Research in Learning Technology
Vol. 30, 2022

ORIGINAL RESEARCH ARTICLE

Providing dementia education with augmented reality: a health sciences and medicine feasibility pilot study

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(Received: 17 September 2021; Revised: 7 February 2022; Accepted: 1 March 2022; Published:2 May 2022)

Understanding the key physiology and anatomy of the brain, and the mechanisms underlying dementia, represents essential components within a medical curriculum. This study assessed the implementation feasibility of an augmented reality (AR) three-dimensional (3D) brain visualisation learning mode and the knowledge improvements in medical students when compared to a text-based pamphlet. The pamphlet group learnt from a double-sided information pamphlet, while the AR group used an AR app. In AR, participants held a cube in front of the camera on the tablet, rendered on-screen as a 3D brain model, and received a narrated lesson containing the same information as the pamphlet verbatim. Both resources were also evaluated for perceived usefulness via pre-post tests and written survey. A total of 24 students participated in the study. A significant overall difference in knowledge scores (p < 0.001) was found for all participants but without significant differences between groups. Prior education was a significant covariate for pre-post change (p = 0.016) across all participants but had no impact on group outcomes. Positive feedback was received on both resources where the majority perceived them as easy to use, enjoyable, and helped develop their knowledge of dementia. Both the text-based pamphlet and AR delivery modes improved knowledge, although neither was significantly superior to the other. However, the AR lesson was perceived highly for learning, and has the potential for implementation within a medical programme.

Keywords: dementia; neurological disorders; augmented reality; medical education; technology-enhanced teaching

Introduction

There are over 46 million people living with dementia worldwide (Wimo *et al.* 2015). It is estimated that 472 000 Australians currently have dementia, with the prevalence expected to increase to over a million by 2058 (Dementia Australia 2018). Dementia is not only the second leading cause of death of Australians (Australian Bureau of Statistics 2018) but also the single greatest cause of disability for older Australians aged 65 years or older, and the third overall leading cause of disability burden (Australian Institute of Health and Welfare 2012).

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Citation: Research in Learning Technology 2022, **30**: 2668 - http://dx.doi.org/10.25304/rlt.v30.2668
(page number not for citation purpose)

Dementia education sits within one of the seven cross-cutting principles within the World Health Organisation's global action plan on the public health response to dementia (World Health Organisation 2017). Dementia education, which includes information about the physiology and anatomy of the brain, as well as the mechanisms underlying dementia, is a vital component of dementia diagnosis, care, and management. Knowledge deficiencies of dementia among health professionals, including doctors and medical students, are common (Annear 2020; Nagle, Usita, and Edland 2013). Generally, in medical curriculum, dementia is taught amongst subjects or units covering other neurodegenerative diseases, or as part of geriatric blocks of content. The physiology and anatomical presentations of diseases such as dementia are presented to medical students as two-dimensional (2D) photographs, images, or illustrations within a textbook or a slide presentation. There is an identified need for enhanced education within the dementia workforce, including but not limited to doctors and medical students (Surr *et al.* 2017). As such, research into effective educational interventions remains an important addition to the global response to the growing rates and prevalence of dementia. There is therefore an urgent need to develop new means of providing dementia education to health professionals, including doctors and medical students, in a way that is easily accessible and effective (Jones, Jones, and Moro 2021).

One technological advance that may assist in addressing this need is *augmented reality* (AR). AR is the use of a computer tablet or smart phone with a camera to view items in the real world as a digital model. The person using the tablet or smart phone is then able to interact with both the digital model and the real-world item (Moro *et al.* 2017). Research has shown that AR can be effective in medical education (Moro *et al.* 2021). In physiology education, AR has been shown to benefit learning by increasing engagement and immersing the learner in the experience (Moro, Smith, and Finch 2021) and increasing knowledge gain (Albrecht *et al.* 2013). However, it is unknown whether this process can be used to improve the effectiveness and accessibility of dementia education for medical students.

This project will explore whether AR can be incorporated into education to enhance the knowledge of medical students regarding dementia. Currently, disorders such as dementia are commonly taught in didactic style lectures using 2D illustrations. However, utilising the additional interactivity and 3D viewing that AR allows, it is hypothesised that this new mode of learning is feasible for implementation and may be more effective than traditional methods. The expected result is that users will display improved knowledge of dementia after undertaking the lesson, and be more informed about the mechanisms underlying dementia, such as the key anatomy and physiology changes occurring within the brain.

