The Role of Personalized Virtual Reality in Education for Patients Post Stroke—A Qualitative Case Series

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Background: Education is essential to promote prevention of recurrent stroke and maximize rehabilitation; however, current techniques are limited and many patients remain dissatisfied. Virtual reality (VR) may provide an alternative way of conveying complex information through a more universal language. *Aim:* To develop and conduct preliminary assessments on the use of a guided and personalized 3D visualization education session via VR, for stroke survivors and primary caregivers. *Methods:* Four poststroke patients and their 4 primary caregivers completed the 3D visualization education session as well as pre- and postintervention interviews. Each patient had a different stroke etiology (i.e., ischemic thrombotic stroke, ischemic embolic stroke, hemorrhagic stroke, and transient ischemic attack followed by ischemic stroke, respectively). This new approach uses preintervention interview responses, patient MRI and CT datasets, VR head mounted displays, 3D computer modeling, and game development software to develop the visualization. Pre- and postintervention interview responses were analyzed using a qualitative phenomenological methodology approach. *Results:* All participants safely completed the study and were highly satisfied with the education session. In this subset of participants, prior formal stroke education provision was limited. All participants demonstrated varied improvements in knowledge areas including brain anatomy and physiology, brain damage and repair, and stroke-specific information such as individual stroke risk factors and acute treatment benefits. These improvements were accompanied by feelings of closure, acceptance, and a greater motivation to manage their stroke risk. *Conclusions:* Preliminary results suggest this approach provides a safe and promising educational tool to promote understanding of individualized stroke experiences.

Key words: Virtual reality—visualization—technology—stroke education—stroke prevention—stroke rehabilitation

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Introduction

Stroke affects between 30,000 and 50,000 Australians annually.[1,2] Survivors are at a 6-fold increased risk for recurrent stroke,[3,4] with a 20%-30% recurrence rate recorded in the first 5 years.[5] In developed countries, stroke is largely preventable via adherence to prescribed medication and appropriate changes in lifestyle.[6-8] Effective education is therefore key, and in an Australian Stroke Foundation report, patients linked adequate knowledge and understanding of stroke with their ability to access appropriate treatments and manage their own stroke risk.[9] To date, a range of active (e.g., lectures) and passive (e.g., brochures) education methods have been explored[10-14]; however, patients continue to report dissatisfaction with available programs.[15,16] In addition, literature suggests that only 1 in 2 poststroke patients can identify the brain as the affected organ and can only correctly list 1 warning sign or risk factor of stroke.[17]

Complex medical information is often difficult to convey via traditional written and verbal delivery methods, especially in the case of stroke where risk factors and causes vary greatly and the affected population is diverse; presenting across all ages, levels of education and cognition, English proficiency, cultural and socioeconomic backgrounds and at times with language impairment. This implies that many traditional forms of education are not appropriate for all patients,[18] and therefore, an innovative approach to personalize education for greater relevance and comprehension is desirable. The use of virtual reality (VR) as a medium for education may be a solution. Both immersive and nonimmersive forms of VR have been proven effective in enhancing rehabilitation outcomes after stroke[19,20] but their use in education is not yet established. This preliminary investigation is a collaboration between the Department of Rehabilitation at St. Vincent's Hospital Sydney, St. Vincent's Private Hospital's Radiology Department, and the University of New South Wales (UNSW) Art and Design. It sought to investigate the effectiveness of a new personalized 3D visualization method of delivering poststroke education.

Aim

To develop a series of 4 visualizations of stroke mechanisms: ischemic thrombotic stroke; ischemic embolic stroke; hemorrhagic stroke; and transient ischemic attack followed by subsequent cardioembolic shower; and to utilize these in guided, personalized, VR education sessions with stroke survivors and their primary caregivers.

Methods

Participants

Eight participants (4 poststroke patients and their 4 primary caregivers) were recruited from Sacred Heart Hospital's Rehabilitation ward at St. Vincent's Hospital, Sydney between 5 and 47 months post stroke (18.0 ± 19.5 months post stroke [mean ± SD]). The patients, aged between 24 and 71 years, had different stroke etiologies (Table 1). Patient inclusion criteria were a complete CT or MRI brain imaging dataset following a confirmed diagnosis of stroke. Exclusion criteria included: blindness, deafness, and significant cognitive impairment that interfered with the ability to comprehend/respond to simple commands/information. Participant demographics including age, occupation, first language, and highest level of education were recorded (Table 1). This study was approved by the St. Vincent's Hospital Human Research Ethics Committee.

