A VR-based Method for Evaluating Outdoor Environments with People with Dementia

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Abstract

The importance of designing outdoor environments that are 'dementia-friendly' increases with the ageing of populations world-wide. VR is a promising tool for the evaluation of these environments before they are actually built or redeveloped. We developed a VR-based method for evaluating outdoor environments with people with dementia. An existing town centre was modelled in VR. People with dementia took part in outdoor and (indoor) VR walks. The VR walks were conducted in a cinema-type auditorium, using a personal computer, a new system using two LCD projectors and a curved projection screen. Each participant's walks were rated and, based on the results of the walks, the model was redesigned. The model was then tested again. People's performance on the walks improved. From the findings potentially beneficial adaptations to outdoor environments were identified. We conclude that VR models, together with a rigorous behavioural testing method, can be a useful tool for the evaluation of outdoor environments and for identifying improvements for people with dementia.

Keywords

Virtual reality, outdoor environment, dementia, evaluation, method, empowerment

1 INTRODUCTION

Currently, there are approximately 700,000 people with dementia in the UK and this figure is expected double over the next fifty years as the population continues to age. An estimated 80 per cent of people with dementia are living at home in their community, almost a quarter on their own, and many are still active outdoors making trips for pleasure and visiting local amenities (Audit Commission, 2000). Therefore, to enable this growing section of society to continue participating in social, functional and leisure activities in their community (which has associated health benefits for people with dementia and their carers/relatives) environmental obstacles to wayfinding, orientation and well-being need to be identified (Blackman *et al.*, 2003). The large and growing number of people with dementia living in the community means that even if better urban design produces only a modest improvement in independence and quality of life the potential benefits are significant for people with dementia nationwide. The project 'Using virtual reality (VR) technology to empower people with dementia in accessing and using public spaces' addresses urban design for people with dementia by using VR technology. It is funded by the Health Foundation.

The main research aims were to examine the barriers and facilitators to orientation and wayfinding for people with dementia of the Alzheimer's type (DAT) in outdoor environments by making innovative use of virtual reality (VR) technology to explore the 'dementia friendliness' of public spaces. VR technology enables people with dementia to participate in the planning and design of public spaces and amenities, potentially improving the navigability and comfort of these environments. The project explores how VR can contribute to the empowerment and inclusion in the design process of people with dementia and their carers who tend to be low beneficiaries of innovative technologies.

Design for dementia in outdoor environments may complement biomedical efforts such as the new drugs approved by The National Institute for Clinical Excellence (NICE) for treating symptoms of dementia in the early stages. In addition, the project's results will benefit people with dementia beyond design for public spaces as they are likely to be extended to inform research dementia-friendly indoor design (such as the person's home or residential facilities), as well as the development of more useful neuropsychological assessment, cognitive rehabilitation techniques and therapeutic immersion in outdoor environments for people in the advanced stages of the disease. Concomitant benefits would also follow for carers and relatives of people with dementia by reducing mental health problems and enhancing social inclusion.

One of the key methods used in the project was outdoor- and (indoor) VR-walks with people with dementia, in which they carried out tasks that typically occur in a town centre environment, for example crossing a road and finding destinations such as a post office and a bus station. In this paper, we describe the VR model, the method, present results from using this method and discuss our findings.

2 VR MODEL

An existing VR model of the commercial centre of the northern English town of Middlesbrough (see Figure 1) formed the basis of the new model. In addition, digital Ordnance Survey data were used for accurate outlining of building footprints, pavements, kerbs and road boundaries; digital photographs were used for creating buildings from footprint shapes and to add detail, and were converted into texture images to be mapped onto the model's geometry; and web resources such as the Highway Code website were used to obtain images of road signs and fonts used for signs and road markings.

The real-world walk was planned to follow a route that could be simulated in the VR model. So as to include a reasonable amount of variety but not exhaust participants, the walk was organised into three sections, with a short taxi ride between walks 1 and 2 and a second short taxi ride between walks 2 and 3. It was not necessary to simulate the taxi journeys in the VR application, so the VR model could switch between the three sections of the walk as required, also giving participants an opportunity to rest. This enabled the VR model itself to be separated into three sections, each of which could run separately - approximately trebling the amount of detail that could be included in each section of the model while remaining within the limits of the hardware.

Having started with a fairly old and basic VR model, there was scope for extensive additional detail. Some of the existing geometry had to be discarded, such as 'blocky' areas of road construction. Many street corners in the original model were very angular and were made more realistic with smooth curves. Parking ramps had to be added. The original model did not contain any pavement or road markings such as yellow lines and bus lane markings, and no kerbstones were defined. Paving and flagstones were simple in form and had to be re-done to simulate the present-day details of the real-world town centre. All of the texture maps for the pavements had to be at a very high, detailed resolution.