Methods

Study aim

The aim of this study is to determine the feasibility of using a 3D brain visualisation using AR technology to enhance medical students' knowledge of key components regarding the physiology and anatomy of the brain, and its relationship with the mechanisms underlying dementia. This small-scale study is intended to test the feasibility of methods and procedures to guide future larger scale research, as well as to investigate for possible effects that warrant follow-up in a subsequent study.

Study design

An adapted version of the Bowen Feasibility Framework (Bowen *et al.* 2009) was used to ascertain the acceptability, efficacy, as well as implementation and practicality of the 3D brain visualisation using AR technology. This was accomplished via a pilot two-group randomised controlled trial (RCT). The study received ethics approval from the Bond University Human Research Ethics Committee (reference number: CM03400) and took place on the university campus.

Participants & recruitment

Utilising a convenience sampling, students in their second year of the medical programme at Bond University (Queensland, Australia) were recruited for this study. These students had not completed any formal lessons or training regarding the underlying science, or clinical management, of dementia. Participation was voluntary, with recruitment occurring during lectures and via an online course site. Participants were provided an information sheet describing about, but not limited to, the background and aim of the study as well as the participation criteria involved. Volunteers were asked to sign an informed consent form prior to commencement. Participants were then emailed details of the day, time, and location where the study would take place. On the day of the study, further recruitment was carried out at the end of a laboratory session by an open walk-in invitation to students who were interested to participate in the study.

Interventions

The control group received an educational pamphlet on the key anatomy and physiology of the brain, and the mechanisms underlying dementia, that was developed by the research team, with proofreading undertaken by a volunteer medical student. The pamphlet provided a brief overview of the major structures of the brain, including images and descriptions of the four main lobes of the brain cerebrum as well as the cerebellum, brainstem, limbic system, and diencephalon. Information about dementia, with a focus on Alzheimer's disease (AD), was provided, detailing both the microscopic and macroscopic changes seen in the brain of a person living with AD and its progression over time, as well as how it affects daily activities of living.

The AR group was introduced to an application (app), downloadable onto a mobile device such as a tablet, that was created by the research team where the educational pamphlet content was audio narrated verbatim alongside a 3D brain visualisation using AR technology. A user can view the brain in 3D by holding a 3D printed cube in front of the camera on the tablet. The cube is transformed into a digital 3D image of the brain on the tablet's screen that could be viewed from different angles by rotating the cube as the user desired. By touching different parts of the brain on the tablet's screen, associated information such as labels, narrated audio content, and further brain dissection revealing the innermost structures are presented to the user. The use of the app was initially tested by a volunteer medical student and faculty staff to identify and troubleshoot any technical issues.

Procedures

The study took place on-site at Bond University in a pre-booked room. Participants were randomly allocated to either the pamphlet or AR group via a computer-generated list. Participants in the pamphlet group sat in a section of the room different from those in the AR group. All participants were asked to complete a pre-intervention questionnaire that sought their demographic information (e.g. age, gender, and prior dementia-related training and/or education) and existing knowledge regarding the anatomy and physiology of the brain, and dementia. Following this, participants, depending on their group allocation, were either provided the educational pamphlet to read or experienced the 3D brain visualisation using an AR app via a tablet. Post intervention, participants were once again asked to complete the same questionnaire that sought their knowledge about the anatomy and physiology of the brain, and dementia, as well as their feedback about the usefulness of, and experience in, using the learning resource together with suggestions for improvements to either the educational pamphlet or 3D brain visualisation using AR technology. Although no time restriction was imposed, participation in the study was anticipated to take each student approximately 30 min to complete where all received a copy of the educational pamphlet and chocolates as a token of appreciation at the end of their participation.

Outcome measures

Participants' knowledge regarding the anatomy and physiology of the brain and dementia was assessed using 15 multiple choice questions (MCQs) developed by the research team. These MCQs focused on typical neuroanatomy as well as neurological changes and corresponding signs and symptoms of AD along with impacts on daily activities of living. Each question is worth 1 mark, with a total score of 15 and a higher total score indicative of better knowledge of the respondent. Five evaluation questions using a five-point Likert response scale ranging from strongly agree to strongly disagree and three open text questions were used to ascertain users' perceived usefulness of, and experience in, using the learning resource together with suggestions for improvements for either the educational pamphlet or 3D brain visualisation using AR technology. Participants in the AR group were asked an additional two evaluation questions specific to the AR technology. These questions were initially tested by the volunteer medical student to examine difficulty and relevancy to the learning resource as well as proofread to identify errors for correction.