Interview

Participants completed a structured interview before the education intervention to establish their understanding of brain anatomy and physiology, brain repair and damage, their stroke-specific information, and their education needs. Following the intervention, the interview was repeated with additional questions regarding their experience and opinions of the session and virtual technology. Both interviews were recorded and transcribed.

Visualization

Preintervention interview responses, the patient's MRI/CT DICOM datasets and 3D visualization software (Osirix, Maya, Unity) were used to develop a personalized 3D visualization of each patient's stroke[21,22] (Fig 1). The education intervention occurred ≈1 month after the first interview. Under the guidance of a neuroradiologist, rehabilitation physician, and researchers, design academics used MRI/CT images of the patient's brain to generate virtual representations of their cerebral vasculature and animate the bespoke mechanism of the stroke. Following a multidisciplinary team discussion (involving neuroradiology, rehabilitation specialists, researchers, and design academics), the treating rehabilitation physician then facilitated a one-on-one education session with the patient and their caregiver, which utilized their personalized 3D visualization.

Intervention

The patients wore a VR Head-Mounted Display (Oculus Rift) and were guided through their own "stroke-affected" vasculature and custom stroke visualization by their rehabilitation physician. They were then given a hand controller (Xbox 360) to travel through at their own pace. The primary caregiver sat beside the patient and viewed the patient's movement through the visualization on a large monitor (with the opportunity to view the immersive visualization after the patient). Participants were encouraged to interact with the visualization and ask questions of the rehabilitation physician. The session took approximately 20-30 minutes.

Table 1. *Patient and caregiver demographics*

	Patient 1	Patient 2	Patient 3	Patient 4
Gender	Male	Male	Male	Female
Age	68	66	24	71
Ethnicity	Caucasian—born in South Africa	Caucasian—born in Israel	Caucasian—born in South Africa	Caucasian—born in Australia
First language	English	Arabic	English	English
Education	University graduate	University graduate	University graduate	University graduate
Diagnosis	Right carotid occlusion, treated with thrombolysis, followed by right MCA infarct	Medullary pontine infarct	Left intracerebral hemorrhage	TIA followed by a multifocal left hemisphere infarct likely cardioembolic
Date of stroke	14/12/2013	28/10/2014	4/5/2012	9/02/2017
Time post stroke	8 months	12 months	47 months	5 months
Medical history & risk factors (prior to stroke)	Ischemic heart disease, 3× CABG in 2002, high cholesterol	3× ischemic stroke: 2x left anteriomedial medullary infarct 2014 and right MCA 2011, T2DM, mod-severe proliferative retinopathy and neuropathy, hypertension, high cholesterol, right ICA stenosis 90%, PVD.	Migraines, aortic valve incompetence	Prediabetes, history of breast cancer, past smoker (20 years prior), hypertension, possible paroxysmal AF, Sinus tachycardia and premature ventricular complexes
	Caregiver 1	Caregiver 2	Caregiver 3	Caregiver 4
Gender	Female	Female	Female	Male
Age	66	58	49	72
Ethnicity	Caucasian—born in South Africa	Caucasian—born in Israel	Caucasian—born in South Africa	Caucasian—born in Australia
First language	English	Hebrew	English	English
Education	University graduate	Secondary education and diploma in accounting	University graduate	Postgraduate university graduate
Relationship to patient	Spouse	Spouse	Mother	Spouse

Abbreviations: CABG, coronary artery bypass graft; MCA, middle cerebral artery; PVD, peripheral vascular disease; T2DM: type 2 diabetes mellitus; ICA, internal carotid artery.