Apart from the roads, pavements and buildings themselves, other detail was missing from the original model. It was important to accurately reproduce all of the clutter and bustle of Middlesbrough town centre. A large number of detailed features were modelled and added to the database, using digital photographs as a reference: road and street signs, traffic signs, signs for pedestrians, several different types of street lighting, sandwich boards, illuminated poster display boards, traffic lights, electricity junction boxes, sunken spotlights, trees and shrubs. Street furniture that was added included benches, bollards, several types of litter bin, and bicycle racks.

Vehicles and pedestrians were also added to the models. Time and hardware limitations meant that 'billboard' pedestrians were used. These are photographic representations of pedestrians mapped onto a flat plane which rotated so as to always be perpendicular to the participant navigating the VR model, giving the impression of solid, 3-dimensional people. Vehicles were fully modelled in 3D and animated so that they followed specific routes along the roads in the model. Time limitations also meant that functioning traffic light systems could not be created, with traffic responding accordingly, but the continual movement of cars and buses through the streets gave a very effective impression of a busy town centre.

The final element in creating a realistic virtual environment was to add some ambient sound. We experimented with recording sound whilst walking around the real-world town centre during a busy time of the day. We found that these recordings created a very effective ambient soundscape when navigating the models and there was no need to use more sophisticated techniques such as attaching sounds to individual vehicles in the model. Together with the visuals, the sound recordings helped to create a reasonably immersive environment with the visual and aural cues we wanted.

The hardware platform consisted of a personal computer and a new system using two LCD projectors, running at a total resolution of 2048x768 pixels, and the 6m x 2m curved projection screen in the University of Teesside's VR Auditorium.

3 METHOD

The proposal was assessed and approved by a National Health Service Research Ethics Committee. Throughout the research, research ethics were strictly adhered to. This included obtaining repeated consent from the people with dementia and their carers who took part in the research. The first phase of the research used an existing town centre consisting of three parts (side street/shopping street/post office/taxi rank, shopping centre and busy town centre road). The second phase used a redesigned (adapted) town centre model (see Figure 2) based on the results of Phase 1.

3.1 Participants

Participants were 38 people with symptoms of mild to moderate dementia (19 female and 19 male) and their carers. Mean age of people with dementia was 79 (standard deviation = 5). All were diagnosed by medical practitioners as having dementia in the mild to moderate stages, and were recruited through local hospitals where they were out-patients.

3.2 Virtual-Reality Session (Phase 1)

Participants were asked again for their informed consent to take part in the study. Following a short practice with navigating a section of a VR model until the participant was comfortable with using the joystick control, the VR session began with the participant following a set route around the virtual environment (VE). Both carer and researcher allowed the participant to lead the walk. The researcher asked a series of conversational questions at key stages in the walk. These included setting off, en route to a destination, at junctions/nodes, on reaching a destination, and return journeys.

The environmental interaction was analysed using a number of criteria:

1. Navigability was analysed by how well participants followed the route and managed at junctions and other decision points. Participants' navigation of the shopping precinct 'Captain Cook's Square' and use of the 'You Are Here' map in the square offered important information concerning their ability to understand maps and to locate themselves in the environment.
2. Legibility was measured by how adeptly participants recognised and located certain things in the environment, for instance their ability to identify and find the taxi rank, the post office, the bus station and the telephone box. An implicit measure of this was how well they performed tasks that used these places, for instance they might find the post office but might have difficulty finding where to post the letter; this was measured by the number of required prompts.
3. Perceived safety was measured by comparing what participants said in response to prompts along the route. Traffic (including pedestrian) can influence feelings of safety, so comparing responses along different roads to the question "How does the traffic make you feel?" offered an idea about how various amounts of traffic affected participants. By including questions about crossing roads it was possible to elucidate how types of crossing affect participants. Additionally, safety of participants' behaviour and usage of different areas was subjectively assessed, for instance the participants were rated how safely they crossed roads, or how safe they acted along a quiet shopping street.
4. A town's aesthetics are likely to influence the likelihood of visiting it. Certain parts of towns are more aesthetically pleasing and these may increase our feelings of comfort. Comfort and well-being may be affected by elements including paving patterns, levels of noise, pedestrians and traffic, density or design of street furniture, etc. This was assessed by asking 'How do you feel walking along here, is there anything you like or dislike about it?' or 'How do you feel about this part of town?'.