A record of technical difficulties (i.e. type and frequency) in using the learning resource app and the steps taken to address them, if any, was kept. Also, observation notes on issues that may have impacted the intervention and influenced the experience of participants were recorded.

Data analysis

Analysis of collected data was performed using IBM SPSS Statistics for Windows Version 24.0 (Armonk, NY: IBM Corp.). Besides descriptive statistics, *t*-test and Chi-square analyses were conducted to compare between the two groups at baselines for continuous and categorical demographic variables, respectively. Repeated measures analysis of variance (ANOVA) was performed to determine the change in mean

Citation: Research in Learning Technology 2022, **30**: 2668 - http://dx.doi.org/10.25304/rlt.v30.2668

knowledge scores pre- and post-intervention between the two groups, with a significant alpha level set at $p < 0.05$. Lastly, a narrative synthesis of the responses received for the three open text evaluation questions was undertaken.

Results

Participant demographics

A total of 27 second-year medical students, out of a cohort size of 135 (i.e. recruitment rate of 20%), signed up and consented to partake in the study. Of these, 24 students took part in the study (i.e. attendance rate of 88.9%), with 12 students in each group (i.e. pamphlet and AR). No reasons were provided by the three students who did not attend the study.

The age of the participants ranged from 18 to 41 years (M = 21.75; standard deviation [SD] = 5.32), with 14 females (58.3%) and 10 males (41.7%). Except for two, most participants had not received prior training and/or education on dementia. No significant differences ($p > 0.05$) were noted in the demographical parameters between the two groups as shown in Table 2.

Efficacy

As shown in Table 3, there was an overall significant increase ($p < 0.0001$) in participants' knowledge score from pre-intervention (M = 7.79, SD = 2.11) to post-intervention

Table 1. Feasibility framework (focus areas, questions, and data sources).

Focus areas	Questions	Data sources
Efficacy	Does the 3D brain visualisation using AR technology show promise for enhancing the ability of medical students to understand dementia, the brain and its related mechanisms?	• Fifteen knowledge questions developed by the research team
Acceptability	Is the 3D brain visualisation using AR technology deemed to be suitable for educational purpose by medical students?	• Ten evaluation survey questions (including three open-ended, free text questions)
Implementation, and practicality	Can the 3D brain visualisation using AR technology be successfully implemented in the curriculum for medical students at university?	• Intervention checklist • Research team observation notes and reflections

Table 2. Demographics characteristics (n = 24).

Demographics	Pamphlet (n = 12)	AR (n = 12)
Age (mean; standard deviation)	22.9 (6.9)	20.6 (3.0)
Gender		
Female	6	8
Male	6	4
Received prior dementia training/education	2	0

Table 3. Knowledge scores (n = 24).

Stage of assessment	Pamphlet (n = 12)		AR (n = 12)	
	Mean	SD	Mean	SD
Pre-intervention	8.33	1.96	7.25	1.96
Post-intervention	10.75	1.93	10.08	1.93
Total	7.79	1.82	10.42	1.82

(M = 10.42, SD = 1.82). However, there was no significant difference between groups in knowledge scores (p = 0.667).

As the two participants who reported receiving prior training and/or education on dementia were in the pamphlet group, further analysis revealed this factor to be a significant covariate for the pre-post knowledge comparison (p = 0.016). While there continues to be no significant difference between groups in knowledge scores (p = 0.126), inspection of the means (see Figure 1) reveals that the magnitude of change from pre- to post-intervention scores now appears to be larger in the AR group than the pamphlet group following adjustment for training and/or education on dementia.

Acceptability

The perceived acceptability of 3D brain visualisation using AR for educational purpose is reflected in Table 4. All pamphlet group participants, compared to 83.3% of participants in the AR group, agreed or strongly agreed that the information in their learning resource was coherent and easy to understand. On the other hand, compared to all AR group participants, only 91.7% of participants in the pamphlet group agreed or strongly agreed that the pamphlet was informative and improved their understanding of the brain and dementia. However, only a respective 50% and 41.7% of participants in the pamphlet and AR groups felt confident in explaining the brain and dementia to a lay person using what they have learnt from the resource. The same proportion of participants (i.e. 66.7%) from both groups enjoyed using their respective resource. Yet only 50% of participants in the AR group would recommend the learning to other medical students compared to 75% of participants in the pamphlet group.

Further questions posed to participants in the AR group demonstrated that 66.7% of participants indicated that the AR feature of the learning resource enhanced their learning experience and 91.7% of participants would recommend the inclusion of the AR feature in future educational resources.