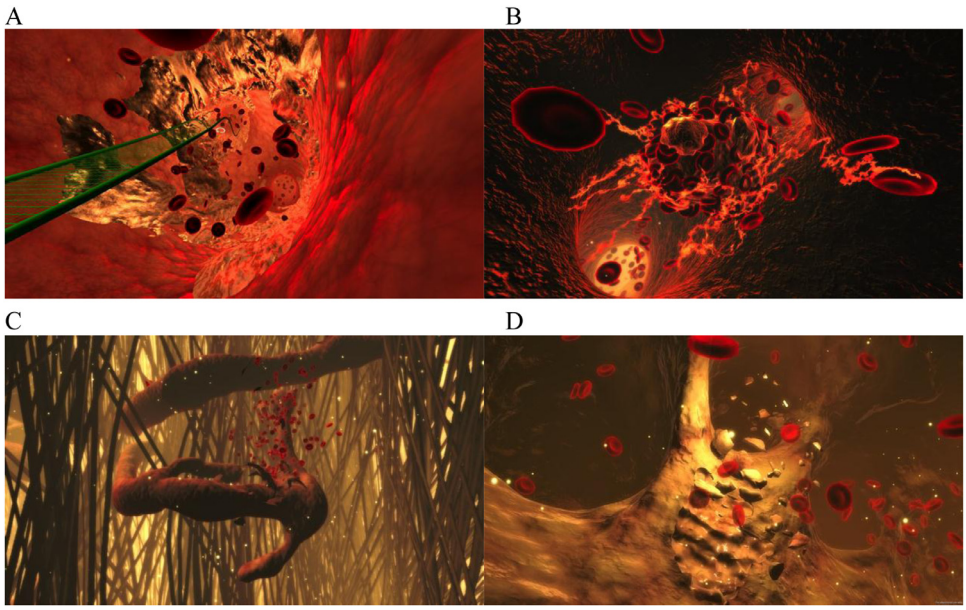

Figure 1. *The visualization for each education session was individualized to the stroke etiology of the patient, including (A) ischemic thrombotic stroke; (B) ischemic embolic stroke; (C) hemorrhagic stroke; and (D) transient ischemic attack followed by a cardioembolic shower.*

Data Analysis

Phenomenology methodology was employed to extract the main themes from interview recordings. This form of qualitative analysis investigates the perceptions and perspectives of participants' experiences.

Results

The 3D visualization was well tolerated by participants with high satisfaction reports. No adverse events occurred, in particular, no cyber-sickness (a vestibular disorientation sometimes associated with immersive VR), nausea, or dizziness. Key themes from the pre- and posteducation interviews are presented below with participant pairings (i.e., patient and their primary caregiver) labeled as pairs 1, 2, 3, and 4. Patient's and caregiver's quotes are presented in italics.

Brain Anatomy and Physiology

The participants in each pair had similar levels of understanding of brain anatomy and physiology. In the preeducation interview, pairs 1 and 4 were well informed with a good understanding of the vascular and nervous systems. Pair 3 had limited knowledge, while pair 2 had no understanding. In the posteducation interview, understanding in pair 2 improved, while the others remained the same.

Brain Repair and Damage

There were mixed opinions on the concept of brain repair both pre- and posteducation sessions, with two pairs under the impression that there was no chance of repair or recovery post stroke. Preintervention, pair 1 was aware of neuroplasticity and the role of rehabilitation and ongoing physical practice in recovery, while pair 3 believed in brain repair but was unaware of the process involved. Postintervention, pairs 1 and 3 were able to acknowledge and explain the process of brain repair by common descriptions of "retraining the brain" and "forging new pathways."

> *Patient: "It is an unfortunate thing that I had to have a stroke to learn so much but neuroplasticity is . . . it is an unbelievable thing, it's unbelievable."*

When questioned about the brain's vulnerability to damage, the majority of participants linked sharp/hard objects and chemicals as harmful but lacked knowledge in the damaging effects of softer objects and blood (including pair 3 who had experienced an intracerebral hemorrhage). In addition, pair 3's understanding of stroke was not linked with their own personal stroke etiology (i.e., associating stroke solely with "clots") prior to the education session. This was improved posteducation session.

All participants showed an improved ability to visualize stroke as well as an improved understanding of the effects of stroke, noting blood flow disturbance leading to brain cell death.

> *Patient and Caregiver: "A piece of coagulated blood that has killed all tissue around it. . . the dead tissue would be grey in colour" and "convoluted and softer putty-like structure"*

> *Patient: The stroke has "blocked. . .messages to different parts of the body"*

Stroke-Specific Information

Preintervention, the majority of participants were unaware of the process/cause of their own stroke. This was particularly the case in the patients, with patients 1 and 2 showing a lack of acknowledgment of their own risk factors role in their stroke event. Noting "theories" regarding causes of their stroke that they were not in agreement with or they stated bad luck as the cause. In comparison, all caregivers were aware of the patients' risk factors and the role in their stroke. Postintervention, all patients and caregivers showed a greater understanding of their own stroke risk and a new understanding of the importance of adherence to medication, rehabilitation, and healthy lifestyle habits.

Patient: "It's amazing. I acknowledge now, before I didn't. Because I have to see it, the cholesterol and the diabetes and all other factors they can affect the human being like myself."

