded to the research group.

3.5. Participants

Participants will be asked to finish a pre-test for the investigator to establish a knowledge baseline. The questions for the pre-test will be randomly generated from the question bank. Then participants will use either the AR version or non-AR version for two days; by the end of this period, they will be asked to complete a series of questions randomly generated

	Null (H0) Hypothesis	Alternative (Ha) Hypothesis
Usability	There is no significant difference in SUS survey result between AR and non-AR mode.	The AR mode is more usable.
Knowledge gain	There is no significant difference in quiz result between AR and non-AR mode.	The AR mode helps participant have better knowledge gain.
Preference	There is no significant difference in preference between AR and non-AR mode.	The AR mode is more favoured by the students.
Usage time	There is no significant difference in usage time between AR and non-AR mode.	The AR mode is used longer.

Table 2: Research hypothesis

from the question bank. After this, they will cross over to use the alternative intervention for another two days. At the end of the experiment, they will complete a series of questions randomly generated from the question bank and complete a SUS survey and a standard questionnaire.

3.5.1. Inclusion Criteria

Participants, regardless of gender, at least 18 years of age and enrolled in the Veterinary Medicine undergraduate or postgraduate programme will be included.

3.5.2. Exclusion Criteria

Participants will be excluded if they had a history of severe motion sickness when using a smartphone display or other displays; or a disability preventing the use of a smartphone through screen touch.

3.6. Statistical Analysis

Simple descriptive statistics are presented using the SUS survey by the end of the experiment, targeting usability. A Student's t-test will be performed to compare subjects' backgrounds between two groups. If the data are normally distributed, the T-test will be used to compare the difference between participants using AR mode and non-AR mode, with the pre and post-test score, time spent as factors individually; if not, the Wilcoxon signed-rank test comparing score between AR and non-AR post test score. A crossover analysis with participants as a random effect and mode and phase time as fixed effects will be performed. A p value of < 0.05 was considered statistically significant and accuracy in score reported in whole numbers.

4. DISCUSSION

Like all other practical subjects, veterinary anatomy relies on the use of animal cadavers for teaching

students. Due to the pandemic situation, there is little chance for students to partake in practical classes and have hands-on experience. Thus, the learning materials that students can refer to during the self-learning process are mainly books, websites and smartphone Apps. Although the mobile app has been a self-teaching support tool since the smartphone becomes ubiquitous, it might occupy an essential role in the future with the development of mobile AR. Previous research has found that, although the mobile AR is not as immersive as the mobile VR headset, it is much more portable and easily obtained (Xu, Kilroy, Mangina and Campbell (2020)). These advantages make the smartphone AR application a natural platform for students to obtain knowledge at home during the pandemic.

The study design enables a close-to-reality condition for the experiment. Unlike the traditional face-to-face experiment, this remote design simulates the actual usage scenario: download the app from the app store; use the app anytime, anywhere without limitations. The results of this experiment will reflect the impact on students of the mobile app and how it can support remote teaching and the self-learning process.

This cross-over study has some limitations:

- The two groups of activation codes are shuffled together by a random algorithm in a spreadsheet and assigned to each potential participants. The study cannot guarantee that group A and group B are an exact 1:1 ratio because not all potential participants will enrol.
- Although the features are the same between the two modes, the AR mode will take up more time to set up than the non-AR mode. For most users, the AR mode needs more learning cost as the operations are not commonly used. Because of this, it is hard to conclude whether

the longer usage time indicates the user's preference.

- The study length is not long enough to conclude what role the AR mobile app would occupy during the whole trimester.

To sum up, this study will take a holistic approach to evaluation to explore whether the mobile application can support student's self-learning processes during the pandemic. In addition, this study will compare the training efficiency and training effectiveness between the AR mode and non-AR mode, exploring the advantages and downside of applying AR features to the learning tool. Furthermore, the student's preference, opinions, and time taken within the application will be gathered to estimate the mobile app's impact on student's learning motivation. The protocol aims to allow this remote experiment to be conducted, but the research group is aware of the feedback loop of providing new learning tools, which may be excellent. However to tease out and gauge their impact can be difficult and the research group hopes this more holistic approach will do the work justice. As mentioned in Mitroff and Blankenship (1973) "The most interesting systems are those where the elements are purposefully designed to be nonseparable", but by examining the time that each student interacts with the application in combination to the standard questionnaires, the research group hopes to gain a unique insight into the potential role of AR learning applications in the classroom.

5. FUNDING

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