Participants in the pamphlet group generally reported the educational pamphlet to be appealing in terms of the use of vibrant colours, succinct phrases, and concise explanation of a complex illness in '*simple non-jargon terms*'. They also found the content in the educational pamphlets '*straightforward and user-friendly*' and '*easy to follow*'. However, some reported a difference of experience where they found the educational pamphlet to be quite '*info-dense*' with '*chunks of text*'. Recommendations for improvement included the addition of interactive and hands-on activity, the use of bullet points, as well as the inclusion of flow charts, diagrams, and other visual aids to help with their learning experience.

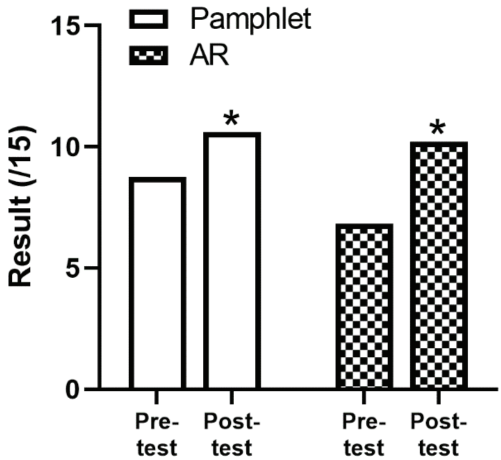

Figure 1. Change in pre- and post-knowledge scores between groups adjusted for prior training and/or education on dementia. *$p < 0.0001$.

Table 4. Acceptability ($n = 24$).

Question statements	Pamphlet (n = 12)		AR (n = 12)	
	DA/strongly DA or neutral (%)	A/strongly A (%)	DA/strongly DA or Neutral (%)	A/strongly A (%)
The information presented in the resource was coherent and easy to understand.	-	100	16.7	83.3
The resource was informative and helped me gain an understanding of the brain and dementia.	8.3	91.7	-	100
I feel confident in explaining the brain and dementia to a lay person using what I have learnt from the resource.	50	50	58.3	41.7
I enjoyed using the resource.	33.3	66.7	33.3	66.7
I would recommend this resource to my peers.	25	75	50	50
The augmented reality feature of the resource enhanced my learning experience.	33.3	66.7	-	-
I would recommend the inclusion of the augmented reality feature in future educational resource.	8.3	91.7	-	-

In contrast, AR group participants found the 3D brain visualisation using AR technology to be interactive, as the '*3D representation of the brain [meant that they were better able] to visualise*', which was particularly useful in identifying different parts of the brain. However, some participants reported being overwhelmed and found '*it was hard to follow along with no text to read*'. Others commented that the audio narration was too fast, which necessitated a lot of rewinding of the audio which was also presented in blocks that in turn made it a '*tedious*' learning experience for some students.

Implementation and practicality

Generally, reflection from the observations did not reveal any significant problem in the potential implementation of the 3D brain visualisation using AR technology in the curriculum for medical students. An area of implementation for consideration is the demonstration and training of medical students in the use of the AR technology and its function to ensure that the most learning benefits are reaped from the introduction of such technology. During the study, some participants were observed as requiring more demonstration, training, and support in the use of the app in comparison to other students. Furthermore, practical considerations are needed in terms of the cost of tablets and the run time of tablets on a full charge for learning and teaching purposes.

Discussion

Overall, the study outcomes reveal that both the educational pamphlet (i.e. didactic 2D approach) and 3D brain visualisation using AR technology were effective in improving medical students' knowledge of the key anatomy and physiology of the brain, and the mechanisms underlying dementia. However, neither learning resource demonstrated an improvement in knowledge that was significantly superior to the other. These results were in line with that of Noll *et al.*'s (2017) study where no difference between an AR application and written text and 2D images was found, despite all participating medical students recording an improvement in their knowledge of dermatology. On the other hand, the results were incongruent with Albrecht *et al.*'s study (2013) where medical students using AR technology demonstrated greater knowledge gain on forensic medicine compared to those using textbook materials. It is worth noting that the research conducted on the use of AR technology in medical education was focusing on different areas of medicine (i.e. dermatology and forensic).