Caregiver: Just by watching them I am thinking how they are going to affect me and I am going to start changing my lifestyle because of that too.

In regards to the effects of acute treatment, preintervention, caregiver 1 believed the thrombolysis her husband received was damaging and a main contributor to his current condition. Postintervention, she showed a greater understanding of the use and effects of thrombolysis and stated it was beneficial.

Education Needs

The majority of participants were not provided with any formal education after their stroke, with some participants such as pair 1 gaining the majority of their knowledge from their own research. When information was given, it was mainly to the caregiver and in the form of pamphlets and brochures, which caregivers noted, were not read in detail. Much of this information was more relevant to acute treatment options to which the participants needed to consent.

Visual imagery was not often used in any education provided with the exception of patient scans used in 2 cases to explain the mechanisms, later in the inpatient rehabilitation phase. However, it should be noted that this was provided by the rehabilitation physician leading this study, prior to study development. In some cases, the only information provided was delivered by a family member or the patient themselves for patients and caregivers, respectively.

There was an overarching theme from all patients and some caregivers that they were unable to take in information during the acute period and the need for education at multiple time periods.

Patient: "I think when I was in the Acute Hospital a lot of things were going on around me. It was confusing for me. I mean I knew what had happened to me but I did not understand the effects of what had happened to me, whereas now I do… If I had the choice I would rather see it (the visualization), I would advise to see it."

Experience with VR

All participants were highly satisfied with the virtual education session. There were no adverse events or side effects from using the immersive technology. However, 2 caregivers found that the experience slightly upsetting as it brought back memories of the event but they also stated that the session provided "closure" and was comforting as greater understanding was necessary.

Caregiver: "It was less scary because you are always scared of the unknown, so it kind of demystified it a bit."

Caregiver: "It brought a bit of closure…Often as a parent you have questions, what could we have done to prevent this? … but this has brought a lot of clarity to that as well."

Participants identified a need to have visual images to fully understand what happened, as well as a need for the visual images to be explained by a trained health professional.

Patient: "What I have is a brain injury…It is different to a car accident. When you have a car accident you have stitches, you can see the blood but with a stroke there is nothing…but this (the education session) has opened that up, I now see what a stroke is."

Patient: "The images… without being here I would not have a clue, what it looks like. I now know what the brain and stroke look like and how the brain works."

Patient: "They (visual images) were important…. They helped me better than words. I do not like words."

Patient Recommendations

Participants recommended this form of education be used in at risk populations and other stroke patients for prevention and secondary prevention reasons. They also suggested after the formal education session that the visualization could be used by patients and caregivers to explain to other family members.

Patient: "In hindsight, if I could have seen this 15 years ago I would have changed my eating habits," and "If someone is given this early on they will rehabilitate quicker because, so much of rehab and getting things working again is your thought process and your mind."

Discussion

This is the first study to investigate the efficacy of using personalized 3D visualization and VR to promote understanding in patients and caregivers post stroke. Preliminary findings included high participant satisfaction and a greater understanding of stroke risk, the effects of acute treatment as well as reductions in anxiety and a new motivation to manage stroke risk among both patients and their caregivers. This multifactorial effect suggets there is potential for this form of education in both primary and secondary stroke prevention. These effects may be due to the individualized nature of the intervention as well as the novelty of viewing the vessels from the "inside" and having the time and context to explore areas of interest in a self-directed manner. The visualization education session in its current format did not seem to facilitate learning in regards to brain repair; however, this could be included in the verbal guidance and/or in modifications made to the visualizations in future.

Recent literature suggests that effective education strategies are active, personalized, intensive and repetitive, and involve both patients and caregivers.[23] The program presented meets these criteria and, once generated, can be viewed multiple times in hospital and at home and used as an adjunct to other educational techniques. Unlike current strategies, the virtual medium may allow patients with different needs and learning styles to engage and comprehend complex ideas.

In current practice, the majority of educational strategies are hospital-based and delivered almost immediately following admittance.[24] This was the case for the participants in the current study, who all mentioned difficulties recalling information delivered in the acute stage due to the impact of the stroke on levels of cognition and consciousness, and altered emotional and mental states. This does not mean that early education should not be provided as it is equally important for caregiver knowledge. Instead, our results suggest that education should be repeated to increase levels of understanding for both patients and caregivers at different stages of recovery. Furthermore, a guided DVD or secure online recording of the interactive session could be developed for the purposes of teaching extended family and friends when formal rehabilitation has ceased.