These prompting methods produced data for individual roads; in addition it was possible to calculate environmental summary scores for three different areas of town.

3.3 Real-World Walk (Phase 1)

The purpose of the 'real-world walk' was to follow the VR route and protocol: the participants walked the same route, did the same tasks with the same prompts for both sessions. The time between the real-world walk and the VR walk in Phase 1 was almost always one or two weeks. This allowed findings from the two different environments to be compared to establish if participants acted the same in both environments.

3.4 Virtual-Reality Session (Phase 2)

The protocol for Phase 2 was the same as Phase 1, except the environment was adapted using the VR and real-world walk data from the first phase. The data recorded in the second VR session were compared with the first VR session to see if the adaptations had any effect on task performance. The participants in Phase 2 were matched with those from Phase 1 as much as possible, with many participants doing both, and the time between the two VR walks was at least three months.

Figure 1: VR model of existing town centre.

Figure 2: Adapted VR model.

3.5 Data and Data Analysis

Data analysis comprised of the following aspects:

1. Both video and audio data were recorded. Two raters reviewed the recordings and independently assessed how well the participants interacted with the environment using a scoring system on each individual item. There were 221 items inside the 10 tasks, most of which consisted of a four point scoring system. What people said was also recorded and any interesting comments highlighted. In Phase 2 the number of items was reduced to 183 items in eight tasks.
2. Each task was either completed successfully or unsuccessfully. These outcomes were further subdivided by the number of prompts needed to complete or abandon the task. The standardised prompts were increasingly specific; the first prompt gave modest information whereas the final prompt was much more exact. The number of prompts was incorporated into the four point scoring system.
3. Key data were taken from the participants, such as age, sex, and cognitive impairment score. The Bristol Activities of Daily Living Scale was administered for some of the participants as an objective measure of behavioural ability.

4 RESULTS

A summary of results from the walks follows; full results will be reported elsewhere. Two indepe006Edent raters (one of whom was the research assistant) scored the walks using a standardised scoring system. Reliability between raters was analysed over all numerical (walk outcome) variables per participant using the intraclass correlation coefficient. All reliability coefficients were statistically significant ($p < .001$ for each of the walks) and on average reliability coefficients were > .70 for each type of walk. We concluded that rating of walk outcomes was reliable. Therefore and given the fact that the research assistant had direct experience of all the walks, in subsequent data analysis the ratings of the research assistant were used.

The analysis of the walk data showed that overall adapting the environment was beneficial for people with mild to moderate dementia. There were few significant correlations of participant's performance during a walk with age but the degree of cognitive impairment did have an effect. Adaptations that improved performance of tasks included clearly displayed numbers for addresses and buses, and signs with clear text to give direction and signify the purpose of buildings such as a bus station. Landmarks designed to support navigation were not beneficial, although various environmental elements were sometimes used idiosyncratically as landmarks. Road crossing safety and comprehension of the dangers of traffic was found to be relatively preserved, although those with greater cognitive impairment were less aware of these dangers. Out of the three town centre environments, the shopping centre was the best liked and most easily navigable; this area was pedestrianised and the lack of cars and other traffic was a frequent positive comment. Modern seating, telephone boxes and bus stops were recognised, although those with lower cognitive scores had more problems with the legibility of seats and telephone boxes. People with lower scores also had more difficulty locating and using a traffic island.

5 DISCUSSION AND CONCLUSIONS

Our findings show that people with dementia are capable of carrying out functional tasks in a town centre environment both in the real environment and in a VR model. These results extend those of previous research (Flynn et al., 2003), where the feasibility of the use of a VR park model by people with dementia carrying out functional and other tasks was demonstrated.

The results also suggest that people with mild to moderate dementia are capable of walking around and enjoying town centre environments, at least when accompanied, and with careful and selective adaptations should be able to walk around outdoors as their dementia increases.

Some limitations of VR as a medium for evaluating outdoor environments was demonstrated by poorer performance of participants with the VR model compared to the real-world environment. An example was less safe behaviour when crossing a road because of a lack of peripheral vision and participants' apparent lack of concern for safety in a VR environment. However, performance improved when participants used the adapted VR model. In addition, some of the adaptations proved to improve performance, for example directional text-based signage.

From our results we conclude that VR models, together with a rigorous behavioural testing method, can be a useful tool for the evaluation of outdoor environments and for identifying improvements for people with dementia. Further research currently underway focuses on the use of VR for the redesign and evaluation of park environments.

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