Systematic reviews conducted by Parsons and MacCallum (2021) and Tang *et al.* (2020) highlighted that there are limited studies that have incorporated AR technology into the teaching of neuroanatomy and the brain, with no specific studies focusing on dementia education. Current literature that specifically assessed the use of AR technology in teaching the anatomy and physiology of the brain also highlighted varying results. A recent study by Henssen *et al.* (2020), which compared an AR app visualising the brain with 2D cross-sections of the brain, highlighted a significant difference in the knowledge scores on neuroanatomy between the two groups. Medical students exposed to the 2D cross-sections reported improvement in knowledge to a larger extent when compared to the AR app, but this greater knowledge gain related specifically to cross-sectional questions. Conversely, medical students in Kucuk, Kapakin, and Goktas' (2016) study who received a mobile AR app demonstrated a significant improvement in knowledge about neuroanatomy compared to students who received lectures utilising written text and 2D images.

Evaluation findings highlighted favourable and unfavourable aspects of both learning resources, with suggestions for improvement. For the educational pamphlet, the

Citation: Research in Learning Technology 2022, **30**: 2668 - http://dx.doi.org/10.25304/rlt.v30.2668

visual appearance, succinct structure, and the use of simple and easy-to-comprehend language were welcomed but presentation of information could be improved through more visual representations, use of bullet points, and inclusion of interactive features. For the 3D brain visualisation using AR technology, the 3D model of the brain allowed for a more interactive learning experience and provided a greater understanding of the anatomy of the brain. However, retainment of knowledge was challenging without textual information and the speed of audio recording with rewinding only possible for large segment of content was indicated as a point of frustration that detracted from the learning experience. These feedbacks were similar to those previously reported (Parsons and MacCallum 2021; Tang *et al*. 2020) in that while medical students generally found AR technology to be '*enjoyable, effective for learning and fun*', there were also mixed responses in which some indicated that it was easy to use and others found the AR technology frustrating and challenging to use.

Furthermore, as opposed to the educational pamphlet, which was self-explanatory and easy to read and follow, medical students who were introduced to the 3D brain visualisation using AR technology found it new and unfamiliar and required more demonstration, training, and support, some more so than others. This observation was congruent to medical students who used the AR app in Henssen *et al*.'s (2020) study and experienced technical problems when using the AR app and had to adjust to using a tablet for a prolonged duration.

Study limitations

Outcomes of this feasibility study need to be considered in terms of its research limitations. Firstly, there was no time restriction imposed at any stage of the study, namely, the use of the learning resource and completion of the pre- and post-intervention questionnaires. Hence, variability in the amount of time each medical student spent participating in the study exists and it is likely that those who spent longer time with the learning resources and/or to complete the questionnaire will achieve better results. Future research should consider the introduction of standardised time permissible to allow for a robust outcomes' comparison between the two types of learning resources.

Secondly, medical students' familiarity with AR technology needs to be considered. Although a quick tutorial in the use of the AR technology was provided to medical students, with the majority reporting positive user experiences in the use of the AR technology, there were a few students who reported a negative experience. With any new mode of learning, there is a learning phase that needs to be considered, that is, the time it takes for an individual to be familiar with the new mode of learning. To eliminate the adverse impact of unfamiliarity in a future study, a separate independent training session may be required before medical students are introduced to the 3D brain visualisation using AR technology.

Thirdly, the study outcomes were influenced by medical students' prior training and/or education on dementia, and may have potentially been affected by the small sample size and the content quality of the learning resources and assessment tool. Nevertheless, the learning resource and assessment tool were reviewed by the research team consisting of medical educators with content expertise in the areas of anatomy and physiology of the brain and dementia. Recommendations highlighted in the study's evaluation findings (i.e. slower voiceover, inclusion of subtitles, audio rewinding in smaller segments, etc.) should be incorporated to improve future reiterations of the 3D brain visualisation using AR technology. Importantly, the superiority (if any including cost-effectiveness) of the 3D brain visualisation using AR technology over text-based learning resources needs further investigation to better inform future medical education. Exclusion of medical students with prior training and/or education on dementia and inclusion of a large sample size are also recommended for future study.

Conclusion

This feasibility study found the 3D brain visualisation using AR technology to be equally effective as the educational pamphlet in improving medical students' knowledge of the key anatomy and physiology of the brain, and the mechanisms underlying dementia. It is generally well accepted, and appears practical with the potential for implementation in medical education. However, superiority of the 3D brain visualisation using AR technology over the educational pamphlet was not established with continuing mixed evidence in the literature, particularly when taking into consideration the cost of the AR technology and required equipment such as a tablet. While the use of AR technology in health sciences and medical education to enrich student learning and comprehension surrounding dementia appears promising, there remains a paucity of research as to whether this is a viable and evidence-based alternative to traditional teaching modes with a need for more rigorous research.

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