Technological advances in VR, immersive technologies, and neuroimaging form a basis for collaborations between academics from disparate disciplines. In this study, researchers from creative arts/design, rehabilitation medicine, stroke research, and neuroradiology came together to develop an interface between gaming technology and neuroimaging for the purposes of patient education. This union between medical research and design resulted in a hybrid visualization where patient data have been augmented with additional visual attributes to enhance the narrative (e.g., including blood cells, digital lightening texture, and animation of processes like thrombosis formation). To our knowledge, this may be the first development of immersive technologies and integrated neuroimaging for such purposes in the area of stroke education.

Neuroimaging is becoming more accessible to clinicians as images are used more and more for therapeutics (theranostics) and disease monitoring (brain repair) and no longer exclusively for diagnosis. It is a natural extension that simplified or transmogrified neuroimaging is likely to be utilized for the purposes of patient education, motivation in rehabilitation, and bespoke medical advice on the prevention of disease. The public's appetite for the moving image has become ubiquitous through social media, specific entertainment platforms, and mobile technology and one may speculate that there is likely to be broad support for the use of VR in medical education, rehabilitation, and disease prevention. It behoves the medical imaging industry to consider the development of software to allow the transition of images from diagnostic tools for clinicians into education resources for the public and clinicians alike. To date, we are unaware of such software development.

Methodological considerations: There are 2 potential adverse events associated with this type of immersive virtual technology: symptoms of cyber-sickness[25] and/or distress at viewing the stroke visualization. Cyber-sickness can occur when the virtual images fail to update in time with the users head movements, or it may be due to a form of sensory conflict between the visual and vestibular systems (i.e., the visual system senses motion while the vestibular system does not).[26] In this study, the Oculus Rift technology rapidly updates with head movements and utilizes slow user speeds to reduce the potential of sensory conflict. Participants were closely monitored and, to date, have tolerated this educational intervention well, with no cyber-sickness symptoms of any kind being reported. In future, if a participant does experience symptoms of cyber-sickness, the education session can be delivered in a nonimmersive format (e.g., viewed on a television screen).

In regards to distress, caregivers 1 and 3 mentioned some distress at viewing the visualization. Although the feelings of distress were experienced, both caregivers stated that the visual representation of the stroke outweighed the uncertainty of not knowing and promoted closure for them and their families.

The use of visual imagery may not be as effective for stroke survivors with visual impairments or more severe cognitive deficits. However, in these cases, the visualization could still be used to benefit the caregiver and patient's extended family.

Interview responses from one pair of participants were subject to potential bias due to the involvement of a media team who were documenting a number of patient stories at the hospital during the time of their

involvement. The protocol and questionnaire utilized did not change.

Logistical considerations: The initial creation of an entirely custom visualization from raw neuroimaging data is currently a lengthy (≈1 month) and a relatively expensive process. However, since we have now developed 4 visualizations of common stroke etiologies, these can act as a visual-effects library to be modified and applied to new patients in a more time- and cost-efficient manner. In many cases, the main modifications are to the verbal guidance provided by the health professional delivering the education session. In addition, it is difficult to quantify understanding with no quantitative questionnaires or measures. For future trials, the stroke knowledge test, Depression Anxiety Stress Scale-21 (DASS 21), and a 10-point visual analogue scale will be included to assess understanding, emotional well-being, and satisfaction, respectively. Measures of health status such as blood pressure, lipid and blood sugar levels, and physical activity could also be recorded to measure any resultant behavior change following the education session. Further, adherence to poststroke rehabilitation, measures of motivation such as speed and performance of tasks being trained and functional outcomes measures such as the Functional Independence Measure and/or Fugl-Meyer Assessment could also be investigated.

Conclusion

These preliminary results suggest that a guided, personalized 3D visualization consultation is a promising educational tool for explaining stroke to patients and their caregivers. This preliminary study suggests that this VR educational intervention, using gaming technology and neuroimaging, is feasible in a clinical setting. Future research will examine the use of VR in a larger number of patients as well as investigating the effect of this form of education on secondary prevention, poststroke rehabilitation, and stroke risk management.

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References

1. Cadilhac DA, Vos T, Thrift AG. Estimating the annual number of strokes and the issue of imperfect data: an example from Australia. Int J Stroke 2014;9:19-22.
2. Deloitte Access Economics. The economic impact of stroke in Australia. National Stroke Foundation. 2013.
3. Senes S. How we manage stroke in Australia. Canberra: Australian Institute of Health and Welfare. 2006.
4. Hardie K, Hankey GJ, Jamrozik K, et al. Ten-year risk of first recurrent stroke and disability after first-ever stroke in the Perth Community Stroke Study. Stroke 2004;35:731-735.
5. Lee AH, Somerford PJ, Yau KW. Risk factors for ischaemic stroke recurrence after hospitalisation. Med J Aust 2004;181:244-246.
6. Spence JD. Intensive risk factor control in stroke prevention. F1000Prime Rep 2013;5:42.
7. Hackam DG, Spence JD. Combining multiple approaches for the secondary prevention of vascular events after stroke: a quantitative modeling study. Stroke 2007;38:1881-1885.
8. O'Donnell MJ, Xavier D, Liu L, et al. Risk factors for ischaemic and intracerebral haemorrhagic stroke in 22 countries (the INTERSTROKE study): a case-control study. Lancet 2010;376:112-123.
9. National Stroke Foundation. Call to action. Fight stroke: this is what we want. Melbourne, Australia: National Stroke Foundation. 2012.
10. Forster A, Brown L, Smith J, et al. Information provision for stroke patients and their caregivers. Cochrane Database Syst Rev 2012;11. https://doi.org/10.1002/14651858. CD001919.pub3.
11. Smith J, Forster A, House A, et al. Information provision for stroke patients and their caregivers. Cochrane Database Syst Rev 2008. https://doi.org/10.1002/14651858. CD001919.pub2.
12. Mant J, Carter J, Wade DT, et al. The impact of an information pack on patients with stroke and their carers: a randomized controlled trial. Clin Rehabil 1998;12:465-476.
13. Spassova L, Vittore D, Droste DW, et al. Randomised controlled trial to evaluate the efficacy and usability of a computerised phone-based lifestyle coaching system for primary and secondary prevention of stroke. BMC Neurol 2016;16:22.
14. Eames S, Hoffmann T, Worrall L, et al. Randomised controlled trial of an education and support package for stroke patients and their carers. BMJ Open 2013;3. pii:e002538.
15. Yonaty SA, Kitchie S. The educational needs of newly diagnosed stroke patients. J Neurosci Nurs 2012;44:E1-E9.
16. Hafsteinsdottir TB, Vergunst M, Lindeman E, et al. Educational needs of patients with a stroke and their caregivers: a systematic review of the literature. Patient Educ Coun 2011;85:14-25.
17. Hickey A, O'Hanlon A, McGee H, et al. Stroke awareness in the general population: knowledge of stroke risk factors and warning signs in older adults. BMC Geriatrics 2009;9:35.
18. Hoffmann T, McKenna K. Analysis of stroke patients' and carers' reading ability and the content and design of written materials: recommendations for improving written stroke information. Patient Educ Coun 2006;60:286-293.
19. Laver KE, George S, Thomas S, et al. Virtual reality for stroke rehabilitation. Cochrane Database Syst Rev 2015: https://doi.org/10.1002/14651858. CD008349.pub3.
20. Pollock A, Farmer SE, Brady MC, et al. Interventions for improving upper limb function after stroke. Cochrane Database Syst Rev 2014: https://doi.org/10.1002/14651858. CD010820.pub2.
21. McGhee J, Thompson-Butel AG, Faux S, et al. The fantastic voyage: an arts led approach to 3D virtual reality visualization of clinical stroke data. Tokyo, Japan: VINCIACM Press. 2015. p. 69-74. (VINCI '15 Proceedings of the 8th International Symposium on Visual Information Communication and Interaction).
22. McGhee J. 3-D visualization and animation technologies in anatomical imaging. J Anat 2010;216:264-270.
23. Maasland L, Brouwer-Goossensen D, den Hertog HM, et al. Health education in patients with a recent stroke or transient ischaemic attack: a comprehensive review. Int J Stroke 2011;6:67-74.

24. Eames S, Hoffmann T, Worrall L, et al. Delivery styles and formats for different stroke information topics: patient and carer preferences. Patient Educ Coun 2011;84:e18-e23.
25. Katz N, Ring H, Naveh Y, et al. Interactive virtual environment training for safe street crossing of right hemisphere stroke patients with unilateral spatial neglect. Disabil Rehabil 2005;27:1235-1243.
26. Johnson DM. Introduction to and review of simulator sickness research. U.S Army Research Institute for the Behavioural and Social Sciences. 2005.